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BIOMIMICRY – INNOVATION BORROWING FROM NATURE

WATER RESEARCH COMMISSION

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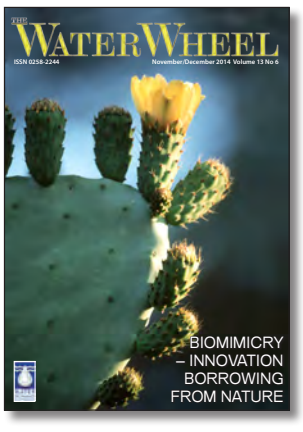
Cover: *The Water Wheel takes a look at the new discipline of biomimicry, which aims to emulate nature's solutions to human problems. Read the story on page 12.*



Fluid Thoughts

WRC CEO, Dhesigen Naidoo

UPPING THE GAME ON GENDER EQUALITY IN WATER

The beginning of November saw one of the world's largest dialogues on gender and water matters, when delegates from 37 countries converged in East London, South Africa to participate in the Gender, Water and Development Conference. The participants ranged from rural community women to Ministers for Water, academics to activists, public to private, and local entities to international institutions.

There was strong convergence that Gender Equality was not only a human rights issue, but that gender inequality was a fundamental constraint to sustainable development. The case studies affirmed the universality of the challenge as the case studies illustrated that gender inequality and the suppression of women and the girl child was a phenomenon of both the developing and the developed world. And there was consensus that gender represents the pinnacle of the degrees of marginalisation (Fig. 1) with women and the girl-child carrying the heaviest burden.

The group of participants, led by the WRC, took a futures journey by creating scenarios for gender and water in the 2055 timeframe. In a variation on classical scenarios development exercises, the team also developed a set of pathways options to the scenario of gender equality in the water domain in 2055, based on the nature of the pre-dominant dividers (Fig. 2).

The Epiphany pathway has the highest potential to make quick gains in the short term in the realisation of increasing degrees of gender equality. The Epiphany pathway relies on the concientising of opinion leaders, decision-makers and society at large on the issues of negative effects and opportunity cost of gender inequality as well as the economical social dividend of equality. This then acts as the major driver of change and through a series of loops, followed by plateaux of consolidation, the 2055 goal is reached.

The Technology pathway is premised on the fact that gender inequality, while pervasive worldwide, is starkest in environments of resource constraints and scarcity. This relates particularly to water scarcity and limited access to safe sanitation services. New and innovative technology based solutions like point-of-use water quality treatment and safe low-water and no-water sanitation solutions present significant opportunities to address the plight of women and girls. The pathway has a lag phase as is generally experienced with user technologies, but acerbated within time to reach the 2055 end goal.

The third pathway has a stronger reliance on Regulation and oversight or the principal driver of change. These will include gender considerations in water allocations, budget distribution, representation norms in governance structures, an oversight system to ensure performance. This pathway has a much larger lag phase to deal with the expected resistance to change. This is followed by a period of accelerated development after both seeing out the change management phase as well as the positive cost-benefit

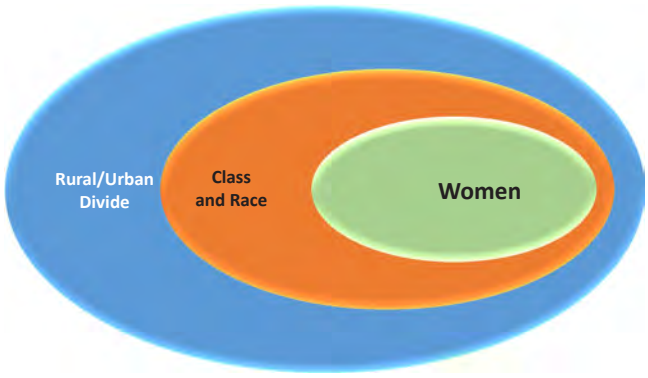


Figure 1
The three degrees of marginalisation still find the rural black woman being most marginalised. She experiences the worst of the urban/rural divide, the burden of poverty and race and then the further differentiation of not being male.

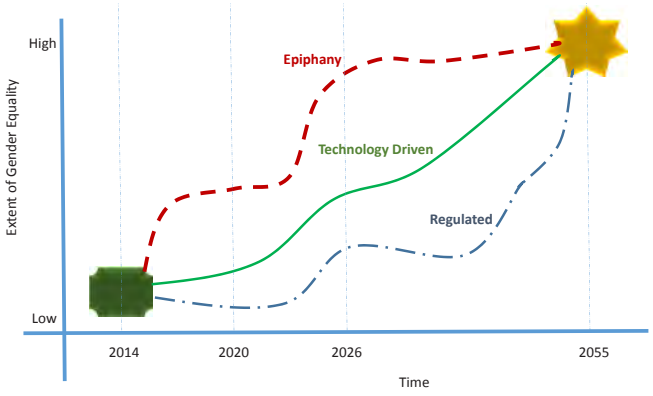


Figure 2
The three pathways to the ideal goal of Gender Equality in Water in 2055. The three pathways to the 2055 goal are the Epiphany, Technology and Regulatory pathways. Although all three have the potential to realise the ideal end state in the long term, they have different lag and acceleration phases over the 40 years.

ratio of investing in gender equality takes a firmer foothold.

In order to better inform the prioritisation of the investment drivers toward the 2055 goal a higher investment in water and gender research and development is required. The WRC and its partners are currently developing the R&D agenda for further consultation and implementation. This is an important dialogue that we invite the entire water family to participate in.

Water diary

Wastewater treatment
27 November

The Water Institute of South Africa (WISA) and the Western Cape Process Controllers Division cordially invites all water and wastewater process controllers to attend the fifth Process Controller Workshop in collaboration with the Department of Water and Sanitation, Overberg Water, South Africa Local Government Association and Saldanha Bay Municipality. *Enquiries: Gavin Williams, Tel: (022) 701-7047; Email: gavin.williams@sbm.gov.za*

Residuals and biosolids
June 7-10, 2015

The Water Environment Federation, together with the International Water Association, is hosting a conference on Residuals and Biosolids in Washington, USA. *Visit: www.residualsbiosolids-WEFIWA.org*

Social science
July 2015

The third World Social Science Forum is set to take place in Durban. The forum is a global event of the International Social Science Council that brings together researchers and stakeholders in international social science cooperation to address topical global issues and future priorities for international social science. The theme for this event is 'Transforming global relations for a just world'. *Visit: www.codesria.org/spip.php?article1674*

International award for Rhodes research fellow

Dr Oghenekaro Nelson Odume of the Unilever Centre for Environmental Water Quality in the Institute for Water Research at Rhodes University was announced the winner of the prestigious International Emerging River Professional Award at the 17th International River Symposium held in Canberra, Australia.

The Emerging River Professional Award is an initiative of the International River Foundation and was established to recognise and foster those in the early stages of their careers in river and water resource management. The award identifies and rewards individuals who have worked in their field for ten years or less, and have demonstrated exceptional leadership, innovation and excellence in river, basin and water resource or river-dependent community management.

After entrants from around the world were screened by a panel of judges of international repute, Dr Odume was one of three finalists who competed for the grand prize at a special session. In his presentation he showcased a new research practice in which integration, collaboration and reflection are at the core of water resource management while emphasising stakeholder engagement and combining both ecological and social science approaches and methods in working towards the achievement of integrated water resources management in the context of social-ecological systems.

Dr Odume demonstrated this new way of doing water resource research in the Swartkops River catchment where he collaborated with municipal officials in the Nelson Mandela Bay metro to develop new and innovative tools for managing industrial sewage in relation to river health, and on mainstreaming environmental ethics in value system clarification in the context of multi-stakeholder engagement processes.

Dr Odume, who emphasised the importance of mentorship in water resource research, attributed his achievement to the sterling leadership and guidance he received from his PhD supervisor and mentor, Prof Tally Palmer, Director of the Unilever Centre.

Source: Rhodes University

Researchers identify algae to treat acid mine drainage

Researchers at the CSIR are one step closer to the development of a successful biological method to treat acid mine drainage following investigations into the ability of specific freshwater algae to absorb metals.

Limnologist, Dr Paul Oberholster, biochemist, Po-Hsun Cheng and, microbiologist, Bettina Genthe, joined Anna-Maria Botha from Stellenbosch University's Department of Genetics, to publish their findings in the April edition of the journal, *Water Research.*

Legislation requires operating mines to rehabilitate any environmental damage that may occur during the mining process. However, it is estimated that 90% of acid mine drainage originates from abandoned underground coal and gold mines. In this case rehabilitation comes at the public's expense.

The researchers explain in the article that conventional acid mine drainage systems involve continual addition of expensive chemicals, such as lime, which generates sludge. The disposal of the sludge can be an environmental problem in itself. Thus, for many years researchers have been looking at passive treatment methods, for example, through constructed wetlands.

This relies on macrophyte uptake as a biological process for metal removal. The metal storage capability in artificial wetlands can, however, be lost in temperate regions during winter when plant and microbial metabolic processes are reduced due to lower water temperature and shorter days.

The researchers developed a laboratory-scale hybrid passive treatment system combining an artificial wetland system with an integrated algal pond system using different species of selected macroalgae, with a wide pH and temperature tolerance that can be used for the bioaccumulation of sulphates and metals. They collected algae samples at study sites in Mpumalanga where a number of defunct and flooded coal mines contribute to pollution in the Upper Olifants River catchment.

The ability of three algae species to absorb zinc, aluminium and manganese was compared and the researchers found that Oedogonium crissum fared the best in the laboratory, possibly making it a preferred algae to use in the treatment of acid mine drainage.

According to Cheng, the researchers hope to continue this research through field studies

Source: CSIR

WRC Exec Manager is an international award winner

Water Research Commission Executive Manager: Business Development, Marketing and Communications, Dr Inga Jacobs, has been presented with the 2014 International Water Association (IWA) Young Water Professionals (YWP) Award at the IWA Conference held in Lisbon, Portugal, earlier this year.

The Young Professionals Award is the highest recognition an individual member (under the age of 35) can achieve within the IWA. This prestigious award is given biennially to one exceptional YWP. The holders are recognised water professionals with outstanding career achievements and who have contributed significantly to the YWP network. These young people already have an impact on the water industry, but their potential to have a more influential role in the future is unquestionable.

Dr Jacobs has served as the IWA YWP Chair (2010-2012), the South African YWP Chair (2012-2014) and has also served on the board of IWA and the Water Institute of Southern Africa as YWP representative. She is particularly proud of the South African YWP Chapter, one that has grown in strength since its inception in 2007 and one that boasts the largest YWP regional conferences.

As the award winner, Dr Jacobs will become the honourable Ambassador IWA Young Water Professional for the next two years, and has dedicated herself to host the first YWP Africa Conference in November 2015.

New technology smokes out illegal stormwater discharges

The City of Cape Town is rolling out the use of smoke technology to detect illegal stormwater/sewer cross-connections.

Earlier this year, testing was conducted in various parts of the city and under different conditions to determine the system's efficacy. The introduction of smoke testing technology represents a significant step forward for the City, and is like to result in significant savings for the ratepayer. Preliminary estimates indicate that maximum savings could be in the region of R37-million.

This new method of detection involves pumping smoke into the local sewerage system to local inappropriate ingress of stormwater. Where it is found that such illegal or unsanctioned connections exist, the property owners will be provided with a compliance order to rectify the matter within a stipulated period, failing which a fine will be issued.

"Illegal connections are problematic in that, especially during wet weather, the presence of excess water can stretch the capacity of the City's wastewater conveyance systems," said Mayoral Committee Member for Utility Services, Councillor Ernest Sonnenberg. "Not only can this result in overflows, but the City's wastewater treatment plants are being forced to process water that otherwise should not have been treated. Limiting the amount of water that is unnecessarily treated every year will improve the quality of effluent that enters the environment."

Source: City of Cape Town

SA team improving safety at Moz dam

The National Directorate of Water through the Regional Administration of Water South (ARA-Sul) has awarded a contract for the rehabilitation of the damaged bottom outlet and related works on the 48-m high Massingir Dam in the Gaza Province of Mozambique.

Consulting engineer, Aurecon, has been appointed to supervise the construction of these rehabilitation works.

Following the raising of the full supply level of the dam through the installation of six large spillway crest gates, a sudden failure of the outlet conduits in 2008 resulted in an uncontrolled discharge of around 1 000 m^3/s to the downstream area, threatening the safety of the dam. Funded by the African Development Bank, the latest project will enhance the safety of the dam and render it fully operational again, increasing its capacity to supply downstream irrigation demands.

"In designing the rehabilitation works we drew on our previous experience in delivering cost-efficient and constructible major dam irrigation projects in Africa for many clients," noted Aurecon's Dams Leader, Peter Blersch. "Our local engineers, who have experience working with ARA-Sul and who are familiar with the local environment, will be supervising the construction. They will be supported by specialists in South Africa."

The rehabilitation works comprise the installation of 6.4-m diameter steel liners into the existing reinforced concrete outlet conduits, installation of hydropower offtakes, mass and heavily reinforced infill concreting and grouting, and rehabilitation of the two downstream radial control gates, including new hydraulic and electrical equipment.

Other work on the dam includes the construction of large diameter pressure relief wells, installation of supplementary dam safety instrumentation and crest lighting on the 4.5 km-long earthfill embankment.

Research chair in science communication a first for Africa

The first research chair in science communication in South Africa has been awarded to Stellenbosch University (SU).

It is the first chair of its kind on the continent of Africa, positioning the university to pioneer the development of this academic field across the continent.

Science communication has over the past few decades been established as an important new area of research, and many universities from across the world launched academic and research programmes in this field. Minister of Science & Technology, Naledi Pandor, led the way to promote this learning area locally by means of a research chair.

A number of South African universities competed to host this chair. The National Research Foundation announced the decision to establish the chair at SU after a competitive process which lasted for more than a year. The Department of Science and Technology will fund the chair for a period of 15 years (three terms of five years each).

In reaction to the announcement Prof Leopoldt van Huysteen, Acting Rector and Vice Chancellor at SU said: "Given the lack of research capacity in this area, this poses a unique opportunity for Stellenbosch University to take the lead in research and training of post-graduate students in the area of science communication."

The new chair will be housed within the Centre for Research on Evaluation, Science and Technology at SU. Prof Peter Weingart, a world leader in the area of interaction between science and society, will occupy the new science communication chair. He is professor extraordinaire at the University of Bielefeld in Germany, and has been a visiting professor to SU for the past 15 years.

The new chair will create opportunities for post-graduate students and researchers to study science communication within an African context, as well as to hone their practical communication skills.

New Knersvlakte Nature Reserve proclaimed on National Heritage Day

The Knersvlakte, one of the crown jewels in the country's rich botanical treasure trove, has been added to the national network of protected areas.

WWF South Africa, Cape Nature and the Leslie Hill Succulent Karoo Trust announced on Heritage Day the declaration of the new Knersvlakte Nature Reserve during a celebratory event at the historical Griqua farm, *Ratelgat,* near Vanrhynsdorp.

The Knersvlakte, located north of Cape Town, has long been recognised as a priority region for plant conservation. The area is known for its characteristic white quartzite gravel that conceals unique vegetation, including rare dwarf succulent plants with an indomitable instinct for survival.

The Knersvlakte boasts about 1 500 plant species, with 190 endemic species, of which 155 are threatened with distinction according to the IUCN's Red-list of species in the area. Experts say some of these plants are extremely vulnerable to climate change.

The reserve – the first to be declared in 20 years in the Western Cape – has been proclaimed in terms of the National Environmental Management: Protected Areas Act. The new 85 500 ha reserve falls within the succulent Karoo region.

Dr Morné du Plessis, CEO of WWF South Africa commented: "We are celebrating an extremely vital moment in our country's conservation history by protecting this seemingly desolate, largely under-appreciated area. This land holds immense biodiversity, and its plants have adapted to the arid hot climate making them beautifully unique."

Source: WWF-South Africa

DST announces new council on innovation

Water Research Commission CEO, Dhesigen Naidoo, is one of 19 new members of the National Advisory Council on Innovation (NACI) announced by Science & Technology Minister, Naledi Pandor, in September.

NACI is a statutory body established to advise the Minister of Science & Technology and Cabinet on all matters pertinent to innovation. The council provides advice to the Minister on the role and contribution of science, mathematics, innovation and technology in South Africa's social and economic development.

The NACI council members are drawn from various sectors and are people of distinction, influence and expertise in their fields. The council will be headed by Vice Chancellor and Principal of the University of Pretoria, Prof Cheryl de la Rey.

Announcing the new members, Pandor said: "I am pleased with the calibre of the Council members and the wealth of knowledge and expertise that they bring to this institution, which is a key priority for government. All appointees bring an impressive range of skills and experience from a diverse range of backgrounds. I am sure you will make a valuable contribution to the innovation of the country."

Regional chapter of International Water Security Network launched

In a move to secure South Africa's water, Deputy Minister of Water and Sanitation, Pamela Tshwete, has launched the South African regional chapter of the International Water Security Network.

This global network brings together the University of the West of England, Monash South Africa and the University of Arizona to investigate issues around water security. Under the themes of 'risks and vulnerabilities' and 'innovation and adaptive capacity', the programme with investigate urban water security, transboundary water security and improving water quality security.

"This five-year collaborative initiative will complement our strategies as a country and the work we have been doing as part of water provision in the different spheres of government," Tshwete said at the launch.

"We take note of the fact that South Africa has been selected to be among the first countries targeted for this programme. Our participation will also improve participation, collaboration and cooperation in other international platforms where we are involved in relation to water security, sourcing, control and provisioning to all our communities."

Source: DWS

SA research giants renew collaboration agreement

The CSIR and Stellenbosch University (SU) have renewed a Memorandum of Understanding (MoU) following successful collaboration between the two organisations in various areas of research and development.

Dr Rachel Chikwamba, CSIR Group Executive: Strategic Alliances and Communication (pictured with SU Deputy Vice-Chancellor, Prof Eugene Cloete), says that the relationship established in terms of the original MoU signed in 2008 was fruitful, and has resulted in numerous successful projects.

"Historically our scientists (of CSIR and SU) have collaborated in a variety of areas. The MoU seeks to elevate collaboration in specific priority areas, which are aligned to national priorities and are core to the strategies of the two organisations," she said. "Human capital development is a critical mutual objective, and this partnership will allow the two institutions to join forces in creating skilled human capital and increase the number of people with post-graduate training as articulated in the National Development Plan and various strategies of government."

According to Prof Cloete, the university is exploring possible areas of collaboration which will position them as one of the leading research universities in the world. "The most critical challenges that South Africa faces require collaboration among different universities and research councils to create critical mass to investigate and solve these problems. SU and the CSIR have had a synergistic relationship in the past and with this MoU, we aim to intensify the collaboration in areas where we have complementary expertise. The collaboration expands the capacity of the university to produce highly qualified staff, especially at doctoral level, while doing directed research."

In the area of natural resources and the environment, areas earmarked for collaboration include sustainability studies, including wind and solar photovoltaics, ocean energy, invasive biology, resource economics, sustainable energy, environmental assessment and management, ecosystem services, coastal engineering, groundwater and environmental microbiology.

Plants have little wiggle room to survive drought – study

Plants all over the world are more sensitive to drought than many experts realised.

This is according to a study by scientists from the University of California – Los Angeles (UCLA) and China's Xishuangbanna Tropical Botanical Garden. It is expected that the research will improve predictions of which plant species will survive the increasingly intense droughts associated with global climate change.

Predicting how plants will respond to climate change is crucial for their conservation. But good predictions require an understanding of plants' ability to acclimate to environmental changes, or their 'plasticity'. All organisms show some degree of plasticity, but because they're stationary, plants are especially dependent on this ability.

"Plants are masters of plasticity, changing their size, branching patterns, leaf colours and even their internal biochemistry to adjust to changes in climate," said Lawren Sack, a professor of ecology and evolutionary biology in the UCLA College and the study's senior author.

Little has been known about the degree to which plastic changes might allow plants to endure worsening droughts.

"Plants have evolved this amazing ability to sync with their environment, but they are facing their limits," noted Megan Bartlett, a UCLA doctoral student and the study's lead author.

Compiling and analysing data for numerous species from various ecosystem around the world, Bartlett found that most species accumulate salts in their cell sap to finetune their tolerance to seasonal changes in rainfall. But that adjustment only provides a relatively narrow degree of additional drought tolerance.

Saltier cell sap gives plants the ability to continue to grow as soil dries during drought. Unlike animal cells, plant cells are enclosed by cell walls. To hold up the cell walls, plants depend on 'turgor pressure' – the pressure produced by internal water pushing against the inside of the cell wall. As the cells dehydrate, the turgor pressure declines until the cell walls collapse, and the leaf becomes limp and wilted.

Drawing on both new data and previously reported data, the team determined the overall picture of how much plant species adjust their cell sap saltiness to maintain turgor and continue to grow during drought. "For most plants these adjustments were small," explained Sack. "This means they only have limited wiggle room as droughts become more serious. On the plus side, this discovery means we can estimate species' drought tolerance relatively simply. We can make a reasonable drought tolerance measurement for most species regardless of time of year or whether we are sampling during dry of wet conditions."

The research has been published in the journal, *Ecology Letters*.

Water world saddened by passing of international award winner

The international water community is mourning the death of 2014 Stockholm Water Prize Laureate, Prof John Briscoe, who passed away on 12 November from colon cancer.

South African born, Prof Briscoe received the 2014 Stockholm Water Prize from Sweden's King Carl Gustav (pictured on the right) for his unparalleled contributions to global and local water management, inspired by an unwavering commitment to improving the lives of people on the ground.

His genius lay in his fusion of science, policy and practice, which gave him unrivalled insights into how water should be managed to improve the lives of people worldwide. Prof Briscoe became known for his passionate commitment to sustainable economic development, his disrespect for constructed boundaries between sectors and people, and for his insistence that the voice of people who are affected – from the poorest of farmers to the private sector, to political leaders – be heard.

At the time of his death he lived in the United States and worked at Harvard University.

Shortly before his death Prof Briscoe sent out the following message:

"I lived a very blessed life as many of you know. This is true with my friends, my family and with my profession. I had every opportunity imaginable to a young boy from South Africa. And always my life was a lucky one with immense opportunity at every stage, including the 22 years at the World Bank and the last six at Harvard University."

As a last act of his kindness and generosity, Prof Briscoe used his prize money to set up the John Briscoe Science, Technology, Engineering and Mathematics (STEM) Award at his alma mater, St Patrick's Christian Brothers College Kimberley. The award will be made to the 12th grade student who has shown the greatest achievements in mathematics and science, has shown an interest in technology and has indicated an intention to study engineering.

UN launches handbook on human right to water and sanitation

A new publication, *Realising the human rights to water and sanitation: A handbook*, has been published by UN Special Rapporteur, Catarina de Alburquerque.

The handbook will serve as a practical guide, explaining the meaning and legal obligations that stem from the human right to safe drinking water and sanitation. It translates the often complicated legal language into information that can be readily understood by practitioners, including government officials and members of civil society organisations.

Specifically, the handbook has been developed to clarify the meaning of the human rights to water and sanitation; explain the obligations that stem from these rights; provide guidance on implementing the human rights to water and sanitation; share good practices and how these rights are being implemented; explore how governments can be held to account on delivering their obligations; and provide checklists, so users can analyse how they are complying with the rights.

To access a digital copy of the handbook, Visit: http://unhabitat.org/un-launches-handbook-on-human-right-to-water-and-sanitation/

New from the WRC

Report No. TT 589/14

Manual for fish kill investigations in South Africa (B Grant; D Huchzermeyer & B Hohls)

Large-scale fish kills have become a common phenomenon that is increasing internationally. An understanding of the causes of fish kills and why they occur is fundamental in order to implement preventative measures to reduce their frequency and magnitude. However, despite the advancements in fisheries and aquatic sciences, the science of fish kill investigations at an international level is still considered rudimentary. The purpose of this study was to adapt and refine current internationally-applied protocols and local guidelines for fish kill investigations specifically for the South African context. In doing so, the study sought to promote a consistent national approach in response to the investigation of such incidents and improve the management thereof.

Report No. 1986/1/14

Wetlands in South Africa: Their contribution to well-being (D Hay – Editor)

It is widely accepted that unmanaged competition is causing degradation that reduces the supply of ecosystem services. This is particularly prevalent at wetlands where inappropriate land use leads to declining supply relative to need, competitive behaviours and over-utilisation. This study investigated how to sustain the linkages between well-being and wetlands through governance and adaptive management systems through which rights to access, use and benefit from the ecosystem services derived from wetlands are granted, acknowledged and honoured.

Report No. 2195/1/14

New housing unit designed for ceramic water filters in rural and peri-urban communities in South Africa

A previous WRC study was carried out in the Limpopo Province and the results showed that the Potters for Peace ceramic water filter (sourced from Ghana) is a viable option. Part of the study was looking how the rural communities accepted these filters and what possible changes could be made to increase the efficiency of the filters. It was found that if certain design aspects could be addressed, the water filter would be better accepted. In this follow-up project an industrial designer was appointed to assist with the redesign of the ceramic filter housing to be both functional and effective for local use.

Report No. 2098/1/14

An approach towards developing technical sanitation solutions for informal settlements (A Lagardien & C Muanda)

This research project was aimed at investigating technical sanitation solutions for informal settlements in response to numerous sanitation challenges faced by dwellers. The intention of the research is mainly to develop an approach for sanitation concepts and solutions that respond to particular conditions of informal settlements.

Report No. TT 605/14

Wetlands and well-being: Getting more out of South Africa's wetlands (D Hay; D Kotze & C Breen)

This handbook is a product of a research project on the contribution of wetlands to the well-being of communities. The focus here is on freshwater inland wetlands but the lessons are derived from and could equally be applied to other aquatic systems, particularly lakes, rivers, dams, estuaries and our coastline. The decision-support system has been developed as part of this project.

Report No. TT 603/14

Quality of harvested rainwater and application of point of use treatment systems (PH Dobrowsky; A van Deventer; M Lombard; M de Kwaadsteniet; W Khan & TE Cloete)

Domestic rainwater harvesting (DRWH), which involves the collection and storage of water from rooftops and diverse surfaces, is successfully implemented worldwide as a sustainable water supplement. In this study, available literature on the chemical and microbial quality of DRWH, with a particular focus on the sources of microbial pollution and the major pathogens associated with the water source was reviewed. Incidences of disease that have been linked to the consumption and utilisation of harvested rainwater are also discussed. Finally, various procedures and methods used for the disinfection and treatment of harvested rainwater, such as the implementation of filter systems, heat treatment and chlorination, among others, are presented.

Report No. 1958/1/14

An investigation of water conservation in food value chains by beneficiaries of water allocation reform and land reform programmes in South Africa (W de Lange; K Nortje; N Funke; A Nahman; B Mahumani; C Musvoto)

The project on which this report is based was conceptualised by the WRC in an attempt to engage with the need to improve the alignment of water and land reform initiatives in South Africa. Among others, the report sought to review the social, cultural, institutional, economic and political variables influencing water allocation reform and land reform programmes and projects; assess the efficient development and use of water within the broad framework of food value chains; analyse alternative opportunities for including beneficiaries of selected water and land reform projects in the food value chain; and to develop guidelines for the sustainable development and use of water in food value chains within water allocation reform projects. Also available is *Volume 2: Guidance on water conservation in food value chains.* This volume is divided into three parts, *Part 1: Guidebook for emerging farmers in the Maruleng Municipal Area* (**Report No. TT 607/1/14**); *Part 2: Guidebook for extension officers in the Maruleng Municipal Area* (**Report No. TT 607/2/14**); and *Part 3: Guidebook on different types of emerging farmers and the everyday challenges they face: Insights for policy advisors* (**Report No. TT 607/3/14**).

To order any of these reports, contact Publications at Tel: (012) 330-0340; Fax (012) 331-2565; E-mail: orders@wrc.org.za or Visit: www.wrc.org.za

ALI MAZRUI – Celebrating the life of an intellectual giant

On 12 October 2014 Africa – and the world – lost one of its greatest sons with the passing of renowned Pan-Africanist, scholar and teacher, Prof Ali Mazrui. He died aged 81 at his home in Vestal, New York, following several months of illness.

Born in Mombasa, Kenya, Prof Mazrui was one of the world's most prolific writers on Africa, its people, history and future. In a career stretching over 50 years he authored and co-authored more than 40 books as well as hundreds of articles in major scholastic journals and for public media. In this way, he profoundly influenced ideas about Africa among scholars and members of the general public alike.

Described as a free thinker who would not distort the truth and facts to the dictates of the establishment, Prof Mazrui's views did not always sit well with some audiences, yet his powerful writing style made it impossible for even his harshest critics to ignore the unique perspective he brought to a variety of African issues. The subject matter of his writings ranged from politics, sociology, philosophy, languages, literature, history, heritage, religion, to spirituality, and demanded that people from all walks of life participate and contribute to discourse and dialogue.

His soft-spoken charm and eloquence as a lecturer also made him a favourite among students at every university he served. So revered was he as a teacher and mentor that family and friends referred to him as 'Mwalimu' (Swahili for teacher).

At the time of his death, Prof Mazrui was the Albert Schweitzer Professor in the Humanities and Director of the Institute of Global Cultural Studies at Binghamton University, State University of New York. He had also been serving as the Andrew D White Professor-at-Large Emeritus and Senior Scholar in Africana Studies at Cornell University and as the Albert Luthuli Professor-at-Large at the University of Jos, Nigeria.

Prof Mazrui became a well-known figure outside of academia in 1986 when he wrote and hosted the nine-part television series, *The Africans: A Triple Heritage*. The show's subtitle refers to the three legacies – Islamic, indigenous and Western – that have been most apparent in the formation of modern African identity.

Wrote the South African Presidency in 2007: "Prof Mazrui is one of the greatest minds ever to have been produced by the African continent. His prolific writing, coupled with the variety of fields he has been covering in his academic life proves the versatility of his intellect. He has put the African continent on the pedestal, unearthing and laying bare the grandeur of Africa to a world that had been but paying marginal attention to the intellectual depth of the African continent."

Mazrui's honours are numerous. For example, he won the Distinguished Faculty Achievement Award of the University of Michigan in 1988 and the Distinguished Africanist Award of the African Studies Association of the U.S. in 1995. The President of Kenya awarded him the National Honour of Commander of the Order of the Burning Spear and the President of South Africa made him Grand Companion of Oliver Tambo. Morgan State University awarded him the DuBois-Garvey Award for Pan-African Unity. In 2005, the American journal Foreign Policy and the British journal Prospect ranked Mazrui among the top 100 public intellectuals in the world.

In November 2012, the Water Research Commission (WRC) was privileged to host Prof Mazrui as a special keynote speaker at the International Conference on Freshwater Governance for Sustainable Development, held in the Drakensberg. Here he emphasised our inextricable link with water not only as it sustains life, but also in terms of culture, religion and heritage. "The issue of water affects the farmer praying for rain, affects a villager in fear of a hurricane, affects a mother terrified of river blindness, and affects the whole society in quest of hygiene in water usage," he said.

Prof Ali Mazrui with WRC CEO Dhesigen Naidoo in 2012.

Prof Mazrui's vision for Africa, is in many ways shared by that of the WRC. In the words of lifelong friend Burjor Avari, honorary research fellow at Manchester Metropolitan University, Prof Mazrui wanted the people of his beloved continent to enjoy the benefits of modern science and technology and become more prosperous.

His eldest sons, Jamal, Alamin and Kim posted a heart-warming tribute to their father on Facebook: "Our father's love of life leaves us all to pause and consider more deeply: what would we be, what could we be, if we moved beyond fear and anxiety and embraced, as he did – our incredible human potential and the fulfilment of life in all of its glory."

Says WRC CEO Dhesigen Naidoo: "Baba Mazrui's empowering contribution has been to demonstrate that harsh corners of fundamentalism and discrimination can be smoothed through the calmness of intellectual enquiry, paving the way for a more informed dialogue to sow the seeds of sustainable solutions. His legacy will continue to inspire Africa and all her partners for many generations to come."

Prof Mazrui was laid to rest according to his wishes in the 900-year-old Mazrui family cemetery in old town Mombasa. He is survived by his wife, Pauline, five sons and a daughter. ❑

Why apps fly and cell phones should float

Any water scientist worth his salt will tell you to always expect the unexpected, especially in the field. And as Shanna Nienaber, Mark Graham, Tembeka Dambuza and Jim Taylor found out, sometimes stories have a happy ending.

When a story starts with "it's a true story" it's seldom true. But here's a story of the trials, tribulations and comedies of working in the water sector that really is true. You may have heard about the Stream Assessment Scoring System (mini-SASS), a citizen science tool that has been developed to monitor the health of a river and help ordinary people develop a river health index? MiniSASS does this by reading the stories that the insects, or actually the groups of macro-invertebrates, that live in the stream have to tell us. By studying these creatures we get closer to the truth about river health.

A unique partnership between the Water Research Commission, Department of Science & Technology (DST), WESSA and GroundTruth is now developing a miniSASS cell phone app. This is the stuff of goose bumps and 'realising the dream'.... everyday citizens uploading important river data in real time, alongside rivers around the country – and for free!

The 15 August 2014 marked the grand occasion when the App development team visited Howick to meet the Mini-SASS team and to get their feet wet with a real experience of mini-SASS-ing in KwaZulu-Natal. It was imperative to visit the site where the mThimzima stream enters Midmar – a site of some of the most serious point source pollution to enter the dam. The best way to get there is by canoe, which is also a cool way to travel, and have fun!

At the Mthimzima stream confluence, whilst trying simultaneously to admire some fish eagles, study some algae and balance in a K2 canoe; Shanna Nienaber, our unfortunate DST colleague, dropped her cell phone into Midmar dam. No amount of river searching, swearing or sloshing was to reveal the phone – it was gone for good – or so it seemed.

And so life moved on, phones will always come and go, won't they? Except for the two dedicated WESSA and GroundTruth canoe enthusiasts, Jim Taylor and Mark Graham, who never gave up looking. They dutifully revisited the site of the cell phone's fatal plunge as the days went by. Twenty-four days later, on 7 September 2014, no rain and some evaporation later, Midmar Dam revealed the extremely muddy, and wet, white Samsung S3 on its banks.

The wet cell phone was cleaned, wiped and placed on a window sill to dry. On the 30 September the Mini-SASS team held a SADC-wide workshop to learn about citizen science tools and put mini-SASS through its paces. Whilst presenting the exciting news of the new mini-SASS app, which is still under development, Shanna was presented with her, now clean, white cell phone with a still very muddy cover and guess what, it works! Lo and behold, the phone switches on as if nothing ever happened to it. This begs the question, should we be developing a mini-SASS cell phone app or a phone that floats? ❑

Above: *A triumphant Mark Graham (in front) reunites Shanna Nienaber (in front left) with her phone while members of the SADC mini-SASS workshop look on.*

A TRUE STORY THAT'S REALLY TRUE

There once was a girl who
didn't know what to do,
When she dropped her cell
phone off the side of a canoe!
Weeks went by, she let all hope
die.
But then, the magic of Midmar
dam,
Spat the phone out of the
water onto the banks for a tan.
Where 'lo and behold' (as the
story is told)
Two blokes going by, spotted
the phone from the corner of
their eye.
So now the girl has no reason
to moan,
Because the universe has
reunited her with her phone.
And best of all .... It switches
right back on
As if nothing at all, ever went
wrong!

BIOMIMICRY: Exploring nature's genius for a better tomorrow

As populations expand and pressures on our water increase, scientists have to find new, innovative ways to protect the nation's scarcest natural resource. A new research discipline is illustrating that the secret to a successful survival strategy might lie in nature itself. Article by Lani van Vuuren.

Man has studied nature for hundreds of years. First we tried to tame it, to control it with our structures and machines. In many ways we now seek to protect it against those same structures. Yet our challenges remain – billions of people around the world still lack access to clean water while pollution threatens the supply of those who have access.

In 1997, US biologist Janine Benyus introduced the world to the concept of biomimicry. Since then this new discipline has taken off in leaps and bounds. Biomimicry is described as the practice of learning from and then emulating natural forms, processes and ecosystems to solve human design challenges and create more sustainable designs.

"We are very used to learning about nature," explains biomimicrySA founder, Claire Janisch, speaking at an interview earlier this year. "Biomimicry turns this around and asks what can we learn from nature and how can we take that learning and apply it to our own designs so that we ourselves start to emulate that genius we see in nature?"

Peter Chadwick/Africa Media Online

There are three types of biomimicry – one is copying form and shape, another is copying a process, like photosynthesis in a leaf, while the third is mimicking at an ecosystem level, such as building a nature-inspired city.

The core idea is that nature, imaginative by necessity, has already solved many of the problems we are grappling with. Animals, plants and microbes are the consummate engineers, physicists, chemists and engineers. They have found what works, what is appropriate, and most important, what lasts here on Earth.

By looking to nature's examples we can begin to create innovative and progressive solutions to the design, engineering and other challenges we now face: in energy, food production, climate control, transportation, water supply and more. The vision of the biomimicry movement is to create products, processes, organisations and policies – new ways of living – that are well adapted to life on earth over the long haul. An important note on biomimicry is that it uses the recipes from organisms – not the organisms themselves.

BIOMIMICRY'S POTENTIAL FOR WATER

Realising the potential of this new discipline for water, the Water Research Commission (WRC) initiated a five-year project to demonstrate the biomimicry methodology in a South African setting. The project, being undertaken by Golder Associates Africa, together with Cape Peninsula University of Technology, the University of the Witwatersrand and biomimicrySA, will be completed next year.

Traditionally, we have thought in very linear ways when looking to solve our water problems, look at a typical wastewater treatment chain: wastewater goes in through concrete structures, gets treated, then flows out again, explains WRC Research Manager, Dr Valerie Naidoo. "The biomimicry methodology challenges us to think more three-dimensionally. Instead of fighting against nature we are now looking to it for innovations, using nature's own principles to come up with solutions to our challenges."

Since this is the WRC's first foray into this field, for now the project is focused only on biomimicry and wetland design. Researchers are looking to nature for innovative ways of enhancing constructed wetlands and rehabilitating existing wetlands. "Wetlands serve as natural filters, removing pollution from waters flowing through them. The economic value of this natural filter is immense, reducing the full cost of downstream (potentially high energy) treatment systems and water purification, notes Dr Naidoo. If successful, this methodology can then be implemented on other systems and processes where appropriate.

The study is looking to exploit knowledge on how nature cleans water to better engineer constructed wetlands to meet the challenges of current and emerging pollutants and pathogens. The core project team comprises engineers and scientists with expertise in various sectors. During the duration of the project experts have been consulted and invited to participate in workshops and seminars in order to incorporate their knowledge and delivery a novel approach to constructed wetland designs for water treatment.

"This project is really exciting as it is not an easy methodology to apply. We are asking researchers to stop thinking about innovation in a traditional sort of way and enter a more creative, multidisciplinary space," says Dr Naidoo. "This project is only the start of what we hope will be a new wave of creativity to enter the South African water space."

To date, the team has had a mixed reaction from colleagues, with some researchers not seeming very keen on giving up their conventional way of thinking and others seeing the potential of biomimicry. Perhaps the true worth of biomimicry will not be in solving just the water sector problems but in contributing to economic growth and the knowledge economy through the development of innovative products and processes for the marketplace, notes Dr Naidoo.

HOW DOES BIOMIMICRY THINKING WORK?

Golder environmental engineer, Priyal Dama Fakir, explains in a Water Institute of Southern Africa conference paper what the key steps in

Wikipedia

The mouth of the humpback whale has an excellent water filtering mechanism.

the biomimicry innovation methodology are. The first step is to **identify** the core problem that needs to be solved, asking questions such as: What do I want to achieve? and What do I want my design to do?

The next step is to **interpret** or to 'biologise' the question. "As an example, consider a design problem where the designer is required to treat water containing high concentrations of sulphate. Typical questions would be: How does nature remove sulphates from water? How does nature survive under high sulphate conditions? What natural processes require high sulphate conditions?," explains Dama Fakir. One also needs to understand the overall context of the solution being investigated.

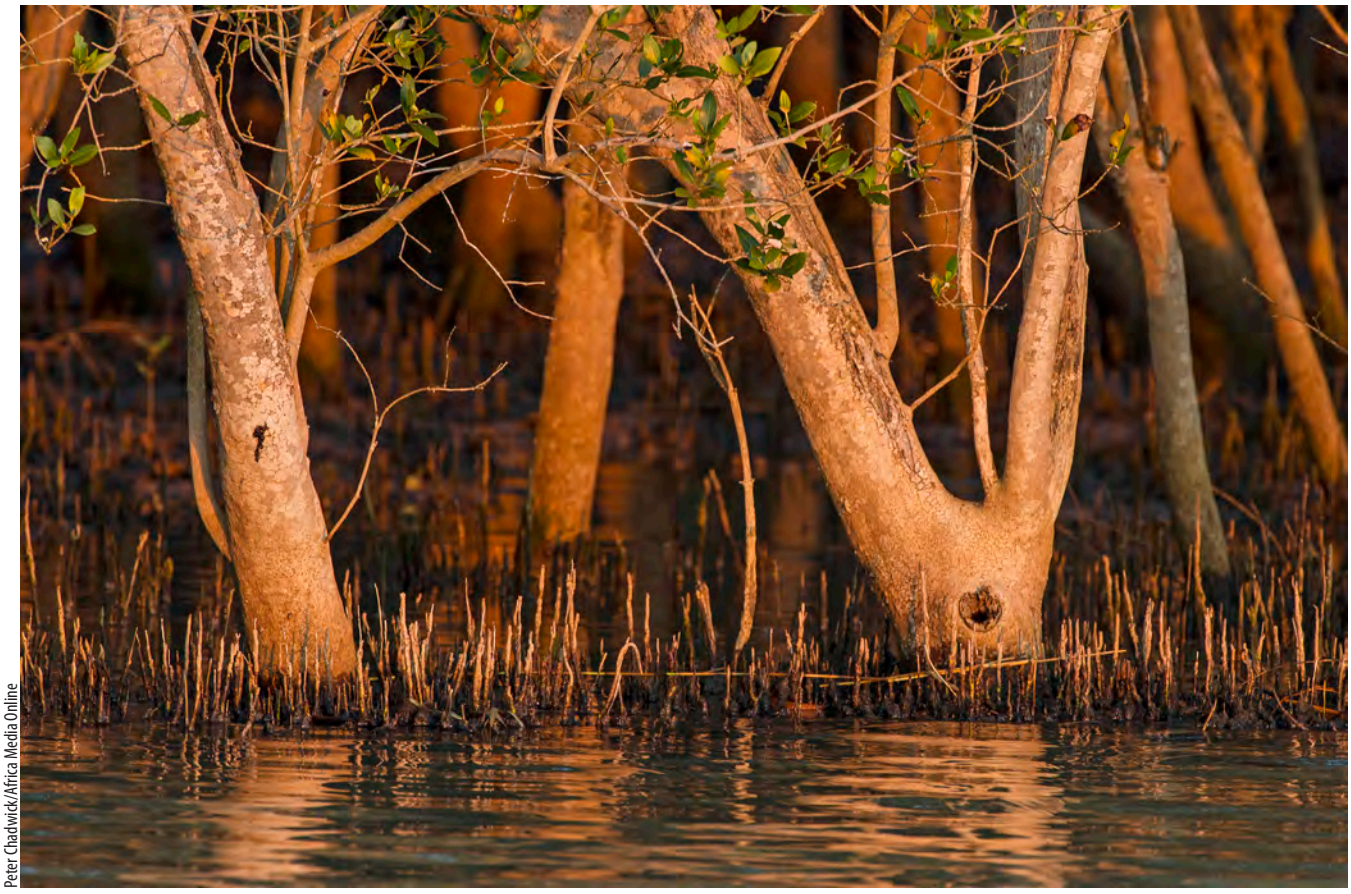
The third step is to **discover** – actually finding solutions in nature. This means brainstorming between designers and biologists, identifying nature's models which meet the functions indentified, and selecting the champions by considering the context and identifying the organisms whose survival are dependent on the function.

The next step is to **abstract** or understand the principles and context and select a shortlist of champions. Key here is to look for repeated successes and the principles that achieve this.

Now it is time to **emulate** – to actually mimic the innovation discovered. The last step is to **evaluate** your innovation again life's principles and identify areas of improvement to the design. These principles include being resource efficient, using life-friendly chemistry, integrating development and growth, being locally attuned and positive, adapting to changing conditions and evolving to survive.

EXAMPLES FROM NATURE

The WRC study has come up with a tool to guide a whole host of potential innovations. Nature is full of examples of sufficient and efficient ways to treat water. Take the mangrove, for example. Remarkably tough, mangroves can live in water up to 100 times saltier than most other plants can tolerate. This is because of the ability of these estuarine plants to filter out the salt as the water enters their roots.



Mangroves can tolerate extremely salty water due to their desalinisation abilities.

Peter Chadwick/Africa Media Online

Some species of mangroves excrete the salt through glands in their leaves. Others concentrate the salt in older leaves or bark. When the leaves drop or the bark sheds, the stored salt goes with them.

The ability to filter water is also found among animals. Flamingos have bills lined with numerous complex rows of lamellae, which filter out the various small crustaceans, algae and unicellular organisms on which the birds feed. The feeding process requires a series of tongue movements and opening and closing of the beak, which allows food items to be filtered by the lamellae and eventual ingestions.

Unwanted items, such as mud and water are pushed out by the tongue. Swinging the head to and fro allows water to enter the beak. Acting as a pump the tongue moves back and forth sucking the water in and forcing it out.

Looking to an example from the sea, Baleen whales, which feed on krill, have no teeth. Instead, they have developed a keratinous row of fibres, known as a baleen, to filter out organisms from seawater. The keratin sheath of each baleen plate encapsulates hair-like strands that become evident as the sheath is worn down and splits open.

Upon closing its mouth, the whale's lower jaws distends, creating pressure against the baleen. This forces water through the keratin fibres, but retains all organic material. Once material is forced out the whale's tongue rises and sweeps the organic material off the baleen and swallows it.

The principles of Baleen whale filtration have been emulated in existing biomimetic technology, called Baleen filters. Water runs through the filter, causing visible solids and particles to remain behind in the filter. Hereafter, a second high-pressure, low-volume spray of water dislodges the solids and carries it away.

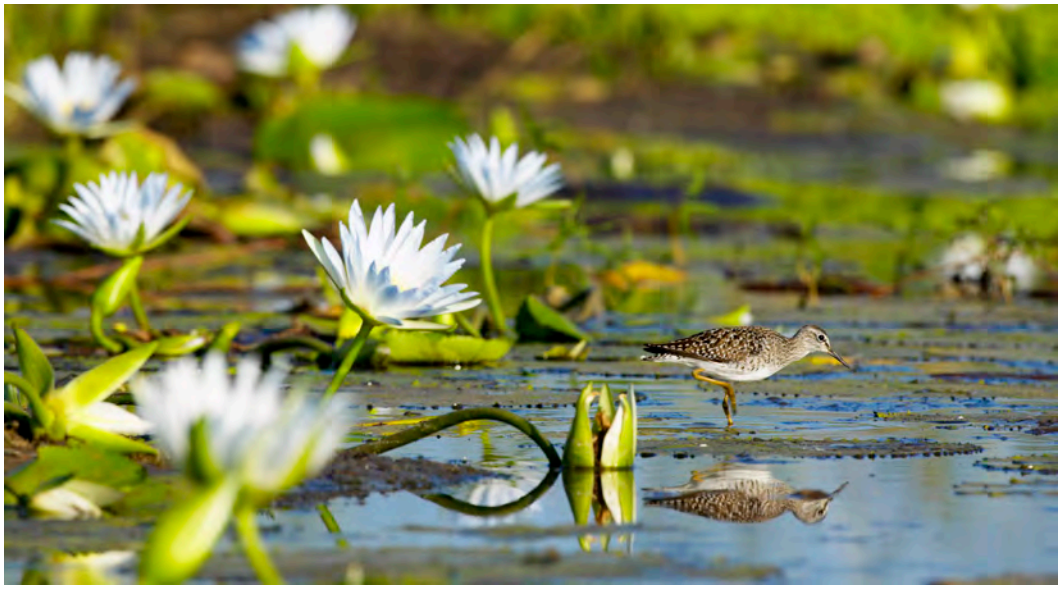
Among nature's genius that has been most successfully emulated are aquaporins. An aquaporin is a membrane protein that allows water to pass through cell walls. These proteins contain pores in the shape of an hour glass, made of crystalline material and are used to transport water in and out of cells. Aquaporins transport the water through membrane at a rate much faster than diffusion.

A Danish firm, also called Aquaporin, has mimicked this by using a forward osmotic system incorporating aquaporins to increase the water transport rate. Aquaporins are embedded into artificial membranes simulating the natural behaviour of biological membranes. Since aquaporins are ubiquitous among all living organisms they can easily be produced.

Several other successful innovations have been identified during the WRC study which could potentially be mimicked to produce sustainable water treatment technologies. It is hoped that some innovations can be tested at lab scale and could lead to new solutions for the water sector and beyond.

It is hoped that this WRC project on biomimicry will be the start of a new way of approaching South Africa's water challenges. As we look to learn from nature's genius, may it also awaken the genius in ourselves. ❑

"Biomimicry asks what can we learn from nature and how can we take that learning and apply it to our own designs so that we ourselves start to emulate that genius we see in nature."



Roger de la Harpe/Africa Media Online

The WRC project is looking to nature to improve the functioning of constructed wetlands.

New project lends from nature to power up villages

Ethel Khumalo

Villages in three provinces in South Africa are now benefiting from greener energy technologies thanks to strategic research by the Water Research Commission (WRC). Article by Petro Kotzé.

"My biogas was installed in November last year and when I started to use it I saw a big difference. I was under a lot of pressure when I used wood and electricity because I would pay R750 and that would only last for three months. I once went three days in darkness and I had to use candles until pension day when I could buy more power. Now that I have biogas it has helped me tremendously."

These are the words of Ethel Khumalo, who lives at Obonjaneni in KwaZulu-Natal with her three sons and three grandchildren. Hers is one of the four households across KwaZulu-Natal and the Eastern Cape, as well as community cooperatives in the Limpopo province, who have proven the effectiveness of an alternative, green energy source to improve lives.

Energy is seen as central to improved social and economic well-being, and a key factor for relieving poverty, improving human welfare and raising living standards. For this project, the alternative source of energy is one that has not received as much attention as popular choices like solar, wind and hydro. "There was a need to investigate biogas as part of the renewable energy mix," explains Dr Sylvester Mpandeli, WRC Research Manager for Water Utilisation in Agriculture. As a result, the WRC initiated a project with the University of KwaZulu Natal (KZN), which focuses on the use of biogas at household level, an aspect that is unique in comparison to other similar schemes.

The project aims to introduce biogas production from cattle manure for energy generation into rural households. It goes further to test the effectiveness of bioslurry as liquid fertilizer as well as rainwater harvesting to feed the biogas digester, and for domestic use and crop production. At the same time, while the project enables people to use a readily available energy source, it is a waste management technology that cleans the local environment, and improves the health and quality-of-life of the participants.

Even though the project was awarded to the UKZN, it is a multi-organisational effort. Partners comprise of various organisations, including the universities of Rhodes and Venda and AGAMA Energy. The

researchers themselves come from a variety of backgrounds. "The integration of having a crop scientist, soil scientist, grassland scientist, hydrologist, economist and a social scientist makes it one of the most integrated projects I've worked with," says project leader Dr Terry Everson, a senior research associate at the UKZN.

"While the project enables people to use a readily available energy source, it is a waste management technology that cleans the local environment, and improves the health and quality-of-life of the participants."

For the WRC, this choice was "a strategic intervention," says Dr Mpandeli. While multiple organisations benefit, a number of post-graduate studies have sprouted from it. Strikingly, the project is also building capacity on a community level – educating and uplifting those that could benefit from the results in future.

This was an important element for any realistic success. According to Dr Mpandeli, buy-in from communities was essential. An important initial part of the project entailed educating community members on what the researchers are trying to do. "We prepared videos, brochures and had meetings in all the communities to raise awareness," says Dr Everson. "One of the most effective methods was cross visits, where we took people to existing biogas projects, where they could see how biogas actually works and learn from other community members."

Once they understood how gas for cooking could be generated from manure, the researchers had no lack of volunteers willing to participate in the trial. "We've had so many requests from community members and school feeding schemes," she says "as they see the huge potential of integrated systems such as this".

Participants were selected according to set criteria. They had to, for example, be able to collect a bucket of water and manure a day. "After establishing the minimum criteria we gave community members the task of selecting the most deserving households", says Dr Everson. "This transparent and consultative process was initiated to promote fair selection of biogas digester beneficiaries".

Four biogass digesters were then installed in KwaZulu-Natal and five in the Eastern Cape. Lessons learnt from here were then applied to a different model for implementation in two community cooperatives in Limpopo. Here, one of the biogas digesters was implemented at a school which feeds over 200 pre-school children.

With no electricity village women and children have to walk long distances to collect firewood.

***Above:** The biogas setup in a participant's home.*

***Right:** The biodigesters are coupled to supply one burner in a kitchen about 30 m away.*

A CLOSER LOOK AT THE SYSTEM

A typical system comprises a fixed-dome pre-fabricated AGAMA bio-digester, which is linked to a burner in a kitchen about 30 m away. Each digester container is 2.2 m in diameter and 2.5 m high. It can produce enough gas to provide two hours of burning a day which is equivalent to 0.8 kg LPG or 3.5 kHh continuous electrical output.

Each digester is fed with 20 kg of organic raw material mixed with 20 ℓ of water at a ratio of 1:1 per day. The produced biogas is stored in the dome of the digester and piped directly to the gas burner. While the gas cannot be connected directly to LPG appliances, it is used on a purpose-built biogas appliance. The records kept by community members indicate that there is sufficient biogas for the average household's cooking requirements, if the gas is used in conjunction with efficient cooking methods (e.g. wonderbags).

A second element of the study was the investigation of the use of bioslurry (the decomposed effluent that is a by-product of the anaerobic digestion process) to enhance yield and quality of food crops (e.g. maize) and fodder crops (e.g. Napier grass). The slurry contains 93% water and 7% solids which is a ready-made fertilizer containing key nutrients (N, P, K) needed for plant growth.

It can be applied directly on to fields to grow crops and there is evidence that the productivity of agricultural land can be increased significantly with its use. Further benefits include that it is completely safe in terms of diseases, and doesn't smell or attract flies, says Dr Everson.

Although community members report an increase in the size of crops like cabbages, experimental trials have not shown a huge increase in production. The correct application is recommended as a potential topic for future research.

A critical factor in the operation of a biogas digester, for both biogas and bioslurry fertilizer, is water. The digester has to be fed 20 ℓ a day to maintain biogas production, amounting to 7 200 ℓ per year or 600 ℓ per

"Now women and children do not have to go off for hours to collect wood or pay R300 to R400 per load."

month. However, access to water is a limiting factor for the households in this study. To bridge this gap, the project relies on rainwater harvesting. From 13 techniques recognised for use in South Africa, rooftop water harvesting was selected as the most plausible option. Rainwater is simply collected from rooftops and stored in tanks.

According to Dr Everson, one of the main advantages about the process is that it only entails natural resources, and that there are no chemical or mechanical aspects involved. There are a host of other benefits too, but before mass implementation can take place, a number of hurdles will have to be overcome.

BENEFITS AND CHALLENGES

Perhaps most importantly for the community members, the project has great potential to improve livelihoods through more efficient use of resources. While the benefits are being felt in pockets by money saved on the purchase of wood or electricity, much time is also saved in firewood collection.

"Now women and children do not have to go off for hours to collect wood or pay R300 to R400 per load" says Dr Everson. There are also health benefits to not breathing in the smoke from wood fires anymore. Plus, the biogas projects are often driven by the female head of the household, giving them the opportunity to claim a stake in the green economy.

However, there are also some prohibitive aspects to project implementation, the biggest concern of which is probably the cost of the infrastructure. At a cost of R32 000 per biodigester, the study has shown that it is not a financially feasible investment. Yet, significant economic advantages were identified as well as significant social benefits.

Biogas implementation requires suitable guidance, education and modification to accommodate various situations. The optimal running of a biodigester is important in achieving the identified financial and economic value. This can be challenging, given the novelty of the technology in South Africa, especially in rural communities.

During rooftop water harvesting rainwater is simply collected from rooftops and stored in tanks.

Regardless, while the benefits and costs are highly site specific, it is thought that there are thousands of households technically suitable for biodigester use. While the project is coming to an end in March 2015 (having run since 2010), both the WRC and researchers are looking forward to taking this initial work further, and bigger, in future.

Community members have given positive feedback after the use of bioslurry as fertilizer on their vegetable plots.

Members of the Maila Cooperative in Limpopo who feed pre-school children with its produce.

UKZN post-doctoral student, Yashwant Singh, admires Ethel Khumalo's vegetable garden.

Community members have participated actively in the monitoring of the technology.

INTO THE FUTURE

"Basically our pilot project was small-scale with implementation at household level so, the next step is to up-scale to village level." notes Dr Everson.

In broader terms, a Green Village is envisaged by the WRC where "a knowledgeable rural community in which a healthy ecological infrastructure is maintained, which practises sustainable and productive agriculture, and utilises renewable energy." The current biogas project is one small step in attaining this goal.

To create a Green Village we need to use, the numerous guidelines, methods and procedures on water services enhancement, food security, energy, rehabilitation, and biodiversity protection that have been produced by the WRC and other research organisations. In essence, it will demonstrate that basic services provision can be achieved without compromising ecological infrastructure, through exploring greener alternatives.

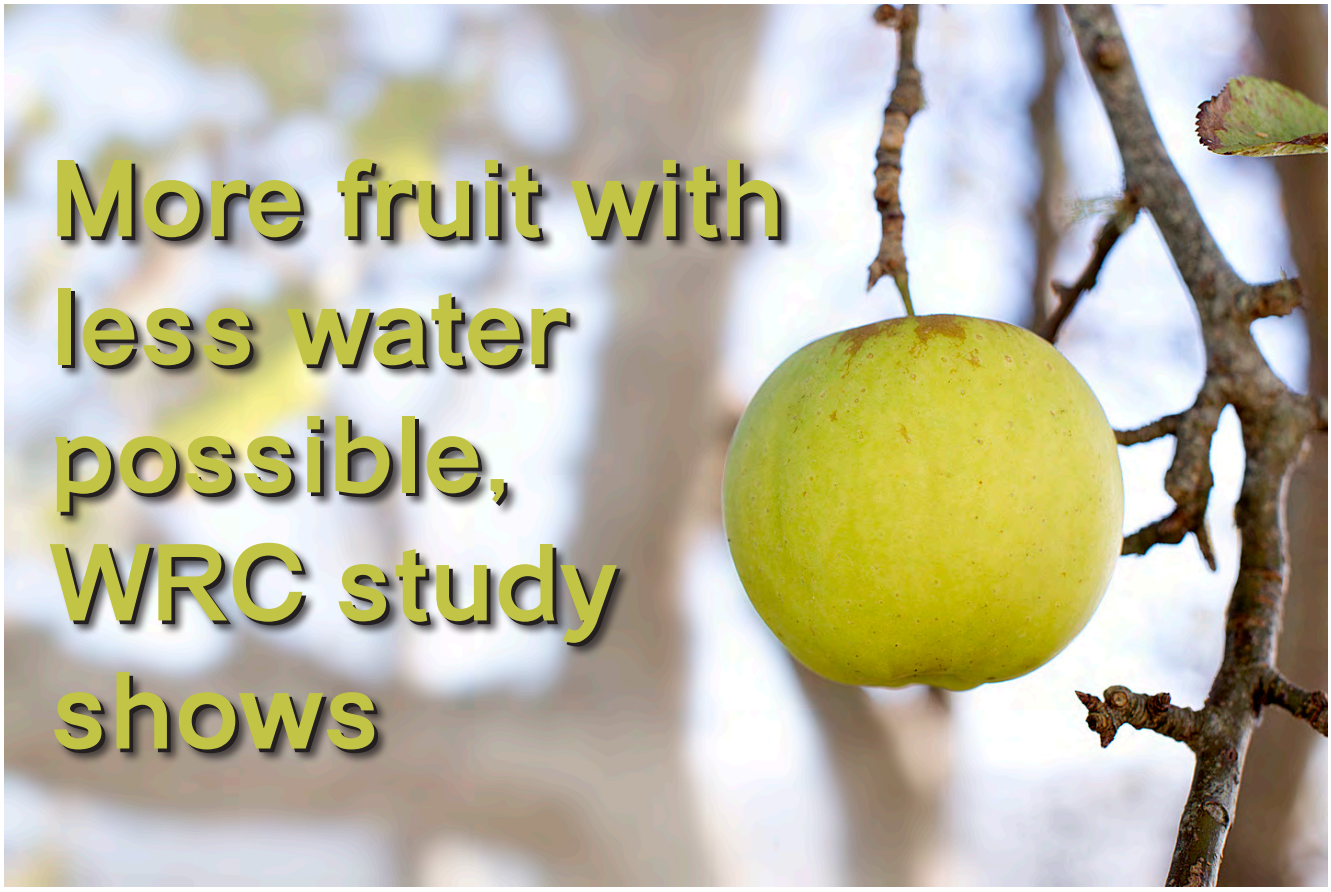
"To ensure we sustain this, we need to form partnerships with local government, and perhaps also become involved with public-private partnerships," says Dr Mpandeli. "Our mandate is to generate knowledge and disseminate it but to implement it, we need partners."

Dr Everson confirms that they are already planning to source funding to investigate the feasibility of a Green Village, and to research potential villages as suitable candidates. She adds that the success of such a project would be dependent on government subsidisation.

Dr Mpandeli is positive about the potential for future implementation of the current project, as it adheres to three important characteristics. Firstly, "as the science community we need to highlight the benefits, and show practical examples." Secondly, the technologies promoted by the project are simple and can be used by anyone. Lastly, he says, we have to make sure that whatever we are driving is aligned with government priorities.

An example of the latter is the National Biogas Platform, established as a key resolution of the 2013 National Biogass Conference and created to assist government to unlock the potential of the biogass sector.

As the current project ticks all the right boxes, it is hoped that it will lead to the improvement of livelihoods of thousands of others like Ethal Khumalo in the future. ❑



More fruit with less water possible, WRC study shows

Over 300 years South African fruit production has become a major contributor to the South African economy, not only in terms of job creation but also with regards to foreign exchange export earnings. With the costs of resources rising along with international competition, this irrigation-dependent sector is constantly requiring ways of raising efficiency. A recently completed Water Research Commission (WRC) study has applied various water use monitoring techniques in the field towards improving the water use efficiency of South Africa's fruit production. Article by Lani van Vuuren.

Covering an area of around 78 000 ha, deciduous fruit production is one of the largest agricultural sectors in South Africa. It is also a sector aimed at the export market, with more than 50% of fruit produced sold to overseas markets, mainly Europe.

Fruit is principally grown in the Western and Eastern Cape provinces where warm, dry summers and cold winters prevail. At last count, there were around 1 700 pome and stone fruit as well as table grape producers in South Africa, according to the Department of Agriculture, Forestry and Fisheries (DAFF).

Due to the country's naturally variable and semi-arid climate, nearly all fruit produced in South Africa is grown under irrigation, also making the sector a large water user. Yet, the exact water use of fruit production has not received much attention in South Africa to date.

Important knowledge in this regard has now been gathered through the seven-year project initiated

"Water is a very strategic consideration in the industry, and is key to the sustainability and expansion of the sector."

by the WRC and led by CSIR and the University of Pretoria on the water use of economically important fruit trees and orchards. The team also worked closely with Citrus Research International.

According to WRC Executive Manager: Water Utilisation for Agriculture, Dr Gerhard Backeberg, the study was not only one of the most comprehensive on the subject ever undertaken in South Africa to date, but has ushered in a new research focus for the Commission. "To date, most research commissioned by the WRC has been on the water requirements of crops, either through measurement or modelling. In the process various agricultural models have been developed, such as SAPWAT and the soil-water-balance (SWB) model, to assist farmers with irrigation scheduling and improved water management."

Of late the lens has shifted wider to consider water use within the entire food value chain as well as to determine the water footprint of crops. "While the focus is still on water use of specific crops, it is now within an explicit framework or broader context," explains Dr Backeberg. "This improves understanding of water use in agriculture beyond the field or farm level."

Government has identified agriculture as an important contributor to rural development. The Irrigation Strategy for South Africa sets a target to increase the area under irrigation in the country. However, while we might in future have more crops in the field, it is unlikely that there will be additional water resources available to irrigate them.

This consequently necessitates significant increases in water use savings so that more crops can be produced with less water. Knowledge such as what is currently being obtained through WRC research will undoubtedly stand South African farmers in good stead in future.

NEED FOR IMPROVED WATER USE EFFICIENCY

According to Dr Mark Gush, Research Group Leader: Hydrosciences at the CSIR Natural Resources and the Environment, the research team set themselves the goal of better understanding water use along the entire production chain of selected fruit crops. The question was what data, measurements and information would be required to accurately quantify the water footprints of the fruit examined and how could this be used to improve water use efficiency?

Courtesy Mark Gush

The Koue Bokkeveld, one of the main fruit production areas in the country.

To come up with an answer, the team applied various water monitoring techniques on seven selected fruit farms. Dr Gush reports that farms were purposefully selected where best management practices were already being applied in terms of irrigation applications. Most of these farms make use of soil moisture measurements for irrigation scheduling.

Some farms were found to be at the forefront of scientific approaches and were using climatic data and existing crop coefficients to assist in scheduling irrigation, reports Dr Gush. "However, results from this project indicated that the existing crop coefficients being used differ significantly from those derived from the project measurements, and if applied should facilitate more accurate irrigation scheduling."

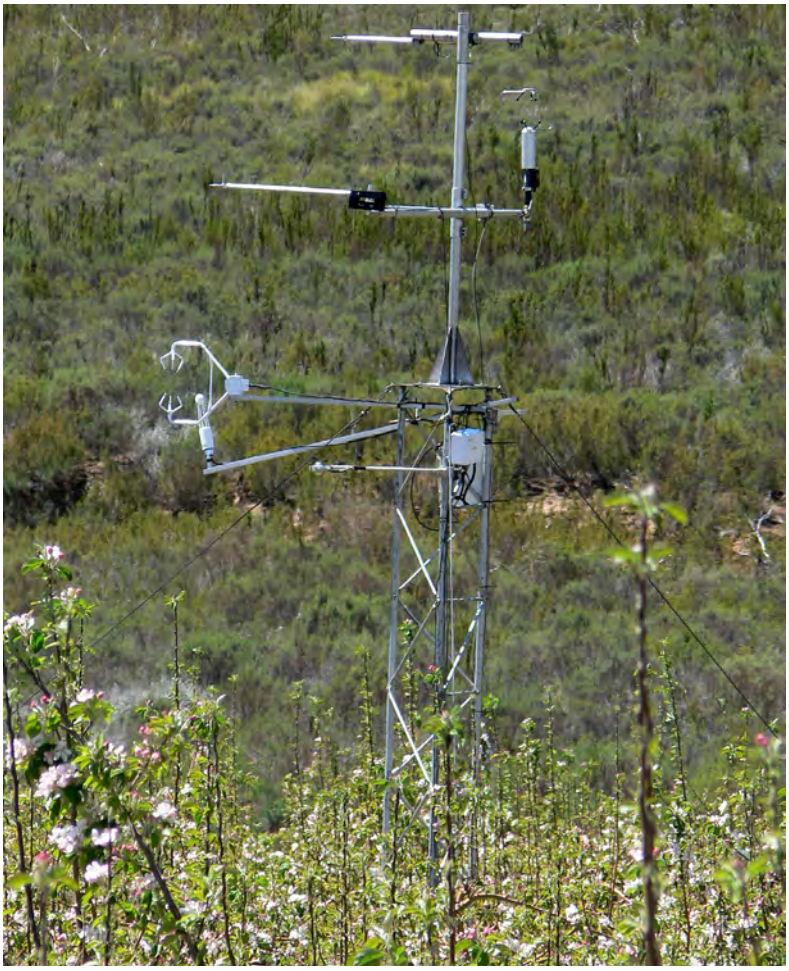
Dr Gush continues to say that the use of soil water measurements can also be misleading due to uncertainties about whether soil water is draining downwards, evaporating upwards or actually being used by the trees. "This is where actual tree water use measurements, as conducted by the research, were very beneficial."

While economic considerations are still top priority, there is no doubt that the importance of water to the fruit tree industry is increasingly being recognised, as well as the risks related to uncertainties about future water supply. "Water is a very strategic consideration in the industry, and is key to the sustainability and expansion of the sector. While there does seem to be more focus at present on how to secure more water for a farm (to allow expansion) as opposed to how to increase efficiencies (make do with less water), this is bound to change in the near future."

WATER USE VARIABLES

Determining how much water goes into growing an apple or a pear is not as easy as it sounds. The water use of a fruit tree is influenced by many factors. The first is the size and age of the tree, mainly due to differences in total leaf area. This changes most dramatically as the tree grows from a sapling, but becomes less of a factor once the canopy is fully developed and relatively constant in size, such as is the case in a mature orchard.

The second variable is the time of year or growth stage, as deciduous trees in particular undergo dramatic changes in leaf area through the year. Then there are the prevailing climatic conditions of the day, mainly the vapour pressure deficit of the air, net radiation and wind. Main drivers for these variables are solar radiation, temperature, humidity and wind speed.



Courtesy Mark Gush

The eddy covariance technique measures turbulent eddies of air above a vegetation canopy, which are important drivers of water vapour exchange (evapotranspiration) from the underlying vegetation.

Soil water content, soil texture, and soil depth also play a role as this determines how much water is available to the tree, and how easy it is for the tree to extract it. Access to soil water is also influenced by root distribution and depth which, in turn, may be influenced by soil nutrition (fertilisation).

Tree water use is also linked to tree health, as vigorous healthy trees will use more water than diseased trees or those growing in water-logged soil. However, they will also produce higher yields, thereby improving their productivity. The last factor to consider is that of management interventions, particularly pruning (which changes leaf area), mulching and obviously irrigation.

VARIETY OF WATER USE MONITORING TOOLS

So how did the team get around all of this variability? The project combined different methods to measure water use. This included techniques

to obtain data on transpiration of trees through sap-flow measurements, orchard evapotranspiration rates, soil water balances and automatic weather station variables, such as rainfall, temperature, humidity, solar radiation and wind speed. The research team also determined irrigation timing and amounts from metered records at the sites or from direct measurements on the irrigation lines.

More specifically, the heat pulse velocity (HPV) technique was used to measure sap flow rates through the trees. This involved installation of probes in the stems of individual trees and allowed the team to calculate the transpiration of the trees (i.e. the volumes of water physically passing through the stem of the tree).

This sap flow data supplied by the HPV system quantified the volumes of water actually being taken up by individual trees, from the roots out through the leaves (as opposed to amounts of water simply being applied by irrigation). This is known as beneficial water use.

Furthermore, the team used the eddy covariance technique to measure the total evaporation of the orchard. This required installation of the system on a mast above the orchard. This instrumentation provided the team with data on the evaporation rates from the entire orchard, being inclusive of transpiration (tree only water use), soil evaporation, water use of the cover crop (working row vegetation), and the evaporation of any intercepted water on the leaves of the orchard (for example, from rainfall or irrigation).

Eddy covariance instrumentation was also established within the orchards.

Courtesy Mark Gush

Apart from these primary measurements the team also measured climatic variables with an automatic weather stations, soil moisture fluctuations at different positions and depths down the soil profile, irrigation applications and some physical characteristics of the orchard, for example leaf area index, tree size, sapwood depth and so on.

This comprehensive sampling strategy then formed the basis for modelling water use, allowing or enabling extrapolation beyond the locality where measurement were done, within specified 'boundaries' (for example fruit type, soil class and rainfall zone). The research determined water use of single trees and given the plant spacing and additional non-beneficial water use, also water use of the orchard as a whole.

Water use was quantified or estimated as evapotranspiration. Within the water balance approach, both these variables constitute consumptive water use, Dr Backeberg explains. "The big advantage is to distinguish beneficial water use from non-beneficial water use. By understanding and improving evapotranspiration within the tree rows and reducing evapotranspiration between the tree rows, beneficial water use is increased. This clearly contributes to increased efficiency and productivity of fruit production."

By reducing or at least limiting non-beneficial water use, water and cost savings are possible with the potential to improve the profitability of fruit farming. "The available research output can therefore be applied for more effective advisory and extension services to farmers in the fruit industry," notes Dr Backeberg.

CASE STUDY ON APPLE ORCHARD

One of the case studies was undertaken on a Cripps' Pink apple orchard in the Koue Bokkeveld region of the Western Cape. The 2.3 ha orchard features mature trees of an average 13 years of age and yields around 60 t/ha of apples a year. The long research period allowed the team to account for year to year differences in climatic and orchard conditions.

An important finding of this case study was the fact that water requirements of the apple trees declined dramatically towards the end of the growing season (from March onwards), but irrigation applications were not curtailed to a similar degree. This provides scope for water savings.

While comparing the water use of different fruit cultivars fell outside the scope of this study Dr Gush and his colleagues did make an interesting observation in the apple orchard case study. "In the apple orchard we found that the pollinator tree species (Hilleri), which comprised every eighth tree in the orchard used less than half the water of the primary (Cripp's Pink) variety." This raises a number of questions for future research studies, especially as to the performance of locally bred stone fruit cultivars compared to imported counterparts.

Another interesting finding of the study was that if the transpiration (i.e. tree only) water use values are considered, then results showed that for virtually all the case studies actual tree water use is less than what was previously thought. "It is important to bear in mind that this data represents only what is used by the trees themselves, and it is unrealistic to expect that irrigation applications could be so accurate as to provide exactly what the tree requires," qualified Dr Gush. "Inevitably, there is non-beneficial loss through drainage or evaporation, so allowance for this fact needs to be made."

Importantly, the research has yielded new insights into the patterns of water use exhibited by the various fruit tree species through the growing season, which could assist in scheduling irrigation more accurately.

The research team gained significant knowledge during the study, mostly associated with the volumes and patterns of water use by the various fruit tree species being monitoring. There is now a better understanding of these water use volumes and patterns, which are incorporated in the species-specific crop-coefficients derived from the observed data. These have indicated that the focus should be on maximising beneficial water use and minimising non-beneficial water use by accounting for seasonal patterns in tree water requirements, and endeavouring to deliver the right amount of water as close as possible to the root zone of the trees.

Dr Gush gives the following advice to fruit farmers looking to improve water use efficiency: "Use the latest and most accurate crop coefficients (preferably based on observed data) when planning irrigation schedules for the growing season. Maximise the use of rainfall during the growing season, and adjust irrigation applications accordingly. Avoid over-irrigation and water-logging, not only due to water use and electricity cost considerations, but also due to the detrimental impact on the health of the orchards. Ensure that water distribution and irrigation infrastructure is in good condition so as to minimise transmission losses."

ADDITIONAL STUDIES

The research team expressed their gratitude to the farmers and farm managers who participated so willingly in the study. All of the results of the study were shared with participating farmers and other stakeholders, mainly through specially organised information days. According to Dr Gush, these information sessions were useful not only in facilitating discussion on water issues, but also to illustrate the technologies employed by the project to determine water use of trees and orchards. "We also used the opportunity to highlight the potential for improvements in water use efficiency, mainly by reducing over-irrigation."

Based on the results of the study above, the WRC has initiated a further two projects on specific citrus and apple varieties. These studies are being undertaken in cooperation with Citrus Research International and HortGroScience.

- To obtain the reports, *The water use of selected fruit tree orchards (Volume 1): Review of available knowledge* (**Report No. 1770/1/14**) and *The water use of selected fruit tree orchards* (*Volume 2*): *Technical report on measurements and modelling* (**Report No. 1770/2/14**) contact Publications at Tel: +27 (0)12 330-0340; Fax: +27 (0)12 331-2565; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy. ❑

Courtesy Mark Gush

Heat pulse velocity sap flow monitoring uses heat as a tracer of sap flow in the stems of woody plants – sap flow being synonymous with transpiration of water use.

Farmers along the lower Orange River are dependent on releases from Vanderkloof Dam, more than 1 000 km upstream.

Drinie van Rensburg

South Africa and Namibia ensuring enough irrigation water together

A demonstration project on water management was recently conducted at the Noordoewer-Vioolsdrift Joint Irrigation Authority under the auspices of the Orange-Senqu Strategic Action Programme. Sue Matthews reports.

The four-year UNDP-GEF Orange-Senqu Strategic Action Programme has recently come to an end, but has provided a solid foundation for sustainable development and environmentally sound water resource management in the Orange-Senqu basin. The programme was established to provide support to the Orange-Senqu River Commission (ORASECOM) in promoting integrated water resource management in the basin and its four member countries – South Africa, Lesotho, Botswana and Namibia. It included the finalisation of the Transboundary Diagnostic Analysis to close knowledge gaps and identify problems, causes and effects in the basin, and the

development of National Action Plans and an overarching Strategic Action Programme to address them. At the same time, a number of projects were implemented, two of which were on the final stretch of the Orange River's 2 200 km journey from source to sea.

A two-year demonstration project on water management in the irrigation sector was conducted at the Noordoewer-Vioolsdrift Joint Irrigation Authority with the aim of encouraging more efficient use of water and better pollution control. Many people might recognise these place names as the Namibian and South African border posts at the international boundary along the Orange River, but back in 1933 – when the then South West Africa was under South African control – the government constructed an irrigation scheme on both sides of the river to stimulate agricultural development and job creation. Namibian independence in 1990 meant that the scheme could no longer remain under South African jurisdiction, so in 1993 the Joint Irrigation Authority was established, with a Board made up of representatives of the two farming communities, the South African Department of Water Affairs (now the Department of Water and Sanitation) and the Namibian Department of Agriculture.

Today the irrigation scheme delivers about 15 million m^3 of water per year to almost 884 ha of farmland, 600 ha of it on the South African side of the river. Water is diverted at a weir 13 km upstream of the border post into an open canal that runs alternately along each bank, criss-crossing the border five times via inverted siphons under the Orange River to supply farmlands spread along a 28 km stretch of river. In a few places water is pumped from the river to augment the flow in the canals, while some farmers pump their own irrigation water directly from the river. Sub-canals carry the scheme's water to the various agricultural fields, where farmers each withdraw their allocation – 0.042 $m^3/s/ha$ for a period of six hours per week – by opening sluice gates.

The system relies on honesty and peer pressure – water usage is not measured, although as part of the demonstration project a number of measuring devices were temporarily installed. These included an ultrasonic flow measuring device in the the canal upstream of the first off-take, multiple submersible pressure probes and V-notches to measure the water usage of flood irrigation, as well as water- and electricity meters on pumps supplying water into the canals and at the farmers' own pump stations.

In addition, an automated weather station was erected and 28 soil moisture probes installed in pairs to provide data at 15 minute intervals for use in irrigation scheduling. These were left *in situ* after the completion of the demonstration project, but most of the soil probes were removed when fields were prepared for a new planting of cash crops.

Project Leader, Francois du Plessis of MBB Consulting Engineers, is not concerned by this. "The demonstration project was to show the farmers what can be done, and it will take a little effort for them to start to apply what they learned," he says. "Plus they may have to contract a service provider to give advice on soil moisture status and to maintain the equipment."

Other components of the project were training sessions on irrigation scheduling, crop cooling and frost protection, and field trips to visit other irrigation schemes in the Northern Cape and Namibia so that best practices being applied there could be observed.

"The field trips were especially valuable for them," says Du Plessis. "They could go and see what other people are doing, opening their eyes to new possibilities. For example, laser-level flooding is really catching on, and more and more of them are doing that now."

Prior to the 1970s, earth canals and flood irrigation were the norm in irrigation systems, especially along the Lower Orange River. While many of the canals have since been lined, flood irrigation – a particularly inefficient form of irrigation – is still widely used. In fact, it is experiencing a resurgence in popularity in the face of rising energy prices, since it is a gravity-fed irrigation system.

Lucerne is the dominant crop in the Noordoewer-Vioolsdrift irrigation scheme, making up 22% of the

IRD & ORASECOM

The Orange River sustains Namibian and South African crops in the Noordoewer-Vioolsdrift Joint Irrigation Authority.

***Right:** Soil moisture probes provide data for irrigation scheduling.*

***Below:** The main canal supplies a number of sub-canals along its route on either side of the border.*

Francois du Plessis

total hectares planted, and almost all of it is flood-irrigated. Other major crops – in descending order of importance – are grapes, tomato, butternut, baby marrow, mango, green beans and pumpkin, while 19 others make a smaller contribution. Most of these crops are flood-irrigated somewhere in the scheme, so this method accounts for 41% of the total hectares planted.

By laser-levelling their land, farmers can improve the distribution uniformity of flood irrigation, and hence make it more efficient. To date, laser-levelling only makes up 4% of the scheme's total hectares, but the number of farmers adopting this technology for a variety of crops is growing steadily. Drip irrigation contributes 31% of the total, being used for green bean crops, the majority of the tomatoes and many of the other crops too. Most vineyards depend on micro-irrigation, which is also used for some mango crops, bringing the contribution of this method to 17%. Pivot and sprinkler irrigation make up the remaining 7%.

Du Plessis predicts that drip and micro irrigation will become increasingly important in the scheme.

"These methods allow for much more effective control," he says. "The traditional flood-irrigation systems are only about 60% efficient, so much of the water that they apply goes back into the river, taking nutrients with it. This is the main reason the farmers are interested in laser-levelling – the saving in fertilizers – and it also requires less labour."

Of course, irrigation return flows may also increase the nutrient loads and salinity of the river, which is why the demonstration project included a pollution control component. A handheld meter was used for monthly water quality measurements in the river and canal system, and samples collected for laboratory analyses, but no deterioration in water quality could be detected from one end of the scheme to the other. The instrument was donated to the Joint Irrigation Authority at the end of the project, with the hope that this monitoring would be continued.

Using all the information collated during the demonstration project, a Water Management Plan was developed for the scheme, which the Joint Irrigation Authority will update annually in accordance with the requirements of Water User Associations outlined in the National Water Act. The process involves analysing current water use, setting targets for improved efficiency, and planning a realistic means of reaching those targets. The aim is to improve water conservation and water demand management in the agricultural sector, which is the biggest user of water in South Africa, and considered the most wasteful.

At present, the farmers have little incentive to save water as the scheme delivers enough to meet their combined quota. However, the water supply is dependent on releases from Vanderkloof Dam, more than 1 000 km upstream, and it is not a constant volume as releases are subject to the dam's complex operating rule. Since the water takes about a month to reach the irrigation scheme and there are a number of other users upstream, temporary shortages do occasionally occur, especially during heat waves. High flows come down the river periodically too

Francois du Plessis

because ESKOM, which uses the releases for hydropower generation, is permitted to release additional water once the dam level is above a certain limit. This water may arrive at times when the farmers cannot make optimal use of it.

Construction of either a small balancing dam or a large storage dam just above Vioolsdrift was recommended a decade ago as an outcome of the joint South African and Namibian Lower Orange River Management Study, better known as LORMS. A pre-feasibility design and costing was subsequently carried out for a small balancing dam, which could be used to re-regulate flows.

At that stage, significant 'operational losses' estimated at 270 million m^3 per year were occurring due to inefficient management of the Orange River system. The operating rules for hydropower releases were amended in 2008 to improve efficiency, but still did not take into account any inflow from the Vaal River, which enters the Orange River more than 180 km below the Vanderkloof Dam. This inflow varies from almost zero flow to extremely high flow when the major dams are spilling, and was estimated to average 1 680 million m^3 per year at the 2005 development level. There are also sporadic local inflows from the catchment downstream of the Orange-Vaal confluence. A dam close to Vioolsdrift could 'catch' these flows and provide more water to downstream users, which may well be necessary given that Namibia is planning new irrigation schemes along the Lower Orange River.

Furthermore, the launch of Phase II of the Lesotho Highlands Water Project in March has highlighted another motivation for building the dam. Phase II includes the construction of the 2 200 million m^3 capacity Polihali Dam, expected to be completed in about 2022. Water will be transferred via a tunnel from the Polihali Dam to the Katse Dam – built during Phase I – and then delivered to the Vaal River basin to meet demand in Gauteng. This will divert flows that currently enter the Orange River, reducing the yield of the Gariep and Vanderkloof dams to such an extent that shortages will be experienced downstream. The Vioolsdrift Dam would provide a means to offset this reduction and correct the yield versus demand balance in the Orange River system.

A reconciliation strategy for the Orange River Water Supply System is currently underway, the aim being to ensure that sufficient water can be made available to supply the current and future water needs of all users to the year 2040. The study will entail analyses of various scenarios, including different projections of future water requirements, revised operating rules and options for infrastructure developments – among them the dam at Vioolsdrift, and whether this should be a small balancing dam or large storage dam.

Of course, the environmental impact of dams is always a concern, but in this case aquatic ecologists recognise the advantages of a small balancing dam at Vioolsdrift. The dampening of floods by Vanderkloof Dam, together with its year-round release of water, mean that flows reaching the Orange River estuary are much more constant than would have occurred under natural conditions. This has had a range of negative consequences, mainly because the mouth now stays open almost permanently and the supratidal saltmarsh rarely gets inundated. Being able to manipulate flows reaching the estuary by controlling releases from Vioolsdrift Dam – 350 km upstream – would allow for mouth closure and back-flooding of the supratidal saltmarsh.

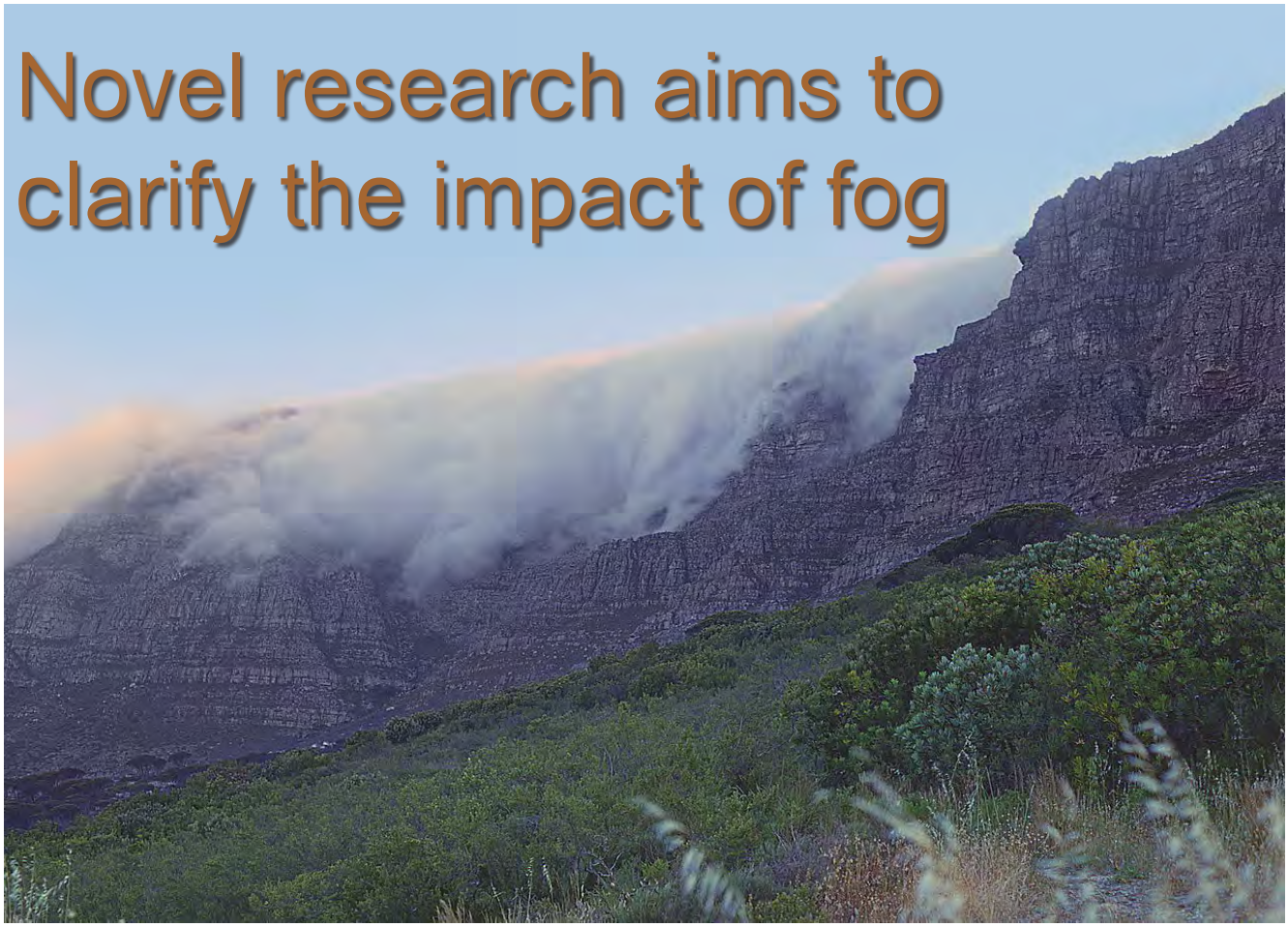
In order to improve understanding of the effects of this and other dams being constructed or considered, the Orange-Senqu Strategic Action Programme included a research project on the environmental flow requirements of the Lower Orange River, focussing on the river reach below the Fish River confluence. More on that in the next issue of *The Water Wheel*. ❑

Francois du Plessis

***Top left:** Site visits to other irrigation schemes allowe farmers from the Noordoewer-Vioolsdrift Joint Irrigation Authority to share experiences and discuss best practices.*

***Bottom left:** An ultrasonic flow-measuring device was used during the demonstration project.*

Novel research aims to clarify the impact of fog



Does fog contribute to the water flow in South African rivers? A new research project is trying to find out. Article by Petro Kotzé.

While fog is frequently experienced in South Africa, its influence on natural systems has not received much attention from local researchers, especially in comparison to most other freshwater sources. While ecologists, botanists and hydrologists seem to agree that its impact must be vital, there is still limited understanding of the ecological and hydrological impacts of fog precipitation in South Africa.

Yet, a number of places here record over ninety days of fog per annum, mostly along the West Coast and in mountainous regions. Along the West Coast, advection sea fog is common. This is formed when moist air from the South Atlantic Ocean passes over the cold Benguela Upwelling region and is cooled down. Along the mountains of the Eastern Escarpment and the Western Cape, the most frequent source of fog is orographic fog and stratus clouds. The first happens when low level onshore flow blows air up the escarpment, adiabatically cooling it as it rises, causing the moisture in it to condense.

The most iconic display of fog is probably the Table Cloth on Table Mountain, and it's also here that the basis was laid for some of the first scientific publications on fog precipitation, not only here, but also in the rest of the world. Renowned botanist, Dr Rudolph Marloth, probably best known for the mammoth six-volume *Flora of South Africa* (published between 1913 and 1932) was interested in the rainfall seasonality experienced by plants growing on the mountain, which prompted him to investigate what condition plants experience during fog events.

He put up the first pair of rainfall and fog collectors to compare the measurements during fog conditions. These were basically rain gauges with some reeds in them on which fog would condense as it blew over the gauge. He discovered that the fog gauge would fill up while the rain gauge recorded little precipitation.

He concluded that plants on Table Mountain do not experience a dry season that is nearly as severe as plants lower down. This is because of the South Easter fog which feeds the plants during summer months, when not much rain is experienced at the base of the mountain.

The specific topic has only received sporadic attention among researchers since then. For the last 30 years or so, most research focused on fog water harvesting for human consumption. The WRC has funded a number of these projects, due to the belief that it can provide clean drinking water of exceptional quality to communities where water treatment facilities might not be available. While the feasibility of the technique to augment domestic water supplies was investigated during the late 1960s, pilot fog collectors were later erected in various parts of South Africa. Yield from 1 m^2 nets ranged from 1 to 5 ℓ/m^2/day along the west coast, while in the mountainous regions, it exceeded 10 ℓ/m^2/day at elevations greater than 1 700 m. This success prompted the erection of larger systems, and with it, the harvesting of bigger amounts of water.

Yet, while it is now widely accepted that fog can contribute substantially to potable water supplies, and early studies showed that it can contribute much water to an ecosystem, there is still a limited understanding of the ecological and hydrological impacts of fog precipitation in South Africa.

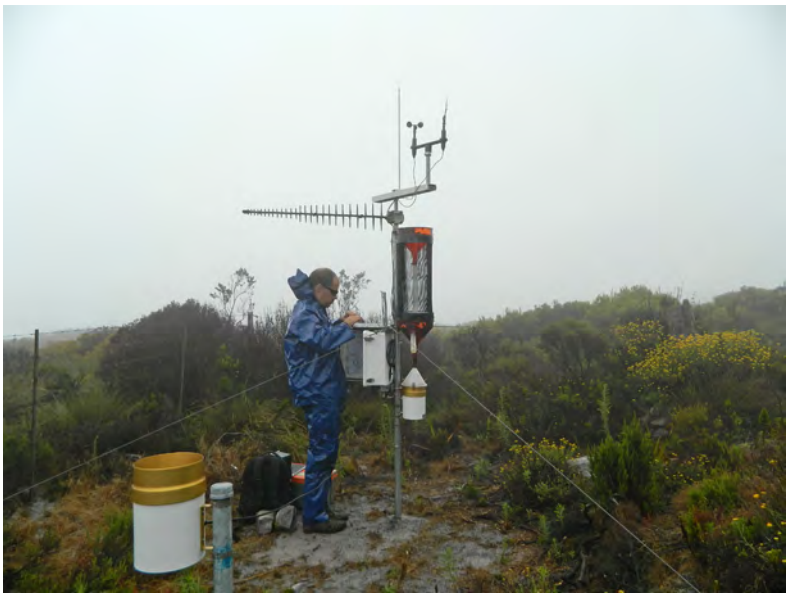
A relatively new project now aims to shed light on these questions, though starting with some basic data collecting first. Under the helm of the SAEON Fynbos Node, the project started in 2013 (SAEON is part of the National Research Foundation and funded by the Department of Science and Technology). "Our first aims are to collect baseline data in order to shed some light on fog precipitation quantities, seasonality, elevation and associated wind direction," explains Abri de Buys, Technical Officer at the SAEON Fynbos Node. They hope to have some of these results published in the first half of 2016. These first few years of their research will serve to inform them how their fog monitoring network should be adapted in order to tackle longer term trends and more sophisticated questions.

SAEON TAKES THE LEAD

To start with, a testing fog collector was first erected on Constantiaberg Peak in Table Mountain National Park at the beginning of 2013. The first fully functional fog collector with a weather station followed in the Cape Nature managed Jonkershoek Nature Reserve in March 2013.

Over the study period of about a year, fog precipitation at both the Constantiaberg and Jonkershoek high elevation site (Dwarsberg) averaged about 100 mm per month. During some dry months fog precipitation was shown to be the dominant form of precipitation that was measured with up to 86%

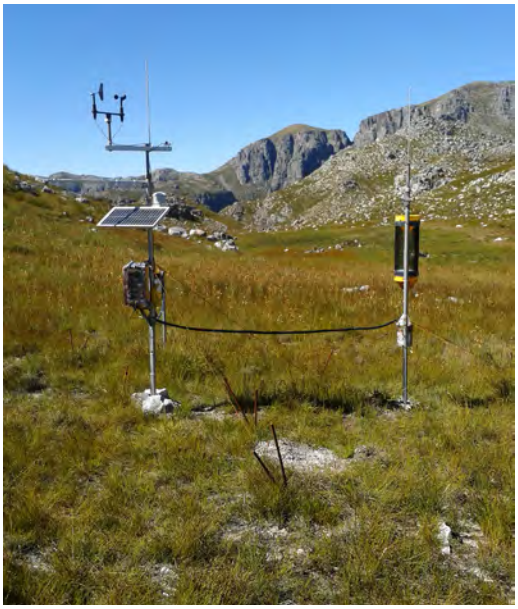
***Left:** The fog collector used at Dwarsberg weather station, Jonkershoek is based on a design used by other fog researchers in North and Central America.*



***Below:** Constantiaberg weather station – configuring the data logger in some wet weather.*

(153 mm) of total precipitation being fog. This precipitation is not measured by standard rain gauges and occurs to a lesser or greater extent, largely unmeasured, across many of our mountain catchments that experience fog, says de Buys. Their measurements show that this is a notable amount of precipitation. "While our Jonkershoek high elevation site recorded just over 3560 mm of rain over the study period thus far, the fog collector measured 1234 mm in the absence of rainfall."

The researchers have also quantified associations with trade winds. "We know that the South Easter which is responsible for the Table Cloth on Table Mountain also often results in cloud cover at Jonkershoek and Constantiaberg". Fog is also associated with the North Westerly winds that occur mostly in winter when frontal systems arrive at our study sites. These two trade winds occur during conditions that result in different cloud formations which both contribute fog."



***Above:** Stratus clouds hiding the peaks in Jonkershoek valley. Lower elevation sites experience fog less frequently than the higher peaks .*

***Right:** Dwarsberg weather station on a brilliantly clear day.*

Eventually this data will lay the cornerstones of more complex questions to be answered. These include how fog precipitation influences stream flow in one of their study catchments. They also aim to test methods of measuring how much fog moisture makes it into the soil.

According to de Buys "the simplest way is to monitor fog and stream flow concurrently and look for increases in stream flow when you've measured fog." Streamflow records at their study sites all show daily fluctuations that are due to changes in how much water evaporates from the catchment. "As transpiration from the vegetation reduces towards nightfall with the decrease in light and temperature, this causes stream levels to increase slightly but measurably. During days with high humidity and cloud cover one can see less of a reduction in stream levels as a result of evapotranspiration, meaning plants don't have to suck up as much water which leads to higher stream levels. When a significant fog event occurs one may be able to detect an increase in stream levels due to water collecting on the plants and dripping to the soil."

He further adds that another way would be by looking at the isotope signatures of rain and fog, and comparing these to that found in stream and ground water samples in order to identify the likely source.

THE VALUE OF FOG

While this project will only focus on fynbos, it will start to fill the gap that currently exists in the evidence necessary to support assumptions that fog plays an important role in botany, ecology and hydrology.

This assumption is already substantiated by work that has been done by researchers in other parts of the world, since the early work took place in South Africa decades ago.

In the Californian redwood forests for example, researchers have measured how much fog precipitation occurs seasonally, how much of it gets into the soil underneath trees and how this happens, says de Buys. They have found that fog collects on the

THE TALLEST TREE ON EARTH DRINKS FOG

The coast redwood (*Sequoia sempervirens)* is earth's tallest tree, reaching higher than a 30 floor skyscraper (around 100 m), while their trunks can grow almost eight metres wide. It is reported that they can live for more than 2 000 years. During California's rainless summers, the trees depend on fog for survival, which they can absorb through their leaves as well.

Studies have found that other plants in the coast redwood ecosystem also have the ability to take water in through their leaves, like **western sword fern (***Polystichum munitum***)**, salal (*Gualtheria shallon*), madrone (*Arbutus menziesii*), tanoak (*Notholithocarpus densiflorus*), Douglas fir (Pseudotsuga menziesii), California huckleberry (*Vaccinium ovatum*) and California polypody (*Polypodium californicum*). The potential impact of climate change to these plants is a question that numerous researchers have investigated.

Source: www.savetheredwoods.org

leaves and branches and drips down or flows down the stems, contributing to the water available to the roots. In areas where there are no trees, fog blows over the site and not as much of it is "harvested" by the vegetation. They have also discovered that several plant species absorb fog water directly through their leaves, supplementing the water supply they get from the root systems. This foliar absorption reduces the need of plants to pull water from the soil. "We have yet to test whether or to what extent these same mechanisms and interactions occur in mountain fynbos," he says.

Additionally, there is also a social angle that makes this research interesting. "Most of our water comes from mountain catchments. In the Western Cape, many of these mountains receive fog precipitation. Our preliminary research has shown that over the period of a year there is a lot of fog, as much as a quarter of total precipitation at one site that we've investigated for a full year, that potentially can contribute to the water coming from these catchments. As a result of the fact that standard rain gauges don't measure fog input, we are missing a significant piece of the puzzle in terms of how our catchments function."

This might have some relevance for future water security. "Elsewhere in the world it has been shown that fog precipitation is influenced by climate change," says de Buys. Regional changes in sea surface temperature and also changes in land cover can influence the height at which fog forms, essentially reducing the area of mountains that comes into contact with fog. "This has implications for catchments and potentially for the water yield that we rely on given changes in climate. In order for us to know whether or to what extent we are experiencing similar climate change effects, and to plan accordingly, we need to first know what our current status is."

News of the project has been greeted with much interest by researchers that have been involved with fog harvesting research projects over many years. Prof Jana Olivier (University of Pretoria professor extraordinaire, UNISA emeritus professor) described the SAEON project as "fantastic work" and that she looks forward to potential collaboration in order to pool existing knowledge. ❑

A close up of the special louvered shade screen that the fog collector is made of.

WATER LOSS: Are we wasting our way into a potential water crisis?

Experts at the Fourth Regional African Water Leakage Summit have warned that failure to adequately address non-revenue water and water losses in South Africa could have serious water security repercussions going into the future. Lani van Vuuren attended the summit.

The summit, held in Midrand, is the brainchild of Dr Ronnie McKenzie, MD of WRP Consulting Engineers, and follows on from the successful series of water demand management workshops and water demand management Master classes presented annually by WRP since 1997.

Endorsed by the International Water Association, with sponsorship from WRP, Rand Water and the Water Research Commission, the 2014 event was the most popular yet, attracting over 180 delegates from eight countries. The main aims of the summit were to create general awareness of the need to manage water losses throughout South Africa, and to highlight the status quote as far as water resources and progress in addressing losses each year.

That South Africa is not yet taking the importance of water loss control seriously enough ran as a key message through most of the presentations at the Summit. And the warning that this could have serious repercussions in areas where maximum water supply levels have been reached was too loud to ignore.

Keynote speaker, Prof Mike Muller, visiting Adjunct Professor at the Wits School of Governance and Commissioner in the National Planning Commission, confirmed the need to elevated water losses to a level where politicians would take interest. Water

conservation and water demand management was a critical intervention required to keep South Africa water secure.

"Reducing growth in water demand is just as important as increasing its supply. Already, 30% of the bulk water-supply systems monitored by the Department of Water and Sanitation (DWS) require water resource security interventions."

Current planning assumes it will be possible to achieve an average reduction in water demand of 15% below baseline levels in urban areas by 2030, Prof Muller continued. "Achieving demand reductions on this scale will require programmes to reduce water leakage in distribution networks and improve efficient domestic and commercial water use."

A CONTINUING CHALLENGE

It was during his 2010 State of the Nation address that President, Jacob Zuma, alerted South Africans to the country's water scarcity and the need to bring water losses under control. The year 2014 was set as the target for municipalities for reducing water loss percentages by half.

While this target date has now come and gone, water loss control has shown no marked improvement. The latest figures from the DWS, presented at the Summit by Allestair Wensley, Chief Director: Water Services Macro Planning, indicate the seriousness of the water loss problem in South Africa. At present, around 37% of all water supplied to municipalities is lost.

While this compares well with the world average, it is far from ideal for a water-scarce country such as South Africa. Even more worrying is the fact that the latest figures were gathered from only 52% of 122 of South Africa's municipalities.

While this represents about 75% of the total water supplied to municipalities, it is concerning that almost half of the country's municipalities still do not adequately monitor their water losses. In the worst performing province, North West, only four municipalities could provide data.

"To manage their water resources sustainably, municipalities need to measure their water use in the form of a water balance, and to continually update this information and report against water conservation and water demand management targets," Wensley explained. "While some municipalities, chiefly the metros, have comprehensive data on a large number of indicators, many municipalities have only very basic information or even no information."

Key issues preventing successful implementation of WC/WDM:

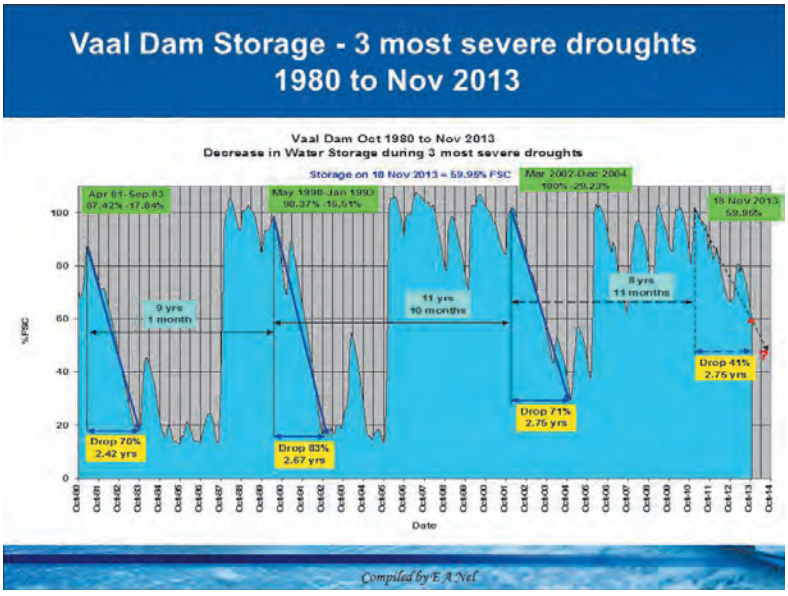
- Poor planning
- Budget constraints and supply chain management issues
- Inappropriate technical solutions
- Lack of community acceptance or support
- Poor levels of own revenue generation and limited expenditure capacity
- Poor metering and billing systems
- Lack of skills, poorly trained and demotivated personnel

Source: A 2011/12 assessment of non-revenue water and water losses in South Africa

It is not only deteriorating water-supply infrastructure that is to blame, we are also wasting water within our homes. The DWS study indicates that average per capita use in South Africa has increased from 252 ℓ/person/day in 2005 to 257 ℓ/person/day. Not surprisingly, the country's metropolitan areas have the highest per capita water consumption, 274 ℓ/person/day.

"Municipalities must encourage their consumers to appreciate the value of water and enforce the user pays principle," noted Wensley. "They should also set cost reflective tariffs and increase payment levels by the encouragement of consumer leak fixing, prosecution of illegal water connections and the reduction of water theft."

The term water losses refers to both real losses (i.e. water lost through leakage) and apparent losses (i.e. water lost through unauthorised consumption and customer meter inaccuracies).



The reaction of Vaal Dam storage levels to drought (Source: Paul Herbst)

"Water loss control requires feet on the ground and many hands donning picks and shovels – potentially the work needed can create many employment opportunities in every municipality."

Levels of water losses in South Africa

Municipal category	% Water losses	Litres/ capita/day
A (Metros)	29.2	280
B1 (Secondary cities)	38.5	249
B2 (Large towns)	38.3	204
B3 (Small towns)	36.2	174
B4 (Mostly rural)	58	164
Total	**37.2**	**226**

Source: A 2011/12 assessment of non-revenue water and water losses in South Africa

THREAT TO WATER SECURITY

For areas such as Gauteng, where continuing water security is already on a knife's edge, reducing water losses has become an absolute necessity. Paul Herbst, Director: Water Use Efficiency at DWS reported on the importance of water conservation in the Vaal River system, which serves about 20 million people and generates around 60% of the national domestic product.

With the exception of Tshwane, municipalities in the province have been unable to achieve the water loss control targets set to maintain water security until Phase II of the Lesotho Highlands Water Project comes on stream in 2023. Due to bulk water constraints main water supply authority, Rand Water, has had its abstraction license capped at 1 600 million m^3/a although it has already supplied 1 652 million m^3/a in 2014.

To date, the province's saving grace has been the above-average rainfall experienced in recent years. However, this could change should a below average year be experienced, and to date, rain in the province has been far from ideal.

Gaining control over water losses is an important step towards water security for municipalities.

Herbst illustrated how when a drought does occur, the reservoir storages in the Vaal River system can drop to restriction levels in less than three years. A previous drought saw the Vaal Dam's water storage levels drop 70% in only two-and-a half years. While three years may seem a long time this is worrying considering droughts lasting longer than ten years are not unusual in South Africa.

He strongly advised municipalities to gear up their water conservation and water demand management activities before the next drought, which is now overdue, kicks in. This can be achieved with a four-pronged strategy comprising social interventions (such as education and awareness campaigns), economic interventions (such as municipal tariff structures), technical interventions (such as active leakage control and improved metering) and legislative interventions.

According to Dr McKenzie, South Africa experiences some of the highest water losses in some areas compared to other African countries. A major contributor to this fact is the legal requirement to provide free basic water.

"In other African countries where such water losses are experienced; they simply cut off the water and move to intermittent supply as is common in many developing countries." However, this is not the ideal way of dealing with water losses, notes Dr McKenzie. "Intermittent supply is potentially very dangerous as it leads to spread of disease, particularly in poorer areas. Without a reliable water supply, diseases such as typhoid and cholera will become commonplace."

Dr McKenzie comments that South Africa has an excellent water supply in most parts of the country, and that intermittent supply must be avoided at all costs – the maintenance costs will pale into insignificance when compared to the costs that the country will face if it allows intermittent supply to become the norm rather than the exception. "You cannot provide hygienic conditions in densely populated urban areas without a reliable, permanent water supply, and you cannot provide a permanent water supply without proper maintenance."

EYES AND SHOVELS ON THE GROUND

There is no quick solution to improved water loss control. You cannot find a buried or closed valve from an armchair, adds Dr McKenzie. "Water losses are increasing in many parts of the

country and will continue to do so until municipalities start spending approximately 2% of the value of their water infrastructure annually on maintenance. Without such dedicated investment, the infrastructure will continue to deteriorate and leakage will increase."

The following are the basic water loss control measures that should be in place in a municipality:

- All visible leaks should be repaired as soon as possible (within 24 hours);
- All boundary valves should be identified and properly serviced. They must be checked monthly to prevent unauthorised opening and closing;
- Communities should be educated on how to reduce water losses within households and assisted if necessary; and
- Bulk management meters must be in place and used to derive a reliable water balance.

Municipalities should start seeing water losses as an opportunity, not only to improve their water security, but also to grow their economies. Water losses offer a great opportunity to municipalities to save water and create employment which can be cost-effective with a payback only a year in some cases. If money is a problem, municipalities should opt for measures that will provide a positive payback in the same financial year.

Unfortunately, water loss control has become a big business opportunity and many new high-tech solutions are being offered as the solution to all of the problems being experienced by municipalities. Only once the basic are sorted out should municipalities embark on the bells and whistles interventions, notes Dr McKenzie. "Water loss control requires feet on the ground and many hands donning picks and shovels – potentially the work needed can create many employment opportunities in every municipality."

NOT ALL DOOM AND GLOOM

It was not all doom and gloom at the Fourth Regional African Water Leakage Summit. Delegates heard various presentations including examples where water demand management measures have been implemented with great success, including case studies from Johannesburg, Tshwane, Ekurhuleni, Emfuleni and others.

Many municipalities in South Africa are doing remarkably well considering the general lack of political support and resources that the water managers receive, says Dr McKenzie. Municipalities where water losses are being successfully addressed usually have a champion in the water department who is both dedicated and enthusiastic in addressing water losses.

Drakenstein, in the Western Cape, was held up as a prime success example where municipal engineer, André Kowaleski, and his colleagues have managed to reduce their non-revenue water from over 33% to less than 12% in less than 15 years (to read more about how the municipality achieved this, see 'Drakenstein proves small municipalities can save water' in *the Water Wheel* January/February 2014)

"All of the large metros have some top quality water loss personnel as do most of the large municipalities and water boards. These people must just be given the political support and resources needed to do their jobs and be allowed to get on with it. Before it's too late. ❑

The 1-2-3 of water loss control now available

The Water Research Commission has published a complete guideline for municipalities on reducing water losses. Authored by Dr Ronnie McKenzie, the guideline encapsulates more than 20 years of knowledge and experienced gained in the application and implementation of water loss control. The publication consolidates many innovative research tools, products and studies which have been generated over the years in response to the challenges associated with water loss management, as well as a number of projects and implementation of water loss management in South Africa. As the publication points out, water loss control is not rocket science, but does take time to achieve. "Immediate savings cannot be expected and municipalities should rather plan for a five- or preferably ten-year programme. The savings will be difficult to achieve but one thing is certain – if no action is taken to reduce water losses, the losses will continue to increase."

To order the report, *Guidelines for reducing water losses in South African municipalities* (Report No. **TT 595/14)** contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; Email: orders@wrc.org.za or download a free copy at www.wrc.org.za.

Climate Change – Both sides of the coin:

How will agriculture in South Africa cope in the future?

The impact of climate change on South African agriculture can depend on the location and type of crop. Investigating how climate change will affect maize, wheat, soya and fruits (grapes, citrus and mangoes) helps to identify viable adaptive techniques that can be used to mitigate potentially negative effects of the future climate. Article by Julio Araujo and Peter Johnston.

One of the biggest concerns about climate change is how agriculture will be affected in the future. Many projections have suggested that future climate change will cause fluctuations in crop yield and quality in grains (maize, wheat and soya) and fruit (mangoes, citrus, avocados and grapes). Will the expected changes favour or inhibit crop yields in South Africa? Can we do anything to adapt to the changes?

Hot topics like this have sparked interest in the response of agriculture to climate change, especially since South Africa benefits so much from the agriculture industry. Interest in this respect has resulted in the undertaking of this project, as commissioned by the Water Research Commission (WRC) and headed by Dr Peter Johnston (UCT), Prof Daan Louw (US) and Prof Roland Schulze (UKZN). The project (no **K5/1882/14**) is entitled 'Adaptive interventions in agriculture to reduce vulnerability of different farming systems to climate change in South Africa.'

The general objective of the project is to investigate the impact of climate change on agriculture, assess the vulnerability of crops, rangelands and farming households and enterprises, identify and suggest appropriate adaptive techniques and practices in selected catchments and farming areas. In short, if we know how and where a crop is affected by climate change, it is possible to adjust farming practices and ensure that the relevant people can cope with the negative impacts or benefit from the positive.

The project spans over 4 years, from its start in 2011 and focuses on maize, wheat, soya, grapes, mangoes, citrus and avocadoes. The areas of interest include Vredendal, Moorreesburg (in the winter rainfall region), Carolina and Hoedspruit (in the summer rainfall region) and include within each region rainfed and irrigated farming systems (Figure 1).

Making use of the advances in crop/climate/financial models and interactions with farmers/experts in the field has allowed this project to address issues while limiting the bias of any one approach. A representation of the approach is shown in Figure 2, where information from all four modules is incorporated into creating the final assessment.

A large aspect of the project lies in interacting with farmers, gathering the necessary information to analyse case study data that can be used to assess the success and failure of the suggested adaptations. It in some way gives purpose to the project, as the results are being used and tested by the people who really need it.

Part of the farmer interaction was through a simple questionnaire, which asks how they feel their farming practices are affected by climate change, if at all. Next they are asked how they currently deal with it, as well as how they plan to deal with it in the future.

In providing sensitive climate change information to the farmers it is important to note our confidence in the results and the variation amongst model outputs. Through the process of downscaling (translating the global information into a regional perspective) the climate projections hold an envelope of uncertainty.

In this respect, we can suggest the conditions of the climate in a specific area (based on climate projections without giving specific changes to rainfall, for example for a specific area for a date in the future, (which is sometimes expected by farmers). Other uncertainty lies within the crop modelling and financial modelling as some processes can't be modelled and thus need to be approximated. This makes the testing of the results with the farmers even more important to validate our results.

CLIMATE CHANGE AND FRUIT

Climate change is generally regarded as negatively impacting agriculture in South Africa and for some fruits such as mangoes and citrus this may well be the case. Predicted shifts in temperature and rainfall patterns could cause yield and quality loss unless adaptive strategies are successfully implemented. Fruit farming is already affected by climate variability and the predicted future change could make the conditions even worse.

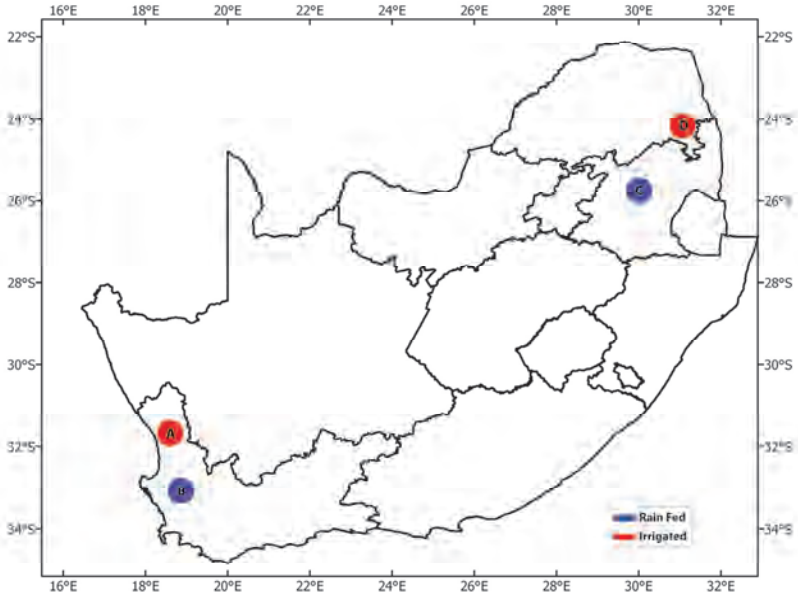
"Over the past 20 years it has become cooler in summer and hotter in winter, with heavy rains in January," says a Lowveld fruit farmer. When asked how the climate negatively influences the fruit harvest, a variety of answers were agreed on including: fungal diseases and rotting fruit from too much rainfall close to and during the harvest, sunburn from daytime temperatures above 36°C and poor fruit set from temperatures below 3°C.

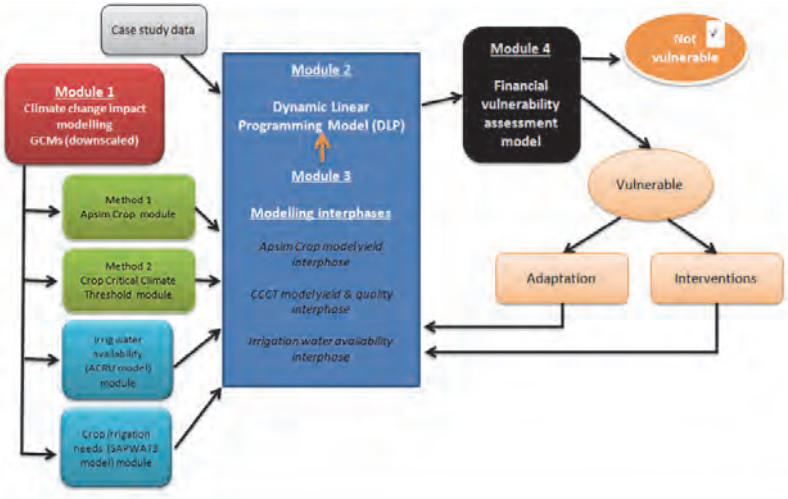
But, it is not all bad for fruit production as applying adaptive strategies helps to mitigate the negative impacts of climate change. Relocating the citrus orchards to cooler (lower) locations, while planting mangoes in warmer (higher) areas, appear to be a good way of addressing the low temperature issues.

"The use of shade netting or sun cups over the fruit is also a good way of reducing the effect of high daytime temperatures," notes another fruit farmer. Similarly using mulch will keep the soil temperature

Figure 1 (below): The case study locations for: Winter rainfall: Vredendal (A) and Moorreesburg (B) & Summer rainfall: Carolina (C) and Hoedspruit (D).

Figure 2 (bottom): Integrating climate, hydrological and economic models.





Irrigated citrus fruit in Hoedspruit is affected by the climate

Peter Johnston

down and ensure that less water is lost through evaporation. This will reduce the need for irrigation and ensure that water is used more efficiently. Given that these adaptive strategies are suggested to have been successful, it is important to determine how they will address the issues of future climate change.

Although mangoes and citrus can be produced in the future under these adaptive strategies, there will still be some impact from future climate change as shade netting and mulch are not only an extra input cost, affecting profitability, but they are also not 100% effective. The models may suggest that the adaptive strategies are a viable option for mitigating future climate change, but it is still necessary to observe the test results on actual farms before the strategies are shown to be effective.

Interviews with the farmers shed light on climate issues

Peter Johnston

After a second round of interviews with mango and citrus farmers, it was clear that some adaptive strategies had been implemented and were considered to be successful. When asked how they plan to change their farming practices based on the knowledge they now have, some farmers said, "we will change from mangoes to citrus because of the cooler temperatures" while others said, "we will plant more fruits under shade cloth and use more effective irrigation methods like drip irrigation".. The success of these strategies from the modelling helps to provide more information and allow the farmers to make more informed decisions regarding their farming practices in the future.

CLIMATE CHANGE AND GRAINS

Maize farmers believe that rainfall is the biggest driver for variations in their crop yield and quality. "The seasons have shifted, maybe starting slightly earlier. Rainfall has also dropped by about 50 mm", says a Carolina maize farmer. Farmers are adamant that the climate is changing and affecting their crop, but they feel that it is not a big concern at present. So how exactly does the climate affect maize? The farmers in this area suggest that abnormal weather, rainfall below the threshold of 510 mm and temperatures below 0°C will reduce the quality and yield of their harvests. This is caused by additional stressors affecting the crop such as increased diseases and poor growth and flowering.

Since the future predictions suggest that the temperature and rainfall patterns will change, maize farmers will have to adapt in order to maintain their current harvests. They felt that increased spraying (diseases), planting shorter growing crops will be a good way to mitigate the negative effects of climate change. Similarly they feel that crop rotation and conservation agriculture will help to ensure that their harvests are not reduced.

Conservation agriculture is a system that replaces conventional tillage with reduced or no-tillage, conserving soil moisture by applying mulch and steering away from mono-cropping by diversifying planted crops (rotations). One of the main reasons for adopting this system is for conserving water, which should allow the farmers to adjust to potentially harsh conditions in the future.

Once these adaptation options are run through the models, we get a clearer picture of how the future

climate change will affect the crops and what will be the best way of dealing with any negative impacts.

The intermediate climate scenarios will likely pose little threat to maize production. In fact, if the farmers make use of conservation agriculture and crop rotations, there is a possibility that their production will increase. Successful implementation of these adaptation strategies will reduce production risk and likely eliminate the negative effects of climate change on the maize value chain in some areas.

Although the models suggest that adaptation will mitigate climate change impacts, it is important to test this in the real world on working farms. Over the past two years, maize farmers have tested some of the adaptation strategies that they feel will work for them, with some promising results. When asked how they plan on changing their farming activities in the future, one farmer said "plant shorter growing cultivars" while others said, "use more conservation tillage". The use of these practices, as suggested by the farmers for the future, stems from the successful application in the past.

PROJECT DEVELOPMENT

In light of the current climate change research regarding agriculture, it seems that the news is not all bad for all crops. There are cases (such as for maize) where understanding the impact of climate change may help to increase production and help to maintain food security. Therefore changing their practices in the future would exploit climate change and not be too costly. On the other hand, mango and citrus production is expected to decline as a result of climate change.

Although there are some adaptation options, which could mitigate the negative effects of climate change, they can be costly. Relocating the mango trees to warmer areas as well as citrus to cooler areas is a viable option although it is still costly and time consuming. Overall, the use of crop rotations as well as conservation tillage seems to be the best option to either mitigate climate change impacts or exploit them.

The project is reaching its final year and another set of interviews with the farmers and relevant experts is in envisaged. This is helping to provide lessons on effective knowledge dissemination in this field as well as provide reliable and useful recommendations that can be applied by the farmers to mitigate the impacts of climate change as well as manage water resources better in the future.

It is also important to remember that this research is based on climate scenarios and models that are being updated with new data and models, which means that further research will always be required. ❑

Peter Johnston

Cool temperatures in the low lying citrus farms are ideal for growth.

Parched prospects: THE EMERGING WATER CRISIS in South Africa

South Africa is over-exploiting its freshwater resources and water could be a large constraint on the implementation of the National Development Plan. Using the International Futures forecasting system, Steve Hedden and Jakkie Cilliers of the Institute for Security Studies modelled and forecast water demand and supply until 2035. Their research found that the gap between demand and supply increases, and that the solutions proposed by the Department of Water and Sanitation (DWS) will not close the gap without additional, aggressive measures.

The first National Water Resource Strategy (NWRS1) was released in 2004 as a blueprint for water resource management and as one of the requirements of the 1998 National Water Act. The NWRS1 provided quantitative information about the present and future availability of and requirements for water in each of the 19 water management areas until 2025.

The NWRS2 is the second edition of the report. It seeks to 'ensure that national water resources are managed towards achieving South Africa's growth, development and socio-economic priorities in an equitable and sustainable manner over the next five to ten years'. The NWRS2 provides hard targets for increasing water supply for each of the recently promulgated nine water management areas.

Among its many goals, the National Development Plan sets the following interrelated targets: all South Africans should have access to clean running water in their homes by 2030, South Africa should achieve a food trade surplus; and the country should produce sufficient energy. The National Development Plan proposes a 33% increase in the area of land currently under irrigation. It states that efforts should be made to make mineral extraction less water-intensive, advocates investments in infrastructure for water, and proposes achieving an average reduction in water demand of 15% below baseline levels in urban areas by 2030.

CURRENT WATER DEMAND AND SUPPLY IN SOUTH AFRICA

The NWRS2 does not provide explicit data on the current water demand by sector, and is somewhat reliant on the studies carried out for the 2004 report. That report put total water withdrawal at 12.87 km^3, and exploitable yield at 13.25 km^3. While this implies a surplus of water still existed in South Africa in 2004, more than half of the water management areas were already being over-exploited.

More recent studies have shown that the NWRS1 may have overestimated water supply. Demand has increased since 2004 and rather than the small positive balance reported in 2004, South Africa is currently over-exploiting its renewable water resources on a national level.

Using the most recent data available for water demand in each sector, as well as the driving variables for water demand, the authors estimate that South Africa is currently withdrawing 15.6 km^3 of water per annum. The agricultural sector is the largest user of water, accounting for 57% of total water usage. Municipal demand accounts for 35% of water usage and the industrial sector accounts for the remaining 8% (Figure 1).

The NWRS2 estimates that the exploitable surface-water yield available on a 98% assurance of supply is 10.24 km³. Even if one includes the 2.1 km³ of treated wastewater produced each year, surface water is being heavily over-exploited at the national level. South Africa's capacity to build more dams is limited by the availability of streamflow, and under conditions of climate change this is likely to decrease as evaporative losses of open water increase. Current water supply is depicted in Figure 2.

More than two-thirds of South Africa's mean annual runoff is already stored in dams, limiting streamflow to a bare minimum. In the case of the Orange River, for every 100 units of rain that fall across the entire basin, only 5.1 units end up in the river (as opposed to in dams). If one calls these 5.1 units 100% of runoff, then South Africa has dams capable of storing almost double this flow.

The NWRS2 estimates that current groundwater withdrawal in South Africa is at 2 km³ out of exploitable groundwater resources estimated at 5.5 km³. Allowing for an underestimation of exploitable groundwater resources, the NWRS2 estimates a total potential of about 3,5 km³ of groundwater available for exploitation.

South Africa has over 1 000 water treatment facilities currently in operation discharging 2.1 km³ of treated water back into the river systems – although the quality of treated water is often suspect. Direct reuse of this water is minimal, but since the treated water is discharged into the river systems it is available as a secondary water source.

Desalination is being implemented on a small scale in South Africa. The industrial and mining sectors desalinate used water for reuse. Brackish groundwater desalination by reverse osmosis provides drinking water to small towns and communities along the West Coast. Desalination of acid mine drainage has been pioneered in eMalahleni, and is now under consideration for the Witwatersrand goldfields.

Seawater desalination is being used to supplement municipal water supplies in towns along the southern and Eastern Cape coastlines. In 2000, however, this accounted for just 0.018 km³ of the country's freshwater supply. The authors estimate that South Africa currently desalinates about 0.025 km³ of water.

MODELLING WATER SUPPLY AND DEMAND

To forecast South Africa's water sector, this authors used the IFs (information on this system can be found in the original paper for which the link is provided below).

To model water supply, the authors used the sum of assured surface water yield, renewable groundwater withdrawal, non-renewable (fossil) groundwater withdrawal, treated and reused wastewater, and desalinated water. Treated wastewater that is not directly reused is added to surface-water yield. Separate equations are used to forecast water demand for the main sectors of water usage, namely municipal, industrial and agricultural.

FORECASTING WATER DEMAND

Demand for water in South Africa can be reasonably expected to increase in all sectors. The authors' base case forecast of water usage (Figure 3) is that the largest increase in water demand by 2035 will come from the municipal sector, followed by industrial (which includes energy and mining) and agriculture.

Municipal water demand is forecast to increase from 5.5 km³ in 2014 to 7.2 km³ by 2035. Industrial water demand increases from 1.2 km³ to over

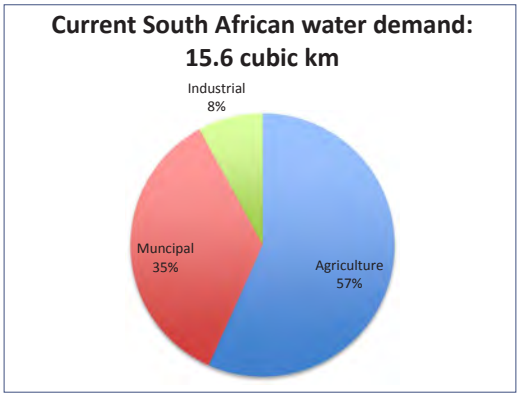


Figure 1

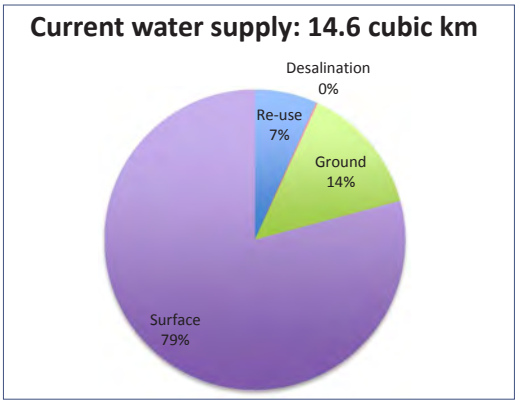


Figure 2

More than two-thirds of South Africa's mean annual runoff is already stored in dams, limiting streamflow to a bare minimum.

3 km³ in 2030 and then decreases to 2.8 km³ by 2035. This decline is due to the onset of renewable energy production, which does not require water for cooling. Agricultural water demand increases from 8.9 km³ to 9.7 km³ in line with objectives of the National Development Plan.

Even though the NWRS2 does not anticipate an increase in agricultural water demand, government's intention to increase the area of land under irrigation will increase water demand for the agricultural sector unless sufficient advances are made in water efficiency or water-withdrawal licences are transferred to other sectors.

FUTURE WATER SUPPLY IN SOUTH AFRICA

This section reviews water supply from surface water, groundwater, water reuse and desalination (See Figure 4).

To increase water supply, the NWRS2 plans for increased investment in surface water infrastructure, mainly from dams – although all significant rivers are at maximum yield, with few remaining dam sites and little remaining streamflow. The strategy plans to increase surface-water yield by about 1 km³ by 2035. Much of this will come from Phase 2 of the Lesotho Highlands Water Project, which supplies water to Gauteng through transfer from the Katse and Mohale dams in Lesotho to the Upper Vaal management area, to be completed in 2020.

With respect to groundwater, the NWRS2 plans to increase usage by 0.117 km³ by 2035. Although more water can be reliably extracted from underground aquifers, it is unlikely that South Africa will be able to increase groundwater withdrawals to the 3.5 km³ limit by 2035.

The NWRS2 sets hard targets for the reuse of water for several water management areas. Altogether, the strategy proposes the reuse of over a quarter of a cubic kilometre of wastewater by 2035.

Finally, the NWRS2 lays out plans to increase the use of desalinated water in several water management areas. The plan calls for at least 0.15 km³/annum by 2035 in at least three water management areas.

One way to reduce water demand is to decrease the volume of water that is lost through physical leakage or commercial losses, referred to as non-revenue water. A study, published in 2012 by the Water Research Commission (WRC) found that 36.8% of municipal water withdrawal was non-revenue water – most of which was a result of direct physical losses. This is on par with the global average of 37% but much higher than other water-scarce countries like Australia, whose non-revenue water is less than 10% of municipal demand.

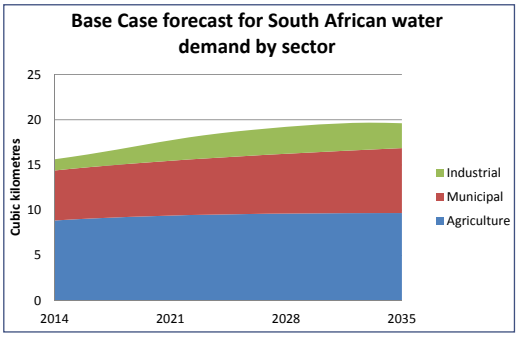


Figure 3

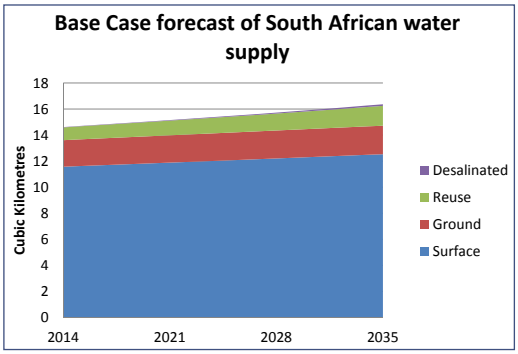


Figure 4

FORECASTING THE DEMAND-SUPPLY GAP

To model the NWRS2's ability to close the gap between demand and supply, the authors built a supply forecast that simulates the NWRS2 plans to increase supply using the IFS model. This includes all of the explicit supply increases outlined in the strategy. As seen in Figure 5, increasing supply

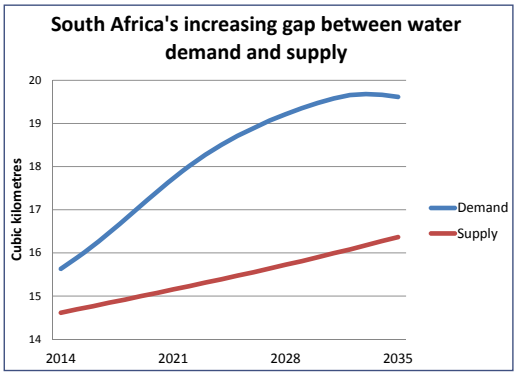


Figure 5

as proposed in the NWRS2 will not be sufficient to meet the growing demand for water.

The gap between demand and supply increases to over 3.5 km³ by 2030, and is only reduced to 3.2 km³ by 2035. This reduction in gap, which is predicted to take effect from 2030, is largely because of the expected drop in coal production together with continued growth in renewable energy.

WATER AS A CONSTRAINT ON GROWTH

If demand for water continues to exceed supply, then water resources in South Africa will be continuously over-exploited. This has serious consequences for the environmental resilience of aquatic ecosystems and the reliability of water supply for human consumption. Over-exploitation of water will also constrain growth, employment and general human development, since hydrology is a defining variable of the potential performance of water-constrained countries' economies.

Due to its naturally variable climate drought recurs regularly in South Africa. Over-exploitation of freshwater resources increases the changes that a drought will exacerbate water shortages. If there is not a reliable supply of water, whatever the source, then communities and industries that rely on rainwater will experience water shortages.

To illustrate the extent of water as a constraint on growth, we turn to the 'Mandela Magic' (high road) scenario from the South African futures 2030 paper. In this scenario, South Africa grows at an average rate of 5.1% from 2014 to 2030 (compared to an average growth rate of 3.8% forecast for an amended baseline called 'Bafana Bafana' in the same paper) and has, by 2030, an economy that is 23% larger than the base-case forecast.

Economic development increasingly drives water demand. Most of this increased demand comes from the industrial sector – total water requirements are 0.7 km³ higher in 2035 in the 'Mandela magic' scenario than in the base case, depicted in Figure 6.

Economic growth is also expected to drive investment in wastewater treatment facilities, thereby increasing overall water supply. Although more wastewater is treated in this high road scenario, more untreated wastewater is also produced, resulting in more contamination of water catchments.

Furthermore, the increase in supply is outweighed by the increase in overall demand, resulting in an even larger gap between demand and supply than in the base case. The gap increases from 3.23 km³ in the base case in 2035 to 3.77 km³ in the Mandela Magic scenario.

Water is therefore a significant constraint on South Africa's development potential and the next section looks at how this gap can be closed.

REDUCING DEMAND

This section discusses methods of reducing water demand and increasing supply and includes a summary of the associated scenario called 'close the gap'.

The average per capita water consumption in South Africa is higher than in most other countries, so behavioural changes in municipal consumption are particularly important. Central to this required change in attitude is the emerging global notion of stewardship, which is based on an ethos of sustainable custodianship rather than on consumption.

Reducing the volume of non-revenue water will greatly curtail the rise in municipal water demand. Better monitoring of municipal and industrial water supply might also help reduce lost water. New technology, such as advanced metering infrastructure, could also help to reduce these losses.

If per capita municipal consumption were lowered to the world average by 2035 (a significant challenge in itself), the demand-supply gap would be reduced by almost half. In the 'close the gap' scenario, municipal water demand falls from 7.18 km³ in 2035 in the base case to 5.74 km³. This is some 20% lower than in the base case – though still above the expected value given the size of South Africa's urban population when compared to urban water use globally.

While the National Development Plan acknowledges that investment in agricultural irrigation may have many social and economic benefits, and aims to increase the area of land under cultivation, the NWRS2 does not allow for any increase in water allocation for the agricultural sector.

The authors' analysis shows that South Africa uses less water for agriculture than one would expect

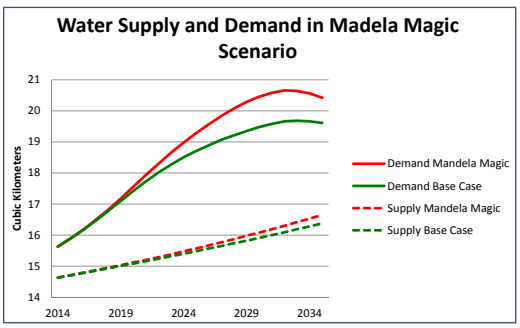


Figure 6

Better monitoring of municipal and industrial water supply might also help reduce lost water. New technology, such as advanced metering infrastructure, could also help to reduce these losses.

given the area of land equipped for irrigation. This does not necessarily mean, however, that water is being used efficiently in irrigation schemes.

However, the economic benefits of irrigation should not be underestimated. While the NWRS2 claims that agriculture contributes only 3% to the national economy, it is estimated to contribute as much as 18% in secondary processing. In the 'close the gap' scenario, the demand for agricultural-use water decreases by only 2% compared to the base case by 2035. This assumes gains in water-use efficiency as well as increases in the area of land equipped for irrigation.

Thermoelectric power generation, the manufacturing sector and the mining sector will primarily drive industrial water demand. Although these area economically important industries, their water needs must be balanced with the needs of other sectors. Industrial water demand decreases by 10% compared to the base case.

Even with all these improvements in efficiency, water demand still increases in each sector over the time horizon – implying that the reduction in demand levels is insufficient. Supply also has to increase as discussed in the next section.

Finally, South Africa faces a legacy of a skewed allocation of water rights. Efforts to balance water rights will be constrained by the supply and demand challenges outlined in this article.

Groundwater is currently not over-exploited on a national level and there is room to increase groundwater extraction significantly, especially in rural areas and on small farms.

INCREASING SUPPLY

In addition to the 1.87 km^3 reduction in overall water demand in 2035, the IFs model forecasts an increase in exploitable water supply by 1.43 km^3 in comparison to the base case. Bear in mind that the base case already includes the hard targets set out in the NWRS and these supply increases are in addition to the plans of the NWRS. Surface water is over-exploited on a national level and while infrastructure is being built to increase the reliable yield, there is a limit on the ability of dams and redistribution networks to satisfy global demand.

Almost without exception, municipal wastewater is not being utilised in South Africa – another opportunity to increase water supply. In addition, reducing non-revenue water represents an opportunity to decrease municipal water demand.

Groundwater offers another potential way of meeting some of the supply increases. Groundwater is currently not over-exploited on a national level and there is room to increase groundwater extraction significantly, especially in rural areas and on small farms. The forecast increases exploitable groundwater from 2.19 km^3 in 2035 in the base case to 2.93 km^3 in the 'close the gap' scenario.

There is some room for developing surface water, but the base case already includes planned infrastructure development, like Phase 2 of the Lesotho Highlands Water Project. Exploitable surface water yield can be increased, however, through the treatment of wastewater. In the 'close the gap' scenario, 80% of municipal wastewater is treated. Two-thirds of this is then directly reused and the remainder is available as exploitable surface water.

In the 'close the gap' scenario, desalination is increased by 70% against the base case, yet it still contributes very little to overall water supply on a national level. Starting from such a small base, it is difficult for desalination to play a significant role in the South African water sector for the next 20 years. An option that this research did not consider is for South Africa to import more water than it already does from Lesotho.

SUMMARY RESULTS

The policies set out in the NWRS2 are clearly not enough to address the water constraints facing South Africa. Even if policies that would close the demand-supply gap by 2035 are put in place now, South Africa will still be over-exploiting water for the next 20 years – even on South Africa's current growth path, which is significantly lower than that presented in the 'Mandela Magic' scenario.

This over-exploitation increases the vulnerability of the water system to shocks such as droughts and will be aggravated by the impact of climate change. Clearly, an attempt to reconcile this gap must include policies to reduce demand, increase supply, improve efficiency and create the necessary incentives for the transition to a recycling economy, in which water of different quality and price is used for different purposes.

Achieving the 'close the gap' scenario requires significant investment in water supply – more than is explicitly called for in the NWRS2 – as well as much more efficient uses of water to reduce demand. The results are presented in Figure 7.

The base case forecasts a gap between supply and demand of 3.23 km^3 in 2035. To close this gap, we set aggressive targets for each sector of demand and each source of water supply. Most of the gains come from demand management – primarily in the municipal sector. This would necessitate significant behavioural changes in urban water consumption, as well as reductions that come about from improvements in the management of non-revenue water.

Generally, the forecasts show that the overall increase in both land under irrigation and thermoelectric generation counteract improvements in efficiency, which means that water demand increases in every sector even with improvements in efficiency.

Figure 8 and 9 respectively present increases in water supply from each source and reductions in water demand from each usage sector that are needed to close the gap between demand and supply. this reflects the huge contribution made from greater efficiencies in the use of municipal water and exploitation of groundwater.

CONCLUSION

South Africa is facing a potential water crisis and the current policies of the DWS are not sufficient to address this problem. Although not impossible to achieve, the reductions in demand and increases in supply necessary to close the gap outlined in this article, are very optimistic.

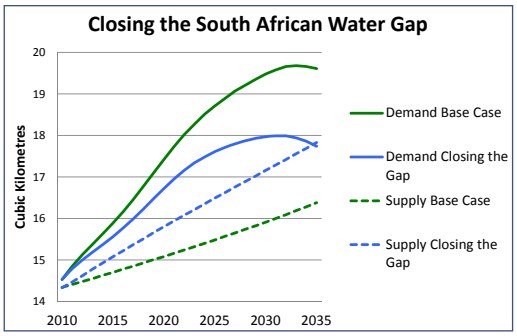


Figure 7

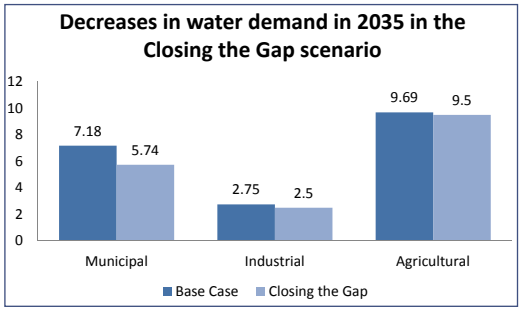


Figure 8

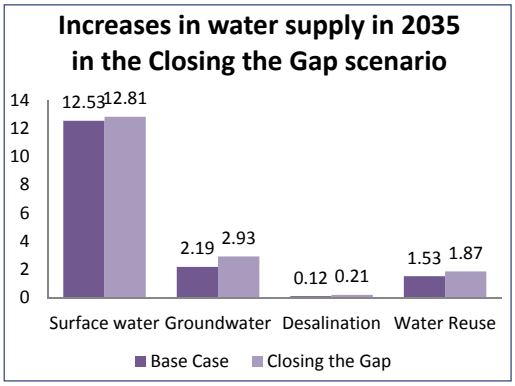


Figure 9

Increases in water supply cannot match the expected increase in demand without additional and far-reaching interventions. The water crisis cannot be solved through engineering alone – demand management in terms of both efficiency and allocation will have to play a large part in the efforts to close the water demand-supply gap in South Africa.

In line with some of the key messages from the reconciliation strategies laid out in the NWRS2, it is evident that South Africa cannot afford to waste any water, anywhere, any more. More specifically:

- Groundwater is important, and currently undervalued and under-used, especially in small-scale rural farming. It may emerge as the most important way in which any expansion in the agricultural sector is possible.
- There is huge potential to increase the reuse of municipal and industrial water at the coast and in inland systems.
- There is limited opportunity for more dams or transfer schemes, but they are inevitable in certain areas.
- Due to the high levels of evaporation and transpiration loss in South Africa, the storage of water in aquifers has to be considered as part of future policy or alternative ways need to be found to reduce evaporation.
- Expensive desalination projects would have to be considered as an option to increase supply of water, especially on coastal areas with limited alternative sources of supply.
- The necessary incentives should be put in place for the transition to a recycling economy, in which water of different quality and price is used for different purposes.
- Monitoring and evaluation of the water sector is necessary to set and achieve the goals outlined in this article.

Over-exploiting water threatens the health and prosperity of South Africa. While there is great uncertainty regarding the future of water demand and supply, it is clear from the forecasts presented here that a business-as-usual future scenario for water in South Africa will result in an unsustainable gap between supply and demand for many years. This gap represents a large risk – a risk that water may become a finite constraint to economic development and a crisis could ensue.

South Africa has a diverse and active community engaged in water issues. Despite the sterling efforts by the WRC, the lack of publicly available and easily accessible data is a major problem in researching water supply and demand in South Africa. The excessive use of consultants and inability to capture and integrate the associated research results presents a serious constraint on planning and accountability. ❑

This article is based on the paper published by the ISS under the African Futures Project. To access the full paper with references, Visit: http://www.issafrica.org/publications/papers/parched-prospects-the-emerging-water-crisis-in-south-africa

WATER Kidz

NURTURING OUR FAMILY FARMS

You might not even have thought about it as you bit into your sandwiches at school, but on October 16 World Food Day was celebrated all around the globe. This year's activities, in particular, paid homage to the importance of family farms in producing food.

So what is family farming then? As the name implies family farming includes all agricultural activities that are undertaken by families – it can be a small home garden or a commercially-sized affair. It is not just limited to growing fruits and vegetables, but may also include keeping livestock and fish farming (aquaculture) – any farming activity that is managed and operated together by a family.

What many people do not know as that in many countries, most of the food is grown not by huge company farms, but by families. And it is important that we protect these family farms too, not only do they help to feed the world, they also preserve traditional food products (like indigenous crops). Many family farmers are more productive per hectare than industrial monocultures – despite receiving lower subsidies and using fewer chemical and fossil fuel inputs.

At the same time, these farms contribute to a balanced diet while playing an important role in protecting the world's agro-biodiversity and improving sustainable use of natural resources (like water!). For many families, farming is an important income, while creating jobs – not only on the farm but also in other related industries.

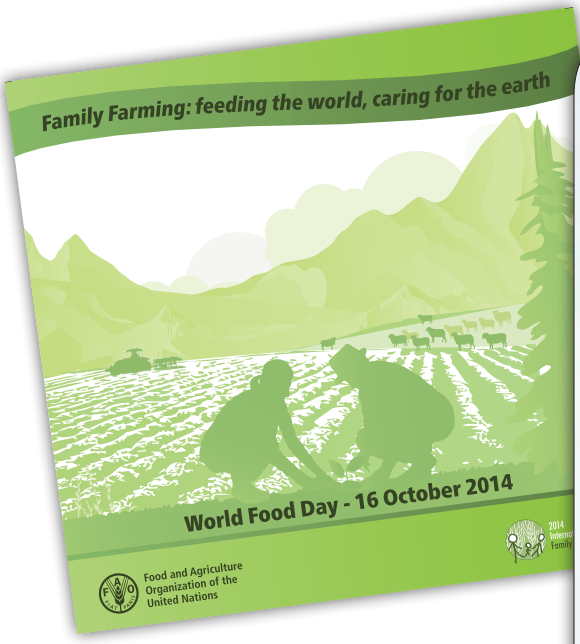
In fact, family farms are so important that the United Nations declared the whole year 2014 the International Year of Family Farming. At a special event UN Secretary-General Ban Ki-moon said that governments can empower family farmers, especially women and youth, by creating laws that help to protect them.

Unfortunately there are a lot of things challenging the future of family farms. This includes climate change, which may worsen droughts or floods in areas where these farms are. Family farms also face

Family farmers around the world

- There are over 500 million family farms
- They make up over 98% of farming holdings
- They are responsible for at least 56% of agricultural production

Family farms grow most of the food in the world.



increasing competition for land and water from, for example, expanding towns and cities. Many of these families also have limited access to financial resources, technology, training, research, advisory services and education to make their enterprises bigger and better. They might also struggle to get a market for their produce.

So why not find a family farm in your area that you can support?

- Why is family farming important? Watch the video at https://www.youtube.com/watch?v=TS_V8CUZX10&index=28&list=PLzp5NgJ2-dK73v2oT-0MG5N6i K9wPT6QnJ

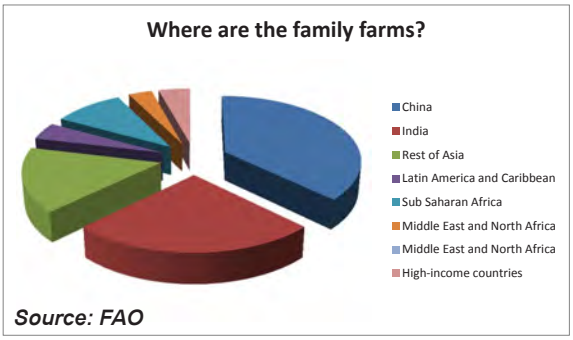
Family farms can be big or small.

START YOUR OWN FAMILY VEGETABLE GARDEN IN 1-2-3

Why not start your own mini-family farm in the backyard? You don't even need a big yard, some containers on your patio or terrace will do. Just follow these five easy steps:

1. ***Stock up on supplies.*** While it is fun to get your hands dirty you will need some equipment, like shovels rakes and hoes. Depending on the type of garden, you might also need some pots and soil.
2. ***Find a location.*** You need a big yard to have garden. Don't have a yard? Get together some pots and start a container garden.
3. ***Pick your plants.*** To give your garden the best chance of survival, make sure your choose the right seeds for your location. Your local nursery should be able to give some advice on this. Crops such as tomatoes, radishes, green beans, and sweet peppers are typically easy to grow, while cauliflower and maize might be more of a challenge. If planting from seeds seem daunting to you why not try some seedlings?
4. ***Start planting.*** Now we get to the exciting part, the planting! Be sure to label each row of vegetables as you plant and take pictures to track the progress of your crops.
5. ***Take care of your garden.*** Planting seeds is only the start. A garden needs to be tended to, weeds pulled, plants watered. Be sure to read up on the crops you are planting as they might each need different care. Your local library can provide some free reading if you don't have access to a computer with Internet access. Once your vegetables come in be sure you pick them at the right time.

Source: ***www.inhabitots.com***



Symposium shows word still out on potential impacts of unconventional gas

The Groundwater Division of the Geological Society of South Africa (GWD) and the Mine Water Division of the Water Institute of Southern Africa were the combined hosts of the Unconventional Gas symposium held in Pretoria in August. With the theme 'Just the facts' the symposium provided a thought-provoking forum on the potential advantages and disadvantages of using unconventional gas in southern Africa. The symposium unpacked the challenges associated with operation and closure, with various lessons being presented from current projects here and internationally. The symposium provided factual presentations from the viewpoints of the regulatory bodies, industrial organisations, non-governmental organisations, and academic researchers to enable delegates to become more familiar with the topic and able to make better-informed decisions.

Dr Kevin Pietersen of SLR Consulting with Christine Colvin of WWF South Africa.

Andrew Stone, Executive Director of the American Groundwater Trust provided an interesting update on the current state of shale-gas development in the USA.

Among the speakers at the conference were Anet Muir (Department of Water and Sanitation), David Love (Golder Associates Africa), Dr Ricky Murray (Groundwater Africa), Fanie de Lange (University of the Free State), Andrew Stone (American Groundwater Trust), Peter Rosewarne (SRK Consulting), and Dr Kevin Pietersen (SLR Consulting).

DEEPLY ROOTED IN SOUTH AFRICAN WATER SOCIETY

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The Water Reasearch 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 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, and innovative water solutions through research and development for South Africa, Africa and the world.

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WATER RESEARCH COMMISSION

THE POWER OF KNOWLEDGE TO THE PEOPLE