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ScienceScope

PUBLICATION OF THE CSIR | VOLUME 6 | NUMBER 1 | NOVEMBER 2011
SOUTH AFRICA'S COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

Strengthening southern Africa's response to global change through research and technology

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our future through science

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Road to Durban and beyond

At the end of November 2011 all eyes will be on Durban, and more specifically, the 17th meeting of the Conference of Parties (COP) at the United Nations Framework Convention on Climate Change.

DUBBED BY SOME AS THE "World Cup of Climate", this international gathering of all those concerned with the challenges posed by climate change seeks to carve a road for climate negotiations beyond the first commitment period of the Kyoto Protocol, which comes to an end in 2012.

The slogan for the Durban conference is *Working together! Saving tomorrow today!* To be sure, the impact of global change on our climate will not be managed or mitigated by any single stakeholder. It requires a society that is aware of the implications of its actions for the way we live; it requires business and industry to implement astute and sustainable working methodologies; and it requires political will – informed by credible and rigorous research.

The CSIR undertakes directed research and development for socio-economic growth. In line with our mandate, the CSIR is committed to national priorities, including:

- Economic growth and the creation of sustainable livelihoods
- Improved economic and social infrastructure
- A rural development strategy linked to land and agrarian reform and food security
- A strengthened skills and human resource base
- An improved health profile for all South Africans
- Cohesive, caring and sustainable communities
- African advancement and enhanced international co-operation
- Sustainable resource management and use.

Against this backdrop, our work in global and climate change cuts across several sectors and includes natural resources, built environment, industry, and green technologies and energy. The natural environment is both an important source of economic opportunity – agriculture, forestry, fisheries, ecotourism – and an irreplaceable habitat for humans and other species. CSIR research in this domain embraces both of these aspects, and the critical tradeoffs between them.

It is about the environment that we live in and use, rather than exclusively about undisturbed nature. Our research aims to develop innovative research and development platforms to provide strategically focused environmental solutions in support of a resilient economy.

The CSIR has a cadre of more than 30 researchers working exclusively in the field of climate change; many of them are respected internationally. This is especially significant as our continent will be one of the worst impacted by climate change; in fact, the results of a changing climate on Africa are already being documented.

In this ScienceScope, we focus on science and technology that contribute to a better understanding of our changing planet. The CSIR's work in this area comprises atmospheric modelling, oceanic and terrestrial measurements and observing our climate from outer space.

However, a better understanding must translate into actions. These are described in the second part of the publication. Since substantial climate change is already underway, and more is inevitable, some actions involve adapting society, businesses and agriculture to a changing climate. Other actions are essential to keep the amount of climate change we will face in future within the adaptable range. This is why the negotiations at COP 17 are crucial.

I trust that you will enjoy this edition of the ScienceScope – strengthening southern Africa's response to global change through research and technology.

Dr Sibusiso Sibisi,
CSIR President and CEO

The CSIR Board's recommendation to the Minister of Science and Technology, Mrs Naledi Pandor, to renew the contract of Dr Sibusiso Sibisi as CEO was approved by Cabinet. She said, "I am confident that Dr Sibisi will continue to lead the CSIR over the next five years with the same level of commitment, passion and understanding of national and global scientific challenges."

BOOK CORNER

WRC: 40 Years of Excellence

The Water Research Commission (WRC) recently celebrated 40 years of water research, reflecting on past achievements, but at the same time deliberating on future challenges. Since 1971, the WRC has played a significant role in providing South Africa with solutions and sufficient knowledge to address water challenges. The book, *WRC – 40 years of excellence*, reflects on the impact of its activities, which have covered capacity building in the water sector, broadening of South Africa's water-centred research and development base, and continued commitment to direct and funded research. **For a copy of the book, contact orders@wrc.org.za**

Capturing glimpses of environmental change in South Africa

Observations on Environmental Change in South Africa was commissioned by the South African Environmental Observation Network (SAEON) with funding from the Department of Science and Technology (DST). A highly illustrative, glossy, hard-cover with striking photographs, satellite images and other graphics, the book gives a picture of environmental change and proposed responses on a range of themes and topics. It draws together work from as many scientific disciplines as possible, extracts pertinent information and presents it in a condensed format. Content is divided into four sections, *People and Environmental Change; Atmospheric System and Climatic Change; States and Trends in the Terrestrial Environment;* and *States and Trends in the Aquatic Environment.* It is a useful resource for the general public and government officials responsible for policy formulation and decision making on environmental issues. It will also be of value to lecturers and students at higher education institutions. Several CSIR staff members contributed to chapters in the book. Dr Konrad Wessels, an environmental remote sensing specialist at the CSIR, was a member of the editorial committee.

The book is available free for download as a pdf from **www.saeon.ac.za**, or contact SAEON at 012 349 7722 to order a hard copy.

Climate change handbook for southern Africa

The *Climate Risk and Vulnerability Handbook for Southern Africa* was designed to provide decision makers with up-to-date information on impact and risk of climate change and variability. It is structured according to four questions dealing with observations of past, current and future climate; the likely impacts of such climate changes in key sectors and how countries in the southern African development community should deal with these adverse impacts.

Launched at the Highway Africa Conference on African media and the global sustainability challenge in Cape Town recently, it will soon be available on Kalahari.com.

New instruments make regional estimation of carbon fluxes a near-reality

THE DEVELOPMENT of a reliable regional network of greenhouse gas monitoring stations will be further enhanced by the acquisition of three high-precision greenhouse gas monitoring instruments.

Funded by the National Research Foundation's Research Infrastructure Support Programme, the Picarro G2401 CRDS Analyser is recognised as a high precision instrument for measurement of the top three greenhouse gasses. It is capable of making measurements every five seconds, with a precision of better than 0.05 parts-per-million volume (ppmv) for CO_2, 0.07 parts-per-billion volume (ppbv) for CH_4, and 100 ppmv for H_2O. According to CSIR systems ecologist Dr Bob Scholes, an improved network of atmospheric monitoring stations over southern Africa will greatly enhance local estimates of carbon sources and sinks, as well as regional estimates elsewhere.

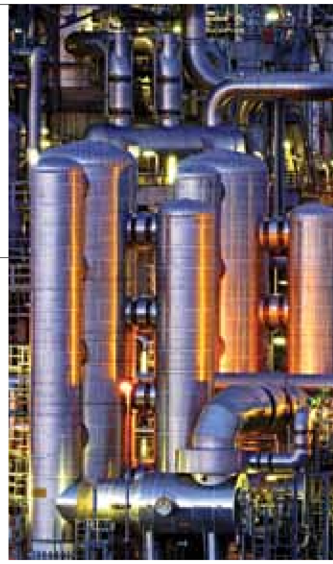
"High uncertainty in one region can lead to compensation in other regions to uphold the conservation of mass limitations imposed on these atmospheric inversions, thereby increasing the uncertainty of these regions as well," he explains.

– Wiida Basson

mLab Southern Africa officially opens doors in Tshwane

A NEW REGIONAL LAB for mobile technology entrepreneurs, application developers, and innovators (mLab) was inaugurated on 15 September 2011. mLab Southern Africa's activities are aimed at making the region a global hub for mobile innovations to boost job-led growth and address economic and social needs. mLab Southern Africa will draw on South Africa's high bandwidth environment and pool of expertise with strong connections to the rest of Africa.

Situated at The Innovation Hub, mLab Southern Africa is co-hosted by the CSIR, The Innovation Hub, InnovationLab and Ungana-Afrika. Financial support is provided by the South African Department of Science and Technology and infoDev, a World Bank Group global programme focusing on supporting technology-driven small and medium-sized enterprises.



Energy efficiency improvement project promotes sustainable development

THE ENERGY CRISIS of 2007/08, the impending water challenge and the current climate change pressures highlight the growing need for sustainable development and to improve the capacity of SA industry to use available energy resources more efficiently and productively.

In response to this, the Industrial Energy Efficiency Improvement Project (IEEP) was established as a joint initiative between the dti, the DoE, UNIDO, the Swiss State Secretariat for Economic Affairs and the UK Association of International Donors. To contribute towards meeting the country's needs in terms of suitably skilled capacity, regular training workshops on energy management systems (EnMS) and energy systems optimisation (ESO) are presented by UNIDO-contracted international experts at a number of locations across the country.

Subsidised options are available for companies (including SMEs) to participate in the IEEP and demonstrate the impact of implementing an EnMS and/or ESO options in their plants.

The IEEP is hosted by the National Cleaner Production Centre of SA at the CSIR.

– Petro de Wet

Health infrastructure research expert wins 2011 JD Roberts Award

THE CONTRIBUTION by Geoff Abbott in the planning, design and management of health facilities in South Africa has won him the coveted 2011 JD Roberts Award. The annual JD Roberts Award is sponsored by Murray & Roberts and awarded in partnership with the CSIR in recognition of research excellence at the CSIR. It was instituted by Murray & Roberts more than three decades ago in honour of one of the group's founding fathers, Dr JD 'Douglas' Roberts.

Abbott, a research architect at the CSIR, plays a crucial role in a national project to provide new long-term accommodation for multi-drug-resistant tuberculosis patients at nine hospitals. One of the most significant strategic planning projects Abbott has been involved with was South Africa's first comprehensive survey and audit of public health care infrastructure in South Africa.

He has also provided valuable guidance in immovable asset management in the public sector over many years.

– Hilda van Rooyen

Africa's first sea gliders have arrived

THE FIRST two long-range autonomous iRobot Seagliders have arrived in South Africa and will soon be deployed into the heart of the world's largest ocean current – the Antarctic Circumpolar Current.

According to Dr Sebastiaan Swart, oceanographer with the CSIR in Cape Town, long-range gliders offer a unique platform for ocean-climate observations, and represent one of the most novel technologies available in oceanography.

Funded by the Department of Science and Technology, the newly-arrived gliders form part of a larger programme – the Southern Ocean Carbon and Climate Observatory (SOCCO) – to build South Africa's capacity in providing high-quality, precise data related to carbon-climate interactions in the Southern Ocean.

Over the next ten months the gliders will undergo sea trials in locations close to South Africa's coast, such as False Bay and off the West Coast.

A group of oceanographers and technicians from the CSIR, the University of Cape Town and the Institute of Maritime Technology are being trained by the manufacturer's engineers to manage the technical aspects of these three-metre-long instruments. They will then be deployed in practice-runs just off the coast, before going on board the SA Agulhas II, South Africa's brand new polar research vessel, for its first trip to Gough Island in September 2012.

These deployments will form a crucial part of SOCCO's Southern Ocean Seasonal Cycle Experiment (SOSCEx) from austral spring to autumn (2012 to 2013), which will combine measurements taken from ships, gliders and floats. The experiment will include the participation of international partners from the United States, Norway and France and will be in preparation for South Africa's participation in a planned multi-nation international experiment, beginning in 2014. This broader experiment aims to improve the global understanding of the link between the carbon cycle and climate in the Southern Ocean.

– Wiida Basson

Dr Sebastiaan Swart

An ICON for southern Africa

EARLIER THIS YEAR, a voluntary committee was established to integrate and synthesise carbon data from various institutions such as the CSIR's decade-old flux tower in Skukuza and the country's longest continuous atmospheric-measuring station at the Cape of Good Hope, administered by the South African Weather Services. Other members include the Department of Environmental Affairs, South African National Biodiversity Institute and the City of Cape Town.

The objective of the newly-established South African Integrated Carbon Observatory Network – SA-ICON for short – will be to foster collaboration among the different institutions involved in the field, and to lead to better application of data, skills and knowledge, explains the CSIR's Dr Pedro Monteiro.

"By working together we can coordinate the placement of instruments measuring carbon and other greenhouse gasses. Currently, South Africa does not have a dedicated carbon observation monitoring network," he explains.

– Wiida Basson

Understanding A CHANGING PLANET

South Africa is located at the tip of the African continent, adjacent to important oceans that influence global weather patterns and atmospheric greenhouse gas concentrations in unique ways that have global, regional and local impacts.

"The need for all South Africans to have a shared understanding of climate change and the mechanisms for transforming its threats into opportunities for sustainable development cannot be overemphasised."

– Parliament of South Africa calling for comments on the climate change white paper, 2 October 2011

Projected regional climate futures
for southern Africa

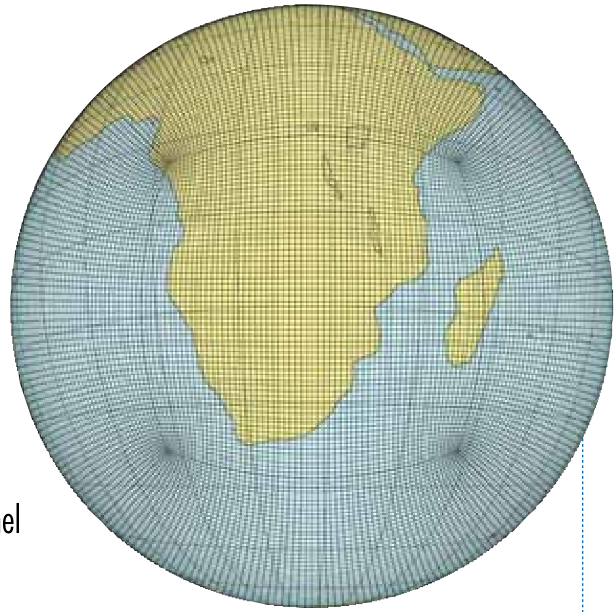


Figure 1: Stretched-grid of the conformal-cubic atmospheric model, providing a resolution of about 50 km over southern and tropical Africa.

Global circulation models (GCMs) have become the main tools for the simulation of future climate change and their projections are being used extensively in the assessment reports of the Intergovernmental Panel on Climate Change (IPCC). GCMs rely on the laws of physics to describe the response of the Earth system to enhanced levels of greenhouse gas concentrations, as well as to other types of anthropogenic forcing.

GCMS ARE COMPUTATIONALLY EXPENSIVE – on today's supercomputers, projections of future climate change can typically be obtained at a horizontal resolution of about 200 km. However, to study the regional impacts of climate change, a much higher resolution is required.

Regional climate models are used to downscale the output of GCMs to high resolution over areas of interest, through a process that has become known as 'downscaling'. That is, in a regional model the grid points at which calculations are performed, are closely spaced over an area of interest, with the resolution decreasing away from this area. In those regions where the resolution of the regional model is low, it receives information about the state of the atmosphere from a GCM simulation.

With support from the Centre for High Performance Computing, we took six GCMs that contributed to the last IPCC assessment report and downscaled these over the southern African region – using a variable-resolution global circulation model as a regional climate model. The simulations were performed for the period 1961-2100, at a resolution of about 50 km over southern and tropical Africa. All the projections are for the A2 (business as usual) emission scenario.

These simulations represent the largest regional climate projection experiment performed to date on the African continent. The high-resolution area of the regional climate model is shown in Figure 1.

It is important to thoroughly test a climate model's ability to represent the key features of present-day climate against observations. If the model can represent aspects such as annual rainfall totals, the seasonal cycle of rainfall and the daily circulation statistics of present-day climate satisfactorily, it increases confidence in the model's projections of future climate

Dr Francois Engelbrecht is an atmospheric modeller at the CSIR in Pretoria.

change. At the CSIR, the climate model used to obtain projections of future climate change is also applied for daily weather forecasting, as well as for seasonal forecasting. This implies that the model's ability to simulate aspects such as convective rainfall events and the response of rainfall patterns over southern Africa to the El Niño Southern Oscillation (ENSO) can be systematically verified against observations. Figure 2 (top) shows a simulation of average mid-summer (January) rainfall over southern and tropical Africa (units mm/day) for the period 1961-1990. The simulation is the ensemble average of the six GCM simulations after downscaling was performed over the southern African region using the Conformal-Cubic Atmospheric Model (CCAM). The corresponding observed field (obtained from the CRU-TS 3.1 data set) of the Climatic Research Unit (CRU) is shown in the lower panel. The model provides an adequate simulation of the prominent features of the January rainfall distribution over the subcontinent, including the west-east gradient in rainfall over South Africa and the position of the Intertropical Convergence Zone (ITCZ) over Angola, Zambia and northern Mozambique. The model has a wet bias, that is, it overestimates rainfall totals over most of the region, and in particular over the eastern escarpment areas of South Africa.

Continued on page 10

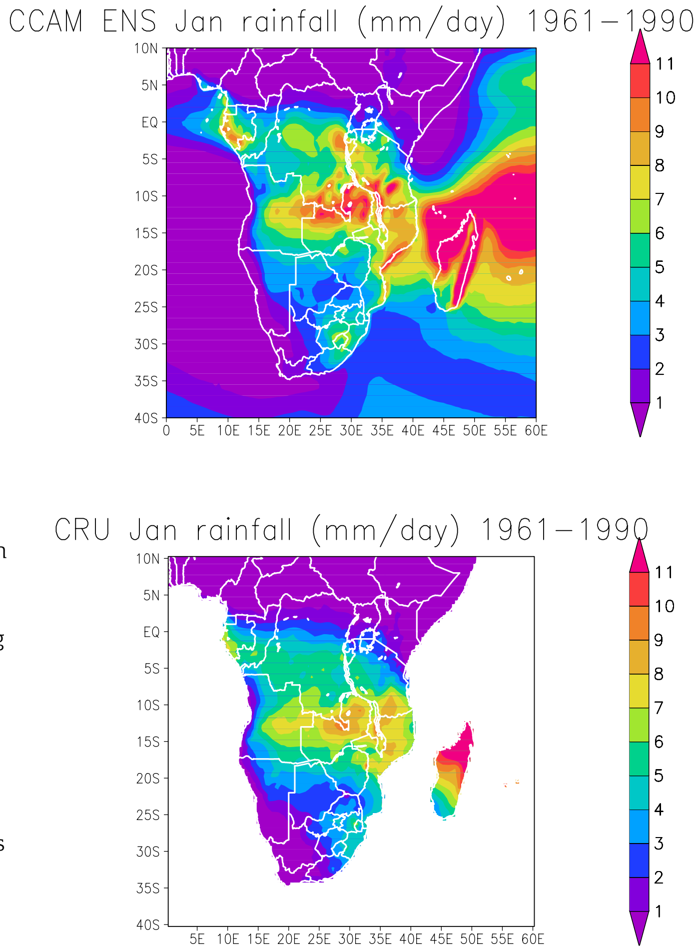


Figure 2: CCAM ensemble average simulated (top) and CRU observed (bottom) January rainfall over southern and tropical Africa (units mm/day), for the period 1961-1990.

What is a climate model?

Global circulation models and dynamic regional climate models are not statistical models, but mathematical models based on the laws of physics – a mathematical formulation of the conservation laws of mass, momentum and energy. Projections of future climate change based on these models do not rely on any knowledge of the statistics of present-day climate.

The typical procedure is to divide the Earth system into a number of grid points: the state of the three-dimensional atmosphere and oceans are then simulated at these discrete points, typically for the period 1961 to 2100. A common approach is to force the mathematical model with observed greenhouse gas concentrations of the last 50 years, and with projected greenhouse gas concentrations for the future period. The model atmosphere then responds to this forcing, hopefully in a way that reflects the response of the real atmosphere.

Because of the uncertainty that surrounds the future rate of greenhouse gas emissions, global circulation models are typically integrated for a number of different emission scenarios. The simulated atmosphere responds to the increasing greenhouse gas concentrations, and just like the true atmosphere, absorbs more heat leading to global warming. Circulation systems in the model's atmosphere and ocean subsequently respond to the atmosphere's ability to absorb heat, enabling the model simulation of future climate change.

– Dr Francois Engelbrecht

The model projection (ensemble average) of change in future mid-summer temperature patterns over southern Africa, for the period 2071-2100 relative to 1961-1990, is displayed in Figure 3. Drastic increases in near-surface temperature are projected for the subcontinent. For the interior regions of subtropical southern Africa, temperature increases of more than 4°C are projected. Indeed, temperatures over these regions are projected to rise at about twice the global rate of temperature increase, in accordance with observed temperature trends over the region. These rapid rises in temperature over southern Africa may be expected to have impact across a wide range of sectors, including agriculture, water resources, biodiversity and human health.

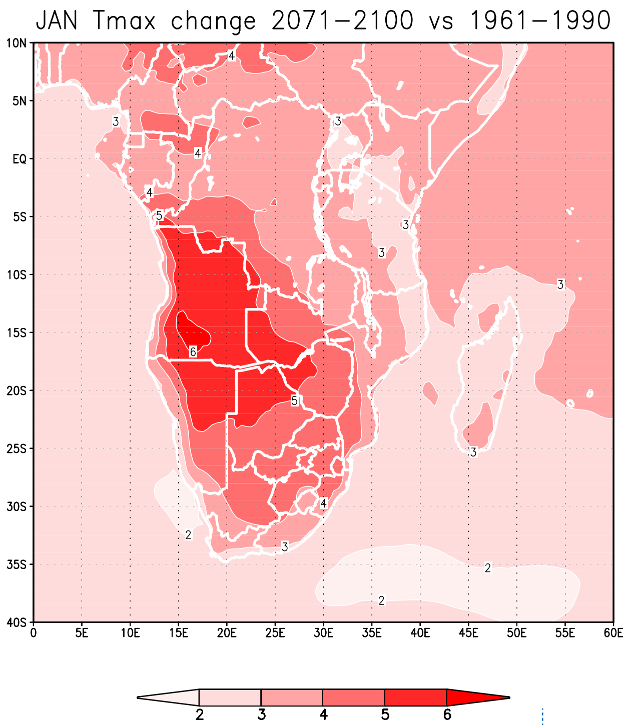


Figure 3: CCAM ensemble average projected change in mid-summer temperature (°C) over southern Africa.

The projected change in mid-summer (January) rainfall patterns over southern Africa, for the period 2071-2100 relative to 1961-1990, is shown in Figure 4 for the 25th percentile, median and 75th percentile of the ensemble of downscaled projections. Southern Africa is projected to become generally drier, while East Africa is projected to become generally wetter. Slight to moderate January rainfall increases are also projected for the central parts of South Africa. These changes are consistent with the projections of GCMs described in Assessment Report 4 (AR4) of the IPCC. The qualitative correspondence in the projected climate-change signal between the 25th and 75th percentile panels indicates the robustness of the projected signal.

– Dr Francois Engelbrecht

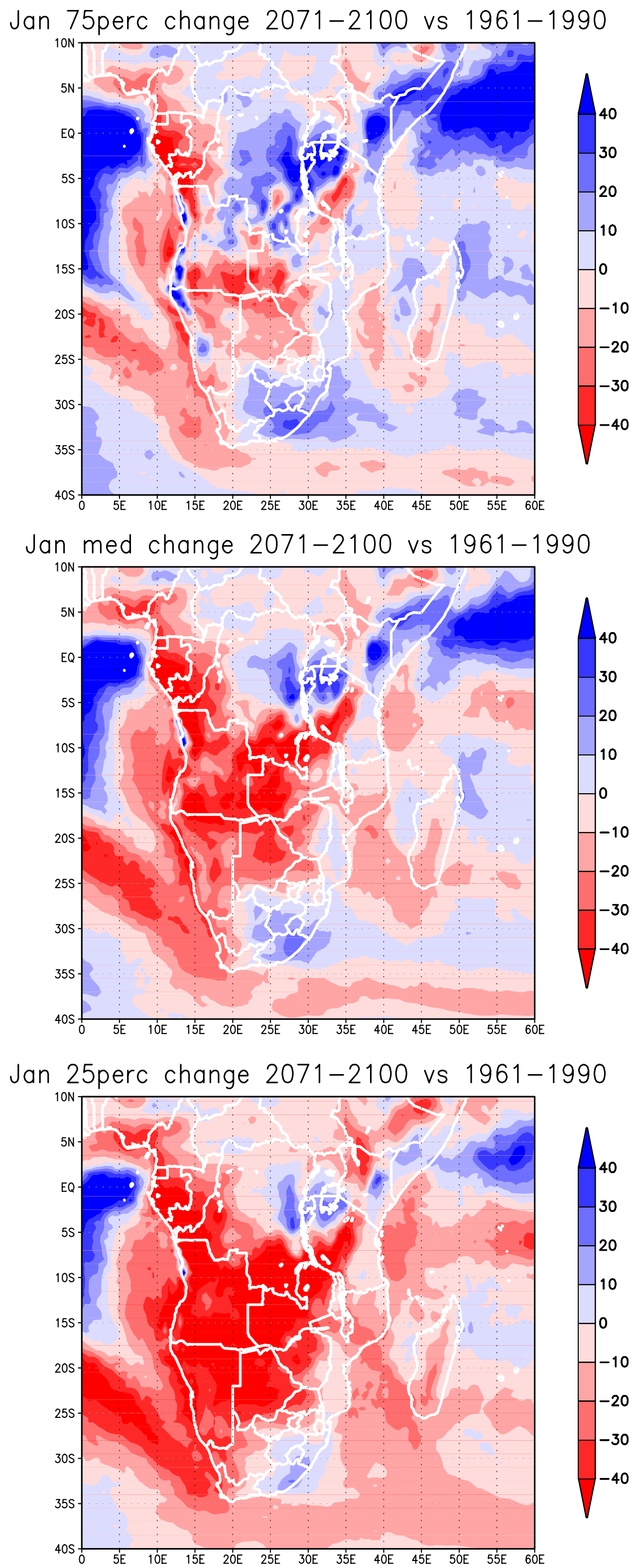


Figure 4: CCAM projected change in mid-summer (January) rainfall over southern and tropical Africa (expressed as a percentage change). The 75th percentile (top), median (middle) and 25th percentile (bottom) of the ensemble of projections are shown.

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Dr Sonali Das (statistician) and Marizelle van der Walt (mathematician).

Coupling atmospheric and ocean models

CSIR mathematicians and statisticians are hard at work to couple disparate models in understanding the interface where the atmosphere meets the ocean.

THERE ARE FEWER measurements of CO_2 concentrations and fluxes in the Southern Ocean than in the Northern Hemisphere oceans. The latter is extensively studied due to a higher intensity of commercial shipping. More extensive research needs to be done on the Southern Ocean and its CO_2 concentrations to construct accurate ocean-atmosphere models and to assess the effects of increases of CO_2 in the atmosphere on global warming.

To enhance much-needed research in this area, a multidisciplinary team of scientists has been assembled under the leadership of the CSIR. The team includes mathematicians and statisticians to process the data. The mathematicians formulate mathematical equations from the data gathered. The statisticians analyse the data gathered by factoring non-deterministic events that have an impact on the accuracy of the data. These equations form part of a coupling scheme, which will influence the construction of a model that couples ocean and atmospheric models.

A complex system in flux

The oceans and atmosphere interact with each other to form an ever-fluctuating system that is devoid of any true equilibrium. Parts of the Southern Ocean act as a carbon sink, meaning that CO_2 from the atmosphere is absorbed into the ocean. It is postulated that in these parts the partial pressure – the pressure exerted by an individual gas in a mixture of gasses – of CO_2 in the atmosphere is greater than that in the ocean. And because gasses will always flow from a region of higher partial pressure to one of lower pressure, a 'sink' of CO_2 in the ocean is created. However, should the partial pressure in the ocean be higher than that in the atmosphere, it will result in the release of CO_2. The degree to which the Southern Ocean absorbs the CO_2 also depends on the current concentration of CO_2 in the ocean as the oceanic waters may become saturated and the uptake of CO_2 in the ocean may be at a slower rate.

Combining deterministic and stochastic methods

It is this interface that scientists and mathematicians want to understand better through modelling. Mathematical models are an abstract description of the phenomena being studied. Models aid in the understanding of phenomena to predict and manipulate their behaviour. Though ocean models and atmospheric models exist, mathematicians are working on a numerical equation that will inform a coupling scheme, which when combined with ocean physics, will describe the events that take place at the interface between the ocean and the atmosphere. As a starting point, mathematicians want to determine the partial pressure of CO_2 at the interface. This is done by using data obtained from ships. The data are used to determine a model and then this model is applied to satellite data, to estimate partial pressure of CO_2. Instruments attached to ships are used to measure sea surface temperature, mixing layer depth (MLD) and chlorophyll concentration in the Southern Ocean. The data gathered are then utilised to find a link between partial CO_2 and the other ocean variables including chlorophyll, MLD and the temperature.

However, because the ocean and atmosphere interact to form a complex system that is subject to random fluctuations, the use of deterministic modelling methods alone is not sufficient. Deterministic modelling restricts practitioners to the behaviour of data at hand. To make predictions over a long period of time while accounting for random events, stochastic techniques are used in the form of statistics. In addition, because of the vast amount of data physically gathered and the data gathered from satellite imagery, statistical methods are used to provide an empirical relationship between the partial pressure of CO_2 and the bio-geographic factors measured by the ships in the Southern Ocean. This relationship takes into account the variability of the factors which allows for a model to be used to estimate the partial pressure of CO_2 in areas of the Southern Ocean not traversed by ships, where no in situ data exist for these areas.

Without understanding the carbon exchange at the boundary with a high degree of certainty and being able to account for random events which may affect data gathered or phenomena being measured, it is not possible to estimate the long-term impact of changing ocean CO_2 sink on the effectiveness of global emission reduction targets.

– Bandile Sikwane

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Africa's dilemma: facing a 2° world

The global community's ideal to stabilise global warming at 2° Celsius is not a solution to southern Africa's climate-change problems. Even if the world achieves this target – and currently that seems unlikely – southern Africa is warming up at twice the global rate of temperature increase.

THIS IS PERHAPS the most important message about climate change for southern Africa, and certainly a more actionable climate-change signal than in the case of projections of future rainfall patterns, argues Dr Francois Engelbrecht, atmospheric modeller at the CSIR in Pretoria.

The rapid warming of the interior regions of southern Africa has to do with the location of our region in the sub-tropics – and the strengthening of the so-called sub-tropical high-pressure belt under conditions of enhanced anthropogenic forcing – as well as the fact that we have a vast African landmass to the north of us. Nowhere else in the Southern Hemisphere is warming projected to occur at the same rate.

In other words, the warming trend should be seen against the background of large-scale changes in the weather systems that have thus far regulated the climate in this region.

Influence of weather systems on regional climate

Regional climate change projections show a generally drier southern Africa, but few people realise that this decrease in rainfall goes along with a projected increase in the strength of the sub-tropical high-pressure belt. When this high-pressure belt is well established over southern Africa, it suppresses cloud formation and rainfall, meaning more sunlight reaches Earth's surface, thus warming it.

According to researchers, changes in the strength and position of the subtropical high-pressure belt are a key factor likely to influence our future climate.

The sub-tropical high-pressure belt plays an important role in regulating the present-day climate of southern Africa (located roughly around 30° South). Its formation is linked to hot air rising in the tropics that reaches the top of the troposphere and then moves towards the poles. Because of the Coriolis effect it starts descending at 30° latitude north and south. The Coriolis effect refers to the deflection of winds (and anything else that moves freely in the atmosphere or ocean), due to the rotation of the Earth. The descending air then forms the subtropical high-pressure belt in the lower troposphere. When the sinking air reaches the surface of the Earth at about 30° south, a portion of it flows back to the equator – thereby completing the so-called Hadley-cell circulation.

The CSIR's Atmospheric Modelling team from left: Dr Francois Engelbrecht, Dr Willem Landman, Ruth Park, Mary-Jane Bopape and Mogesh Naidoo.

When looking at projections of our future climate in terms of circulation dynamics, there is evidence of a strengthening of the regional Hadley cell circulation in southern Africa. An intensification of the subtropical high-pressure belt and associated regions of sinking air under conditions of enhanced anthropogenic forcing may be expected to lead to decreases in cloud cover over southern Africa.

"We have very strong physical reasons to have confidence in model projections that show a general pattern of southern Africa becoming drier and East Africa becoming wetter. Also, this pattern of the subtropical high-pressure belt strengthening has already started to manifest over the past few decades, as is most evident in the strong trend of rising surface temperatures over southern Africa," explains Engelbrecht.

On a regional scale, winters in the south-western Cape are projected to become generally drier and the Eastern Cape generally wetter. Again, changes in the intensity and location of the subtropical high-pressure belt is important in explaining these projected changes – a stronger high-pressure belt that expands southwards would function to push cold fronts (that usually bring rain to the western Cape) to the south. "We are still trying to analyse the physical mechanism responsible for the wetter Eastern Cape in the projections, but it may well be due to an increase in the frequency of cut-off lows," he adds.

Usually occurring in spring and autumn, a cut-off low is a trough forming in the upper air that deepens until it forms a closed circulation. Associated with rising air, about one out of every five cut-off lows leads to floodingl over southern Africa.

Increase in the occurrence of extreme weather events over southern Africa

Although the southern African region is projected to become generally drier under conditions of enhanced anthropogenic forcing, extreme rainfall events (defined as more than 20 mm of rain falling over an area of 50 km^2 within 24 hours) are projected to increase over the central and eastern interior of South Africa. According to Engelbrecht this phenomenon has mainly to do with higher surface temperatures that lead to a deeper 'heat-low' over the western interior – which in turn tends to promote the formation of thunderstorms to its east.

Researchers at the CSIR are currently collaborating with the Agricultural Research Council and other institutions to investigate specifically what is going to happen regarding cut-off low frequencies and tropical cyclone frequencies over the southern African region.

Engelbrecht explains: "The general message so far is that the frequency of tropical landfalling cyclones is not going to increase over our region, but rather over northern Mozambique. However, we're expecting a decrease in cut-off lows in general (except over the winter months), contributing to a generally drier region. But, because of a much warmer climate in summer, there will be an increase in the occurrence of intense thunderstorms, so-called heat thunderstorms."

Similarly, climate modellers are expecting a very large increase in the occurrence of very hot days, that is, days where the maximum temperature exceeds 35 °C. For the period 2070 to 2100, models project massive increases in the number of very hot days, with locations in Namibia (for example) facing up to 180 more of these days per year – compared to the period 1961-1990.

The United Nations World Meteorological Association reported that the period from January to November 2010 was the warmest 11 months ever, beating the previous top years 1998 and 2005. And the years 2001 to 2010 mark the warmest decade ever.

Against this background, Engelbrecht concludes: "The projections of future climate change over southern Africa in general paint a picture of stringent future challenges to agriculture, water resource management and the protection of biodiversity.

"However, the fact that plausible projections of these future changes are available, gives us the opportunity to take action and adapt, where possible, to future climatological conditions."

– Wiida Basson

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Getting the next season right: El Niño or La Niña?

It was probably during the summer of 1982/83 when the country experienced one of the worst droughts in decades that South Africans first learnt of the phenomenon called El Niño. In climate science terms, this El Niño event has been described as a "significant" and "unprecedented" warm episode.

IN SHORT, an El Niño event is most often associated with less rain and higher temperatures, while a La Niña event often brings cooler temperatures and more rain for southern Africa.

Today, CSIR atmospheric modellers are working with one of the foremost experts on the El Niño event. Through the Applied Centre for Climate and Earth Systems Science (ACCESS), a flagship initiative of the Department of Science and Technology and hosted by the CSIR, Prof Toshio Yamagata of the University of Tokyo is contributing to enhance our ability to forecast the possibility of an El Niño or La Niña event to occur for the next season and how these phenomena may impact on southern African summer conditions.

The project, "Prediction of Climate Variations and its Application in the Southern African Region', is supported by the Japan Science and Technology Agency (JST) and the Japan International Cooperation Agency (JICA).

"The Intergovernmental Panel on Climate Change (IPCC) report discusses the global climate tens of years or a hundred years hence, using models of climate change based on greenhouse gas emission scenarios," says Prof Yamagata.

"However, it would be dangerous to discuss the impact on local communities using the results of the models used for the IPCC report. This is due to serious problems with the reproducibility of climate variation in those models.

Of course, the outlook is not all pessimistic. This is because initiatives aimed at predicting climate variation, rather than projecting climate change, have been progressing rapidly of late in the professional climate science community.

"We are now at the level where the occurrence of El Niño can be predicted one or two years in advance. This is all due to rapid growth in wide-area planetary observation using satellites and buoys, the enhancement of scientific knowledge and advances in techniques for assimilating observed data into models and making seasonal predictions," he says.

Why would seasonal predictions, compared to the traditional daily to weekly weather forecasts, be significant? Prof Yamagata explains: "Predicting the likelihood of droughts, floods, abnormally high or low temperatures and other extreme weather conditions, between several months and one year in advance will make a direct contribution to socio-economic activities. Measures aimed at protecting the global environment should be promoted in parallel with this prediction of specific climate variation and application measures based on it. Systems in developing countries are particularly vulnerable to floods, droughts and other calamities. If we can cooperate, based on predicted data, in preventing or mitigating disasters as well as promoting infrastructure development and capacity building, we should be able to encourage an understanding of measures to cherish the environment in those countries as well."

Multi-model ensembles

The South African modelling community has been issuing seasonal forecasts operationally since the early 1990s, but forecast systems have become much more sophisticated since then and are now able to predict seasonal climate anomalies (deviations from average conditions) over southern Africa with a useful level of skill. But just how good are we at forecasting these seasonal anomalies? Driving this research question, and the use of fully coupled ocean-atmospheric

models, is Dr Willem Landman, an expert in operational weather and seasonal prediction and modelling at the CSIR's atmospheric modelling group in Pretoria.

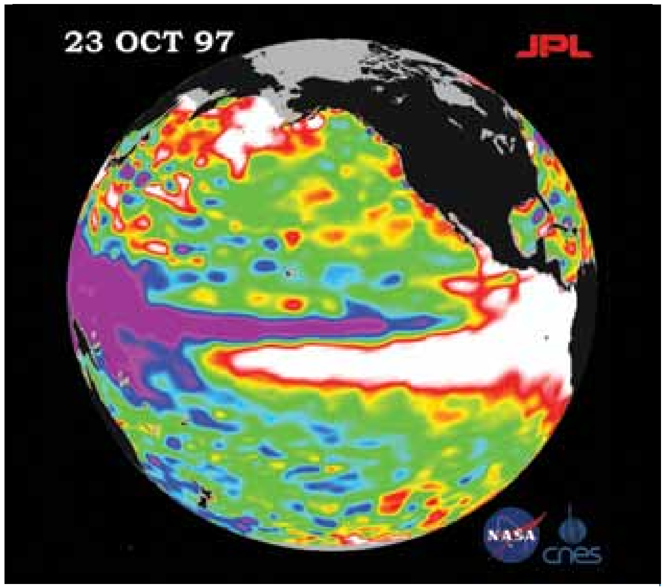
"Despite the fact that we have seen general warming of southern Africa over the past decades, it doesn't mean that every season is going to be warmer than the previous one. In other words, it is not going to become warmer and warmer until we fry!"

According to Landman seasonal forecasts listen to large scale sea surface temperature movements: "These things take months to develop and then stay there for some time. For that reason they impact on the average weather conditions.

"If La Niña events are so important for us, are we any good at predicting them? The good news is, yes. As part of the modelling work we are doing at the CSIR, we have developed a sophisticated forecast system to skilfully predict sea-surface temperature anomalies over the equatorial Pacific Ocean, where El Niño events occur, for up to six months ahead. For example, we could capture the 1982/83 and 1997/98 El Niño events at least six months ahead of time and we were successful in capturing the recent La Niña event of last year too," he explains. For the 2011/12 summer season the group is predicting a La Niña event, but at half the strength of last year's La Niña, again bringing cooler temperatures to the region.

"We are trying to further enhance our state-of-the-art multi-model system by looking at forecast products produced by local institutions such as the South African Weather Service, the University of Cape Town, as well as international centres such as the University of Tokyo, the International Research Institute for Climate and Society in the USA, the United Kingdom Met Office and the Japan Agency for Marine-Earth Science and Technology.

In a next step, South African researchers are looking to improve forecast expertise by including observed greenhouse gas emissions in their operational seasonal forecast models: "The Europeans have significantly improved their seasonal forecast skill by including variable greenhouse gas concentrations. We're hoping to obtain funding to do the same in South Africa over the next few years," Landman concludes.



The 1997/98 El Niño event (in white) was one of the strongest events observed thus far. This image of the Pacific Ocean was produced using sea-surface height measurements taken by the U.S./French TOPEX/Poseidon satellite. It shows sea-surface height relative to normal ocean conditions on 23 October 1997. The white and red areas indicate unusual patterns of heat storage. In the white areas, the sea-surface is between 14 and 32 centimetres above normal; in the red areas, it is about ten centimetres above normal. The green areas indicate normal conditions, while purple (the western Pacific) means at least 18 centimetres below normal sea level.

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PROFILE

Pursuing a career in meteorology means you are **not afraid to be proven wrong**

Starting out with the intention of pursuing physics and pure mathematics as a career, Ruth Park found herself continuously adding meteorology courses as extras, because she found them "so fascinating".

"AFTER COMPLETING some meteorology courses I found that I really enjoyed applying my physics and mathematics background to weather modelling problems. I then decided to use my mathematics and physics skills to direct my career towards meteorology," this MSc student from the University of Pretoria (UP) explains.

Having had two very senior CSIR atmospheric modellers as her third-year and Honours lecturers at UP motivated her to apply for a CSIR studentship. Currently, Park is responsible for the weather forecasting section of the CSIR's atmospheric modelling research group in Pretoria. For her research, she is developing a short-range ensemble prediction system to produce probabilistic weather forecasts, using the Australian Conformal-Cubic Atmospheric Model (CCAM). The basic idea is to combine different configurations of the CCAM model to form different 'ensemble' systems. Park explains: "Each ensemble system will be made to produce rainfall hindcasts for the summer period of 2009 and 2010. We then compare the rainfall predicted by each ensemble system and compare it to actual rainfall observations. The accuracy of each ensemble system then needs to be verified. We then draw conclusions as to which ensemble system produces the most reliable forecasts. The system that is determined by this research to be the most successful will be used by the CSIR to produce weather forecasts."

However, success does not come easily: "The best part of my research is the feeling of elation when the model runs perfectly after days of seemingly futile combat with the computer. Another great thing is that because the field of meteorology is constantly expanding, any study that is conducted is fresh and interesting," she adds.

Her advice for anyone wishing to pursue a career in atmospheric science is that you should not allow yourself to be perturbed by being proven wrong: "This is a field of inherent uncertainty and one can fail to end up with accurate results, but this only serves to make success even more satisfying! A great thing about atmospheric science is that your research has a direct impact on the people and world around you, which makes this field particularly important. If you have the tenacity to press forward regardless of the prospect of failure, then this is the career for you."

– Wiida Basson

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There's something about **Mary-Jane**

Since being a teenager, Mary-Jane Bopape has always had her head in the clouds.

IT IS SELDOM that one hears of learners who excel in physics and mathematics dreaming of becoming meteorologists. Meteorology, the interdisciplinary scientific study of the atmosphere focusing on weather processes and forecasting, is a small sector. As such, it is not widely advocated in schools.

While completing her schooling at Hwiti High School in 1998, where she excelled in mathematics and physics, the CSIR's Mary-Jane Bopape was intrigued by climatology but was unaware that it could be pursued as a profession.

"I liked mathematics and the chapter on climatology in our geography class," she says. "But it never occurred to me that I could pursue a career in meteorology because I did not know any meteorologists and I had no idea how to go about being one," she says.

"After completing matric, I only applied to universities of technology to possibly study civil engineering or electrical engineering. It was said at the time that the theoretical emphasis at universities made it difficult for graduates to get jobs," she adds. "My thinking was if I obtained a BTech in some sort of engineering, I would be far more employable than having a degree in meteorology," she lets on.

Thank you mom

"At the same time, my mom brought home a pamphlet from the then South African Weather Bureau, which highlighted the various careers the organisation had on offer," says Bopape. "After seeing that pamphlet, it was clear that meteorology was a viable career to pursue and I was sold," she says.

And that was a very good thing too as a decade later, Bopape became the first South African to receive the 'World Meteorological Organisation Research Award for Young Scientists' for her co-authored work on 'The Internal Variability of a Regional Climate Model over South Africa'. The paper was published in the *International Journal of Climatology* in 2008.

Development path

In her third year at the University of Pretoria, she was taught by Dr Francois Engelbrecht. "He lectured dynamic meteorology. The mathematical nature of the course made it interesting and challenging. I got my best marks in that course," says Bopape. Subsequently, in her Honours year, she specialised in numerical weather prediction.

Following her Honours, she joined the South African Weather Service (SAWS) where she worked on regional climate modelling reporting to Prof Willem Landman, who would become her Master's supervisor. "I graduated with an MSc in 2007, while working at SAWS," remarks Bopape.

Following her five-year stint at SAWS, she joined the CSIR as a research scientist in 2008. It was not long before she was united with her third-year lecturer, Engelbrecht, who is currently her doctoral supervisor.

Life has had its fair share of challenges for Bopape, "I went through many personal challenges. There were times when it seemed I'd never be able to do a doctorate, let alone reach the finish line," she concedes, "but I'm now at the end and not only that, every morning I get to wake up, go to work, do what I'm very passionate about, and then go home to a loving and supportive family. What more could anyone want?"

– Bandile Sikwane

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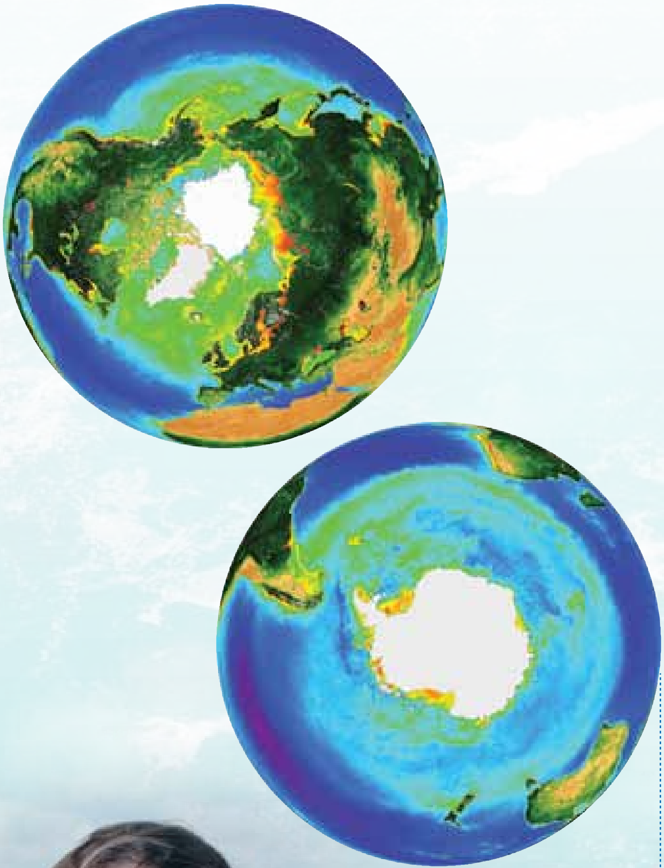
Climate change in the Southern Ocean:
implications for global CO_2 emissions reduction plans and science



Satellite views from SeaWiFS of our planet from the Northern and Southern polar perspectives contrasting the mainly terrestrial character of the North, with the mainly oceanic (Southern Ocean) character of the South. (oceancolor.gsfc.nasa.gov/cgi/biosphere_globes)

For many centuries the Southern Ocean, with its Roarin' 40s and Screaming 50s, has been a mythically remote part of our planet: pristine, freezing, foreboding; the domain of hardy adventurers and whale hunters. Today we know that it has been one of our most important assets as a regulator of regional climate and global atmospheric CO_2 for at least the past million years.

WHEN ONE TAKES A LOOK at our planet from the polar perspective, the reason for this becomes apparent. From an Antarctic viewpoint this is an ocean-planet largely dominated by the circumpolar Southern Ocean; whereas from an Arctic perspective it is the more traditional land-planet. So, whereas land biosphere has a major influence in shaping the seasonal variability of atmospheric CO_2, particularly in the Northern Hemisphere, on an inter-annual time scale, it is the Southern Ocean that governs long-term trends on time scales of decades to centuries.

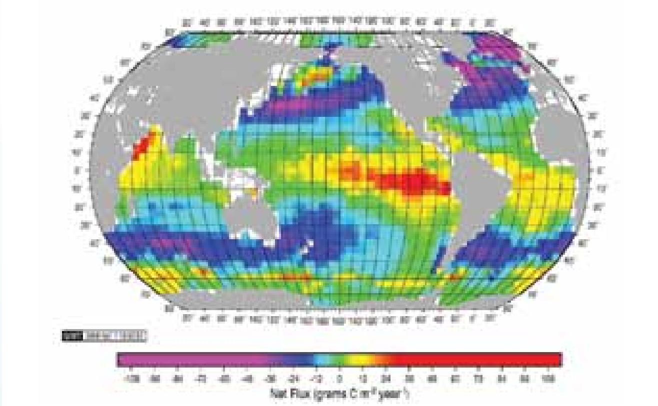
Global atmospheric CO_2 variability, the Cape floral kingdom, the productive Benguela upwelling system and maybe even the survival of a small band of our ancestors in the early ice age (about 70 thousand years ago) with whom all of us have a shared ancestry, all have a strong link to the coupled Southern Ocean-atmosphere system. It is the regulatory capacity of this system that is at risk because of climate change.

What happens when large natural systems change?

Unlike man-made emissions of CO_2, which in theory we can reduce, and terrestrial biosphere, which can to a large extent be managed, changes to ocean systems are not manageable, especially if driven by positive feedbacks that can run out of control. Once these ocean systems begin to change, it will be impossible to regulate the rate of change. International negotiations such as those at COP17 in Durban at the end of 2011 make an implicit assumption that adjustments to carbon fluxes as mediated by the natural systems will be minimal. This assumption is unlikely to be realistic.

What are these possible changes?

The Southern Ocean stores 40% of all man-made CO_2 in its interior waters through two main mechanisms: firstly, the solubility pump, where uptake is a response to cooling and sinking of sub-tropical waters; and secondly, the biological pump, where phytoplankton take up and transport, by sedimentation, carbon to the deep and bottom waters.



The map shows the decadal mean geographical distribution of the global ocean CO_2 sources (warm colours) and sinks (cold colours). It highlights how the Southern Ocean comprises very large sources (upwelled Circumpolar Deep Water) and sinks (Sub-Antarctic Mode and Intermediate Waters) which are balanced such that the net sink is about 0.5 Gtons Cy-1 (Takahashi et al., 2009. Deep Sea Research II).

These CO_2 sinks are offset by the nearly equally large out-gassing of CO_2 to the atmosphere from upwelled Circumpolar Deep Water mainly south of the Polar Front. This area in the Southern Ocean is the only part of the global ocean where CO_2-rich deep waters, from depths greater than 2 000 metres with CO_2 partial pressures greater than 450 μatm (larger than current atmospheric levels), exchange CO_2 directly with the atmosphere. So, although the net annual CO_2 uptake in the Southern Ocean is about 20% of the total ocean sink of man-made carbon (2-2.2 Gtons C y-1), it comprises very large opposing (source-sink) natural fluxes that are sensitive to small adjustments in climate forcing, which easily match the Greenhouse Gas (GHG) emissions reduction targets.

Weakening of the Southern Ocean as a carbon sink

Global climate models predict a weakening of future Southern Ocean CO_2 air-sea exchange through two main vectors, the westerly winds and the weakening of the biological pump. A poleward shift and strengthening of the westerly winds associated with a positive anomaly in the Southern Annular Mode is expected to enhance out-gassing from CO_2-rich Circumpolar Deep Water. This will combine with the warming and freshening of the surface waters that weaken the biological pump. The exact characteristics and scales of these responses remain a key challenge for 21st century oceanography. The net result is likely to be a positive feedback that will weaken the ocean CO_2 sink, thereby placing additional pressure on emissions reduction targets.

Feedback in general is the process in which changing one quantity changes a second quantity, and the change in that second quantity in turn changes the first. Positive feedback amplifies the change in the first quantity while negative feedback reduces it. By definition, forcing factors are external to the climate system while feedbacks are internal. Some observed and potential effects of global warming are positive feedbacks, which contribute directly to further global warming.

Similar adjustments in net CO_2 fluxes as mediated by the natural system were able to drive the global atmospheric CO_2 changes between the ice ages and warm epochs in the past million years. Both large scale processes are connected to surface ocean physics that respond sensitively to climate change impacts. However, their impacts on the carbon cycle and fluxes are likely to be highly non-linear and not predictable on traditional scale views. This sensitivity to seasonal or sub-seasonal forcing is an important consideration in understanding the vulnerability of the Southern Hemisphere carbon cycle to climate change and reducing the uncertainty in predicting long-term trends. Analysing and understanding this is an important focus of our work.

South Africa shares, with the rest of the planet, a concern about the uncertain, CO_2-driven evolution of regional climate towards seasonal cycles that are outside the envelope that sustains the ecosystem services that we as humans have adapted to. Simultaneously, South Africa has its own very urgent development priorities, including education and advanced numerical skills, necessary to successfully understand and assess evolving risk to support resilience in the future.

The challenge and the opportunity for South African science is to simultaneously address both challenges. The Southern Ocean Carbon–Climate Observatory (SOCCO) programme, a multi-institutional partnership through the Applied Centre for Climate and Earth Systems Science (ACCESS), focuses on these science and development challenges.

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The SOCCO programme is a partnership between the CSIR, the Department of Science and Technology, the South African National Antarctic Programme (SANAP), the Department of Environmental Affairs (DEA) and several universities.

Iron is key to Southern Ocean productivity, **but geo-engineering is not an option**

Why did CO_2 levels oscillate between around 150 parts per million (ppm) during glacial periods and around 250 ppm during inter-glacials? And why has the answer to this question led to proposals that climate change might be effectively mitigated by dumping tonnes of iron sulphate into the waters of the Southern Ocean?

SCIENTISTS ANALYSING ice-trapped air bubbles from ice cores from Antarctica have now been able to reconstruct atmospheric concentrations of carbon dioxide (CO_2) stretching back 800 000 years. The key pattern that emerges is of pronounced variability between low CO_2 (cold) glacial periods and high CO_2 (warm) inter-glacial periods and while the phasing is related to solar variability known as Milankovich cycles, the precise mechanisms involved remain enigmatic.

Similarly, turning to the Southern Ocean, the low biomass of small ocean algae called phytoplankton, and the large stocks of so-called macro-nutrients (primarily nitrogen and phosphorous-based) alongside well-lit austral summers, seemed paradoxical. The key development came at the end of the 1970s when scientists were able to measure trace concentrations of metals in seawater without samples being contaminated by their rusty ships. John Martin and colleagues from the Moss Landing Marine Laboratory in California were the first to show that the low biomass of the Southern Ocean was due to the absence of sufficient iron in the water, and moreover, that fluctuations in the amount of iron due to dust deposition might explain the changes in CO_2 recorded in ice cores. *"Give me half a tanker of iron and I'll give you an ice age"*, Martin famously quipped during a seminar at the Woods Hole Oceanographic Institute.

The 'iron hypothesis'

The 'iron hypothesis', as it became known, was controversial to say the least. The idea that atmospheric CO_2 concentrations were modulated by iron implied that future changes in CO_2 could be controlled by reducing iron limitation of Southern Ocean phytoplankton. Alternative theories to explain the low phytoplankton biomass of the Southern Ocean – and by implication to refute the idea that CO_2 can be controlled by iron – included, among others, herbivory and light limitation.

The only way to resolve the debate once and for all was by actually conducting a field experiment in the Southern Ocean. In 1999, an international team 'fertilised' waters of the Southern Ocean with iron sulphate and produced a large increase in phytoplankton biomass, as well as a reduction in surface water CO_2. Thus it seemed that the role of iron was confirmed, and maybe it was possible that iron concentrations could control past or future atmospheric CO_2. Indeed, following this, numerous patents linked to carbon credit ventures have been applied for over the past few years.

Geo-engineering the availability of iron in the Southern Ocean

Despite its acknowledged importance in regulating the biological productivity of the Southern Ocean, viable geo-engineering of atmospheric CO_2 with iron appears unworkable. The latest model simulations suggest that even the most optimistic scenario would only reduce atmospheric CO_2 by 15 parts per million in 2100, which is very minor considering future emissions. This is because although iron is important

for air-sea CO_2 exchange, once it is supplied in excess, other factors end up curtailing the response of the system. Moreover, 'extra' production in iron-fertilised areas ends up stripping out nutrients that would have fuelled production in other regions, causing less productivity there. Even if iron fertilisation were successful in stimulating the necessary biological productivity, for there to be an appreciable impact on future atmospheric CO_2 levels, the consequences would be far from desirable. These include modified foodwebs; subsurface anoxia (very low oxygen levels); or enhanced production of radiative gasses such as nitrous oxide and methane.

Thus it seems that effective geo-engineering by iron fertilisation is unfeasible because it appears that the negative effects may outweigh the (likely marginal) benefits.

Current research efforts focused on the role of iron

Several aspects pertaining to the role of iron in regulating phytoplankton photosynthesis, and the impact on the larger carbon cycle, are underway in South Africa under the auspices of the Southern Ocean Carbon and Climate Observatory (SOCCO) programme.

Our work follows three main avenues: field observations, laboratory experiments and complex models of the ocean's biogeochemical systems. Using the SA Agulhas, we use instruments specially adapted to minimise sample contamination to gain more information on the spatial and temporal variability in oceanic iron concentrations in the South Atlantic, as part of the international GEOTRACES programme.

At this moment, a specialised 'clean' laboratory is being built at the University of Stellenbosch and will be used to grow cultures of Southern Ocean phytoplankton under tightly controlled conditions, free from iron contamination. Using carefully designed experiments, we will be able to illuminate how phytoplankton growth and CO_2 fixation respond to different iron concentrations, light levels and temperatures representative of those encountered in the Southern Ocean.

Finally, state-of-the-art models of the ocean's biogeochemical cycle attempt to synthesise this knowledge and permit us to explore their larger scale implications in the context of a changing planet. While iron may be out of favour as a geo-engineering fix, there is no doubt that its role in governing the ecosystem and carbon cycle of the Southern Ocean still has many questions left to answer.

– Dr Alessandro Tagliabue

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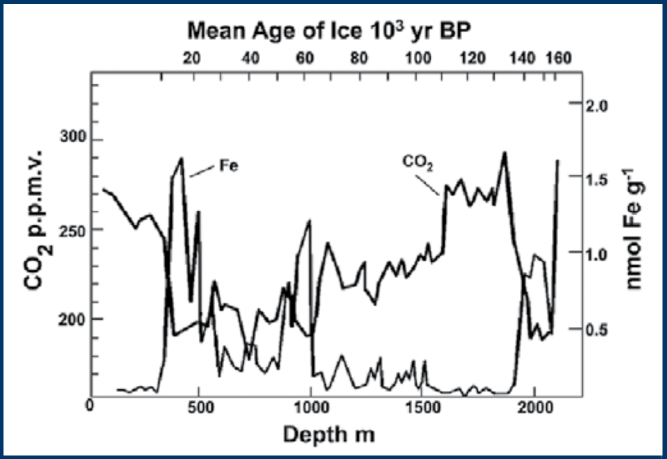

Measurements of the concentration of CO_2 and the iron supply from dust measured in the Vostok Ice Core as a function of core depth and years before the present day (BP) used by Martin (1990) to formulate the iron hypothesis that low glacial CO_2 concentrations were due to the alleviation of iron limitation (Source: Martin, J.H. 1990. Glacial-interglacial CO_2 exchange: The iron hypothesis. *Paleoceanography*, 5:1–13.)

The Southern Annular Mode and the weakening of the Southern Ocean CO_2 sink

The Southern Ocean is feared by sailors for its ferocious winds and gigantic swell, making it one of the most challenging routes to take on a sailing boat.

ALL AROUND THE GLOBE, between approximately 40 and 60 degrees latitude south, westerly winds prevail. Unhinged by the absence of landmasses at high latitudes, they can easily reach 40 knots; and peaks of up to 60 knots are not uncommon. Blowing over large oceanic distances without being slowed down by rugged continental surfaces, they raise the giant, long period swell routinely observed in the Southern Ocean high latitudes.

Changes in the Southern Annular Mode

This Westerly 'wind belt' has a pulse, called the Southern Annular Mode (SAM). At some times the westerly wind belt is pushed towards the pole, contracts, and wind intensifies between the latitudes 50 and 65 degrees south, while they decrease on the northern edge (40-50 degrees south). This is known as the positive phase of the SAM. At other times – the negative phase of the SAM – the reverse happens and the westerly wind belt expands towards the equator, causing winds to mainly decrease at high latitudes.

The SAM has consequences for us in South Africa because it controls the characteristics of the subtropical jet, a strong atmospheric current encountered between 10 and 16 km of altitude. The meanders of this jet largely guide the trajectories of the mid-latitude depressions that hit the South-Western part of our country in winter. It has been shown that during the positive phase of the SAM, fewer depressions hit the region, resulting in drier winters; while the reverse happens during the negative phase. The consequences during the summer are less clear and further blurred by the large influence of another climate pulse, the El Niño Southern Oscillation, on our summer climate.

In recent decades, researchers have recorded a tendency towards increasing frequencies of the positive phase of the SAM. Using cleverly designed experiments on numerical models of atmospheric circulation, colleagues have shown clearly that this trend is not natural, and arises because of

- the ozone depletion in the lower stratosphere over the Antarctic continent, which alters the upper troposphere circulation, propagating down ultimately to the surface; and
- increasing temperatures due to greenhouse gasses, that decreases the equator to pole temperature gradient. In other words, this trend in the SAM is a manifestation of man-made climate change.

Impact of changes in the SAM on the Southern Ocean CO_2 sink

The significance of this trend goes beyond its influence on the winter rainfall in the Western Cape: right now, the Southern Ocean arrests climate change by taking up a large part of our CO_2 emissions. Current estimates are that, since the industrial revolution, the Southern Ocean has absorbed around 40% of man-made CO_2.

We think that conditions where the positive phase of the SAM prevails can profoundly alter the tri-dimensional oceanic circulation there and result in increasing upwelling of deep water south of 50 degrees (south of the polar front). This 'Antarctic Deep-Water' is rich in natural CO_2, which means if more carbon-rich water upwells, the Southern Ocean CO_2 sink may slow down or stall, meaning proportionally more man-made CO_2 would accumulate in the atmosphere. *(See Anderson and Carr: "Uncorking the Southern Ocean vintage" Science Vol. 328 no. 5982 pp. 1117-1118.)*

There is currently very active research underway to assess whether this scenario will materialise as changes in water stratification (the temperature and salinity profiles with depth) as well as whether the response of oceanic eddies to changes in wind-speed might counteract this tendency. The Southern Ocean Carbon-Climate Observatory (SOCCO) programme is participating actively in this leading-edge research, making use especially of two national facilities: the SA Agulhas, South Africa's polar research vessel, and the Centre for High Performance Computing (CHPC) in Cape Town.

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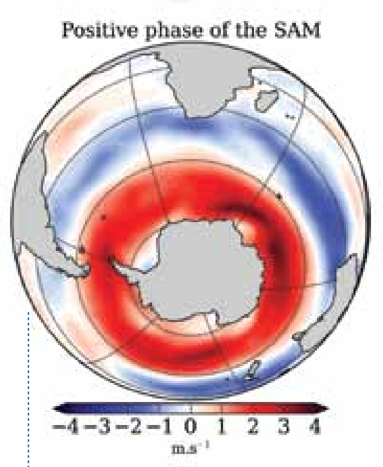
About oceanic eddies?

Eddies (whirlpools) are common in the ocean, and range in diameter from centimetres, to hundreds of kilometres. The smallest scale eddies may last for a matter of seconds, while the larger features may persist for months to years. Oceanic eddies usually have different temperature and salinity characteristics to the water outside of the eddy. Because eddies may have a vigorous circulation associated with them, and transport anomalously warm or cold water as they move, they have an important influence on heat transport in certain parts of the ocean. – http://en.wikipedia.org/wiki/Eddy_(fluid_dynamics)



Typical anomalies in the West-East component of the surface wind during the positive phases of the SAM: red shades denote regions where the westerlies are accelerated and blue, decelerated.

Getting onto 'the fastest train in Africa' means **your ticket must be in order**

It was late on a Friday afternoon when Nomkwezane Kobo received the long-awaited call that she was invited for a studentship interview as part of the Southern Ocean Carbon-Climate Observatory programme at the CSIR.

COMING FROM a disadvantaged background in rural Limpopo and being the first in her family to go to university, this was the train of opportunity she needed to jump on after years of hard work and preparation.

"The fact that my family was very disadvantaged never bothered me, because at least we never went to bed with an empty stomach. I just made sure that I would be ready with the right ticket in my hand – my national senior certificate – when that train eventually came along," she explains from her office in Cape Town.

The first train came with the help of high school principal, Jan Malose Segoa, who made sure that this bright kid was prepared for university. With a senior national certificate in her hand, she received a bursary from the South African Nuclear Human Asset and Research Technology Programme, and her ride was confirmed.

First stop was the University of Limpopo, where Kobo completed a BSc in Applied Mathematics and Statistics, and BSc (Honours) in Applied Mathematics, followed by an MTech in Mechanical Engineering at the Cape Peninsula University of Technology. Based on her thesis, 'Entropy Analysis of a Reactive Variable Viscosity Channel Flow', she wrote a paper with her MTech supervisor Prof OD Makinde.

Through SANHARP, her path crossed with Dr Onno Ubbink, then working at the Pebble Bed Modular Reactor. "He is so good at his work! I really wanted to follow in his footsteps," she recalls. She kept contact and sent him her curriculum vitae (CV) when he started working at the CSIR.

"He forwarded my CV to the Natural Resources and the Environment research unit and that's when I got onto the fastest train in Africa – the CSIR!"

Currently Kobo's research focuses on investigating the current-topography interactions in the Southern Ocean, as this is important to understand the physical and biological processes which drive carbon exchange in the surface ocean.

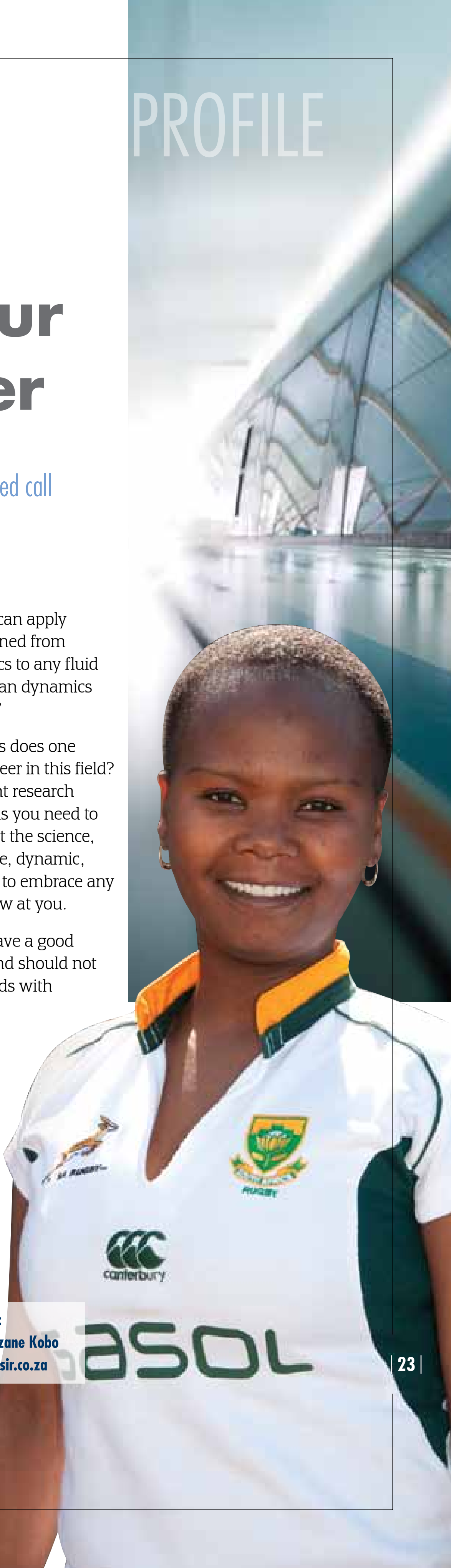
"Climate change affects everyone; and everything that is on the Earth affects climate change. Since the ocean occupies 70% of the Earth, I am eager to learn about the role the ocean plays in climate change. The passion I have for mathematics led me to this fascinating field of ocean modelling. I can apply the equations I learned from applied mathematics to any fluid dynamics field, ocean dynamics being one of them."

What characteristics does one need to follow a career in this field? "I'm part of a vibrant research group, which means you need to be passionate about the science, eager for knowledge, dynamic, flexible and willing to embrace any challenge they throw at you.

"You should also have a good sense of humour and should not be peevish," she adds with a laugh.

When she leaves for Brazil soon to attend a global ocean modelling workshop, she's taking her train ticket to another level.

– Wiida Basson



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Understanding the impacts of ocean acidification **remains a key challenge**

Climate change or no climate change, there is one consequence that is in no doubt: As the concentration of CO_2 in the atmosphere increases, so will its concentration in the ocean – resulting in ocean acidification.

WHEN CO_2 DISSOLVES in seawater it reacts to form a number of ionic and non-ionic carbon species depending on the temperature and alkalinity. The net effect is to increase the concentration of hydrogen ions (H+) and reduce the concentration of carbonate ions (CO_3^{2-}). More H+ ions mean lower pH and more acidic conditions; so as more and more CO_2 dissolves into the ocean, the ocean is becoming more and more acidic. Reducing the carbonate ions means that calcifying organisms, those that form shells and coral reefs, have to spend increasing amounts of energy on this activity, at the expense of growth and reproduction causing long-term changes to ecosystem structure and function.

It is calculated that the pH of the ocean has already decreased by 0.1 units on the logarithmic pH scale since the industrial revolution. This equates to around 30% more H+ ions.

By the end of the 21st century, H+ ions are predicted to more than double, with pH dropping by around 0.5 units. There is a natural process regulating these fluctuations: weathering on land and deep sea burial of calcium carbonate combine in a process called 'carbonate compensation' to stabilise the ocean pH. However, this process occurs over very slow timescales (in the order of hundreds of thousands of years) and is therefore far slower than the rate at which we are modifying the chemistry of the oceans.

The impacts of ocean acidification could be widespread. For example, the calcium carbonate platforms built by coral reefs will be heavily impacted, since the reduced CO_3^{2-} concentration impedes the production of calcium carbonate, and the lower pH promotes their dissolution. Plankton species that form shells will face similar problems, which might impact ocean food webs.

Other more intricate results are starting to be investigated and they reveal the complex interplay between the biological and chemical processes of the ocean. Field experiments, where natural phytoplankton populations are subjected to a range of CO_2 concentrations, have revealed fast rates of photosynthesis under so-called 'greenhouse' conditions, which could lead to greater sequestration of carbon in the ocean by the biological pump. However, greater amounts of sinking organic carbon could result in greater consumption of oxygen in the subsurface, which could promote the release of nitrous oxide (itself a potent greenhouse gas) by the bacteria that thrive in low oxygen conditions.

Other studies have shown that the rate of di-nitrogen fixation, which can be seen as a source of 'new' inorganic nitrogen can be increased under greenhouse conditions, or that the nutrient requirements of CO_2 using phytoplankton can be modified. But their combined effect, even in the absence of any CO_2-induced change to the climate and ocean circulation, is still highly uncertain.

For South Africa, the effects of ocean acidification are likely to be seen first in the slower growth rates of coral reefs off the northern KwaZulu-Natal coastline. If global CO_2 increases at present rates, corals are predicted to die off by the mid-21st century. However, there are also interesting opportunities such as the use of the west coast Benguela upwelling system to study the combined effects of naturally elevated CO_2 and hypoxia on organisms and the ecosystem. The South African oceanography community is embarking on a national initiative to observe and understand long-term evolution and impacts of ocean acidification.

Overall, one thing is clear – the CO_2 concentration in the ocean will increase in the future and has already increased over past decades. This will modify the chemistry of the ocean at rates that have not been seen since the dinosaurs became extinct. While the major consequences are well known, the quantification of the locations, times of year and net result of their impact on the complex processes of the ocean's biological, chemical and geologic systems, and on ecosystems and their services, remain a key challenge in oceanography.

– Alessandro Tagliabue and Pedro Monteiro

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Observing our changing climate from space

Space-based Earth observation makes it easy to view the Earth as a finite system affected by natural and human-induced change.

EARTH OBSERVATION entails systematic, regular, spatial measurements of all aspects of our changing Earth system, including sea surface temperature, atmospheric composition, ecosystem function – carbon sequestration, deforestation (see table 1 for essential climate variables measured from satellite). Medium resolution satellite data (250 m-8 km pixel size) allow us to view the entire Earth system on a daily basis. While climate models are useful for predicting future climatic conditions, satellite data provide undeniable proof of change, despite the relatively short satellite record of only 10 to 30 years.

The NASA Earth Observation System (EOS) was conceived in the early 1990s and currently consists of 17 satellites carrying multiple sensors, launched since the late nineties. Other space agencies have undertaken similar or complementary satellite missions, notably the European Global Monitoring for Environment and Security (GMES) mission.

DOMAIN	ESSENTIAL CLIMATE VARIABLES
Atmospheric	Surface wind speed and direction, upper-air temperature, water vapour, clouds, precipitation, Earth radiation budget, ozone, aerosol, carbon dioxide and other greenhouse gasses, upper-air winds
Oceanic	Sea ice, sea level, sea surface temperature, ocean colour, sea salinity, Chlorophyll-a concentrations
Terrestrial	Lakes, glaciers and ice caps/sheets, snow cover, surface albedo, land cover change (e.g. deforestations), fraction of absorbed photosynthetically active radiation (fAPAR), leaf area index (LAI), biomass, fire, soil moisture

Table 1: Essential climate variables measured from satellite.

What global change has Earth observation revealed?

During the past 10 years, Earth observation data have revealed that sea levels are rising at 3.4 millimetres per year (using radar altimeter and laser), and 95% of the world's glaciers and Arctic Ocean summer sea ice have retreated by 40%.

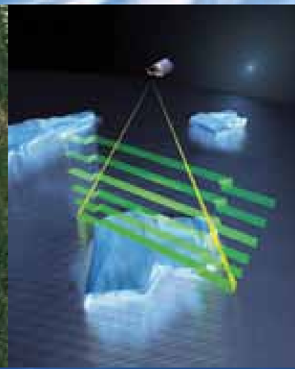
The Arctic's sea ice is a major driver of global weather systems. The light surface of the ice (which in scientific terms has a high 'albedo') reflects solar energy away from the Earth and acts as a natural refrigerator for the planet. Ice and melt water from the Arctic Ocean have profound effects on ocean circulation patterns and climate of the entire planet. Most concerning, the current reductions in ice recorded from satellite is much more than that predicted by climate models. Greenland, the largest source of ice in the Northern arctic, has lost massive amounts of ice; the loss has been measured by the IceSat and Grace satellites.

Twenty years of daily, global satellite data have shown that vegetation growing seasons in temperate northern latitudes are two to three weeks longer now than in the 1980s, thus sequestering more carbon. However, these longer summers have caused boreal forest wildfire activity to increase, also releasing more carbon. In addition, the longer summers in the northern latitude have caused more permafrost to melt, allowing the deep organic soil (of plant origin) to burn during wildfires, thus releasing more greenhouse gasses. These gasses are also continuously monitored with satellite sensors such as NASA's Atmospheric Infrared Sounder (AIRS).

Satellite images of tropical deforestation are always shocking reminders of our human footprint. Globally, calculations based on satellite images and models have revealed that emissions from land cover transformation (e.g. deforestation and expanding human settlements) are higher than emissions from burning fossil fuels.

Programmes to offset fossil fuel carbon emissions, by conserving forest carbon stock and sinks through carbon trading, rely heavily on satellite images for assessing stock of forest biomass. Apart from mapping areas of forest and deforestation, the height and biomass of the forest are estimated with synthetic aperture radar (SAR) in combination with airborne Light Detection and Ranging (LIDAR) and field work. The European Space Agency (ESA) is specifically developing a satellite mission called 'Biomass' for monitoring global forest biomass.

There has been a radical, six-fold increase in the frequency of large fires in the state of California, due largely to longer, hotter summers. Similar future changes are predicted in other Mediterranean climate regions, such as the Western Cape. Active fire detections and burnt area of the past 10 years have been automatically mapped using satellite (e.g. the moderate resolution imaging spectroradiometer (MODIS)



sensor). These data can be used to investigate future changes in fire regimes, which may have a significant impact on fire risk and fynbos biodiversity in the Western Cape.

The value of modelling

In situ measurements are combined with Earth observation data in assimilation models to develop global climate variable data sets. These data sets are essential to provide climate models with a description of the land-surface (e.g. vegetation type, albedo, and surface roughness). Most climate models rely on a static description of the land-surface obtained from remotely sensed data. However, in the most recent developments, Earth observation data of surface parameters are increasingly being used in dynamic, coupled global climate models (CGCMs). These climate models aim to simulate the complex interaction between climate and the Earth's surface. Earth observation data are required not only to provide an initial description of the land-surface to such coupled models, but also to verify the model simulations against the observations.

Tackling challenges

The challenge of studying climate change with satellite is that the data record only goes back to the 1980s, and in most cases to the late 1990s, and we have to statistically distinguish long-term change from significant seasonal and inter-annual variability. The inter-calibration between different satellites and follow-up missions present further unique challenges. In addition, the limited global availability of in situ sensors hampers the calibration and validation of satellite measurements.

The valuable, climate change-related data provided by the various satellite sensors should not be taken for granted. During the past two years, four major NASA climate change-related satellite missions have either failed during launch (Orbiting Carbon Observatory and Glory) or have been cancelled due to budget constraints following the economic recession (DESDynI and Clarreo). In addition to the disappointment of losing years of monitory and intellectual investment, the scientific community has also lost access to essential climate data. A number of satellites that currently provide vital climate information are well beyond their design life, with no immediate prospect of funding for operational, follow-up missions. Essential observations are therefore vulnerable to data discontinuities.

In response, space agencies have committed to supporting the Global Climate Observing System (GCOS) through coordinated efforts of the Community of Earth Observing Satellites (CEOS). Hopefully, the missions planned by ESA and other space agencies will fill the observation gaps in the near future.

In conclusion

Thanks to their synoptic and continuous monitoring ability, satellites will continue to improve our understanding of global climate patterns and our forecasting ability. However, we need to ensure that this information reaches decision makers to allow timely adaptation and mitigation at local and global scales. The compelling satellite images of change inspire action during periods of denial and despair.

– Dr Konrad Wessels

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Using advanced remote sensing methods to assess land degradation

Land degradation is regarded as one of the most important environmental issues facing sub-Saharan Africa and is especially prevalent in the communal lands of the former homelands.

DEFORESTATION and forest degradation currently account for nearly 20% of global carbon emissions, second only to the energy sector. This sector therefore has a major role to play in global attempts to reduce CO_2 emissions with 50% by 2050 and stabilise global warming at 2°C.

The Reducing Emissions from Deforestation and Degradation in Developing Countries (REDD) mechanism seeks to address this issue by linking forest conservation with market-based monetary values based on carbon stock. However, trading forest carbon will only be possible if appropriate systems are developed for monitoring changes in biomass and carbon stock that are cost-effective, repeatable, accurate, and can be implemented over large areas, explains remote sensing specialist Dr Renaud Mathieu.

Dr Moses Cho

Currently, remote sensing specialists from various disciplines – natural sciences, information and communications technology, modelling – are working towards developing remote sensing-based approaches specific to the African environment: "Historically, especially in Africa, most remote sensing-based approaches focused on tropical deforestation. However, more than half of the southern African subcontinent is covered by savannas with about 10 to 50% tree cover and undergoing mostly gradual changes such as bush encroachment or tree logging for fuelwood. Techniques developed for assessing woody biomass in tropical forests with dense canopies cannot simply be transferred to savannas and woodlands," he explains.

Remote sensing techniques for southern Africa

In a recent study, remote sensing specialist Dr Moses Cho showed that it is possible to map vegetation at the individual species level in a typical African savanna.

Tree species mapping with remote sensing is based on the assumption that each species has a unique spectral niche defined by its characteristic biochemical and biophysical make-up. However, thus far the low spectral resolution of most existing spaceborne sensors failed to resolve, inter alia, the subtle spectral features of canopy biochemicals such as chlorophyll content, carotenoid content and foliar nutrients, Cho explains.

Using hyperspectral data from the Carnegie Airborne Observation mission to South Africa in 2008, he simulated the spectral configuration of Worldview-2, a newly launched space-borne multispectral sensor consisting of eight spectral bands in the visible to near infrared. The simulated data were then used for discriminating eight savanna tree species in the Kruger National Park. With an overall classification accuracy of 77%, improved to 82% when applied only to the big trees, he showed that these new systems could prove crucial to the mapping of vegetation at the individual species level (see map on opposite page).

In another project, researchers are assessing a combination of techniques based on ground, aerial, light detection and ranging, hyperspectral, and satellite-based synthetic aperture radar (SAR) to quantify tree cover, woody biomass, and woody carbon stock in southern African savannas.

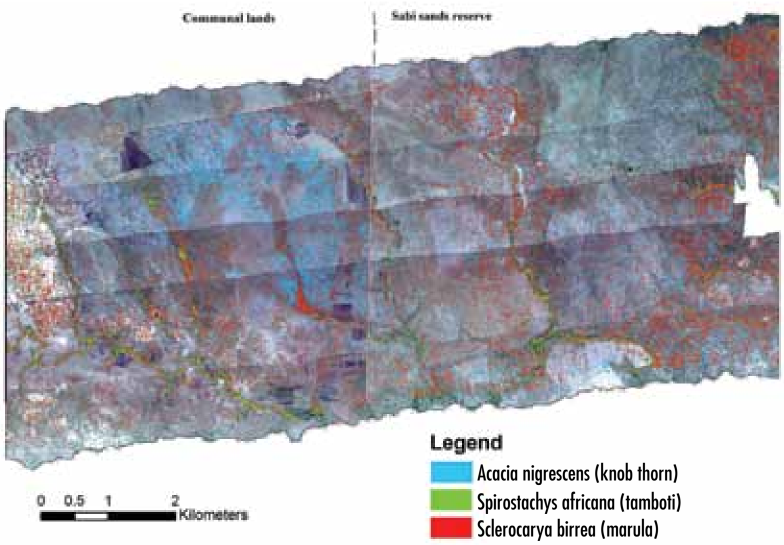
Funded by a CSIR parliamentary grant, the Department of Science and Technology, and the European Union Seventh Framework Programme, the main output will be methods and guidelines which can be used by private industry to offer services related to woody biomass and carbon accounting.

Another concern specific to Africa, and which the researchers are addressing in conjunction with the University of the Witwatersrand, is the often unsustainable use of fuelwood in rural areas. Despite extensive electrification, more than 70% of households in rural areas still rely on fuelwood for cooking and heating purposes. A household typically uses more than three tons of firewood per year of which 93% is cut from live trees.

"There is great concern that the current levels of utilisation are not sustainable, with direct negative impacts on poor people relying on wood for energy, as well as implications in terms of biodiversity loss and conservation," Mathieu says.

In all instances, improved estimates will be instrumental to poverty alleviation in rural areas.

– Wiida Basson



What is land degradation?

It can be defined as a persistent reduction in the capacity of the ecosystem to deliver ecosystem services to the broader community in the form of grazing or fuelwood, or habitat for wildlife.

The process includes:

- Reduction in grass production
- Changes in plant species composition
- Soil erosion as a result of overgrazing
- Increases in tree cover or bush encroachment
- Reductions in tree cover due to excessive wood removal.

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The marula tree *(S. birrea)* is widely distributed across the study area, showing high densities around settlements and in the Sabie Sand reserve. The marula tree is preserved in this area by the indigenous people for its valuable fruit and shade.

The knob thorn *(A. nigrescens)* is concentrated on the gabbro soils of the communal areas and Sabie Sand. The occurrence of this species is generally associated with good ranching land.

The red bushwillow *(C. apiculatum)* is considered a bush encroaching species and is widely distributed in the area.

The distribution of silver cluster-leaf *(T. sericea)* is limited to a few areas close to settlements and on granite soil. Mostly coppices of the silver cluster-leaf were found on the ground as it tends to be over-harvested as live fuelwood. The wood is also used for making furniture and fence posts, the roots for medicine and the bark of young trees for making rope.

Aerosol climatology over SA based on 10 years of multi-angle imaging spectroradiometer data

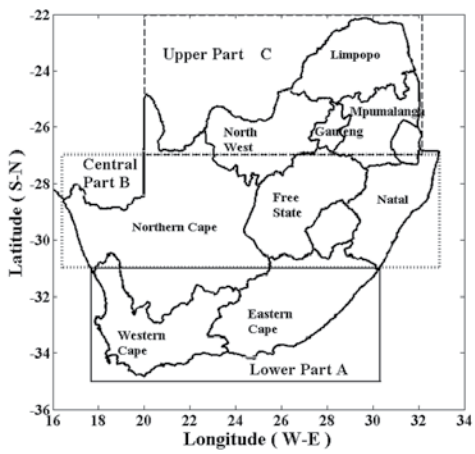

Figure 1: The geographical map of South Africa and three regional spatial classifications in terms of aerosol load level differences.

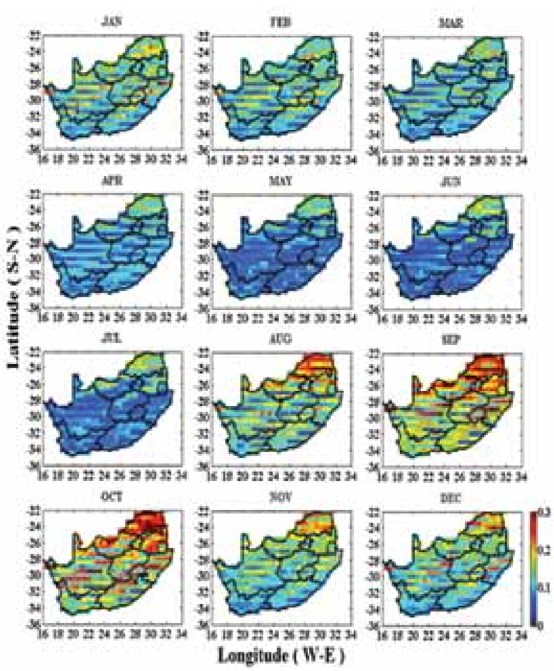

Figure 2: Averaged aerosol extinction optical depth over South Africa obtained from 10 years of MISR data.

Laser researchers at the CSIR recently performed a detailed study of the spatial and seasonal aerosol climatology over South Africa, based on NASA's Multi-angle Imaging SpectroRadiometer (MISR) data.

THE RESULTS CONCLUDED that the upper regions of SA is more polluted in comparison to both middle and lower regions of the country. The upper region of the country is typified by fine particulate matter such as emissions from industries.

Researchers used 10 years (2000-2009) of MISR monthly mean aerosol extinction (Aerosol Extinction Co-efficient), absorption (Aerosol Optical Depth) optical depths at 558 nm, Angstrom exponents in visible (VIS: 446-672 nm), near-infrared (NIR: 672-866 nm) spectral bands and the extracted spectral curvature.

Different aerosol loadings

The study has shown that, in terms of aerosol load level spatial variation, South Africa can be classified into three parts: the upper, central and lower, which illustrate higher, medium and low aerosol loadings, respectively. The prevailing sources of aerosols are different in each part of the country.

The lower part is dominated by the transport of air-mass from the surrounding marine environment and other southern African regions, while the central and upper parts are loaded through wind ablated mineral dust and local anthropogenic activities.

During the biomass burning seasons (July to September); the central part of South Africa is more affected by the biomass burning aerosols (based on Aerosol Optical Depth); by about -20% higher than the rest of the country.

In alignment with the observed higher values of Aerosol Extinction Co-efficient, aerosol size distributions were found to be highly variable in the upper parts of South Africa, which is due to the high population and industrial/mining/agricultural activities in this area.

The above results provide background information on aerosol concentrations and the importance of more frequent measurements. In part of the study, the CSIR's mobile Light Detection and Ranging system has been used for measuring vertical profile of aerosol in collaboration with different universities.

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Is the Kruger National Park a **source or sink of carbon?**

Ten years of uninterrupted atmospheric measurements – 22 times per second and downloaded every half hour from the Skukuza flux tower – show that this part of the Kruger National Park has been a carbon source and not a carbon sink.

EARLY RESEARCH RESULTS indicated that the Skukuza site had a Net Ecosystem Carbon Exchange of 25 gC per square metre per year over the measurement period of 2001 to 2006. In other words, the landscape was a small net source of CO_2 to the atmosphere.

However, according to Dr Bob Scholes, systems ecologist at the CSIR and one of the principal investigators, researchers observed high variation between years: "In wetter-than-average years, the site is a net carbon sink, while in drier-than-average years it is a source. Extrapolation to a 25-year period, including the natural variation over that time, suggests a long-term source strength of about 75 gC per square metre per year," Scholes explains.

In this ecosystem the key driver of carbon uptake or loss is the availability of water, while temperature plays a minor role: "During a year, the carbon exchange is governed by the seasonal progression of tree and grass leaves, which is controlled by rainfall. The total plant productivity at Skukuza is in the order of 20 tonnes of dry matter per hectare per year, with large annual variations. The main source of the variation is in the grass layer, which is highly responsive to variations in rainfall." That production – and a little bit extra – returns to the atmosphere through grazing, fire and the respiration of microbes, leaving a small net source.

Perhaps one of the most surprising findings was that there is hardly any difference between the Net Ecosystem Carbon Exchange in the Combretum savanna and the Acacia savanna during a full year. Scholes explains: "Conventional wisdom had predicted that the net ecosystem exchange in the former should be less than in the latter, because it occurs on sandier, less fertile soils, with net drainage rather than run-on. More detailed analysis shows that the pattern of carbon fluxes in relation to wetting events differs between the two types, but cancels out over longer time periods, leading to a convergent end result."

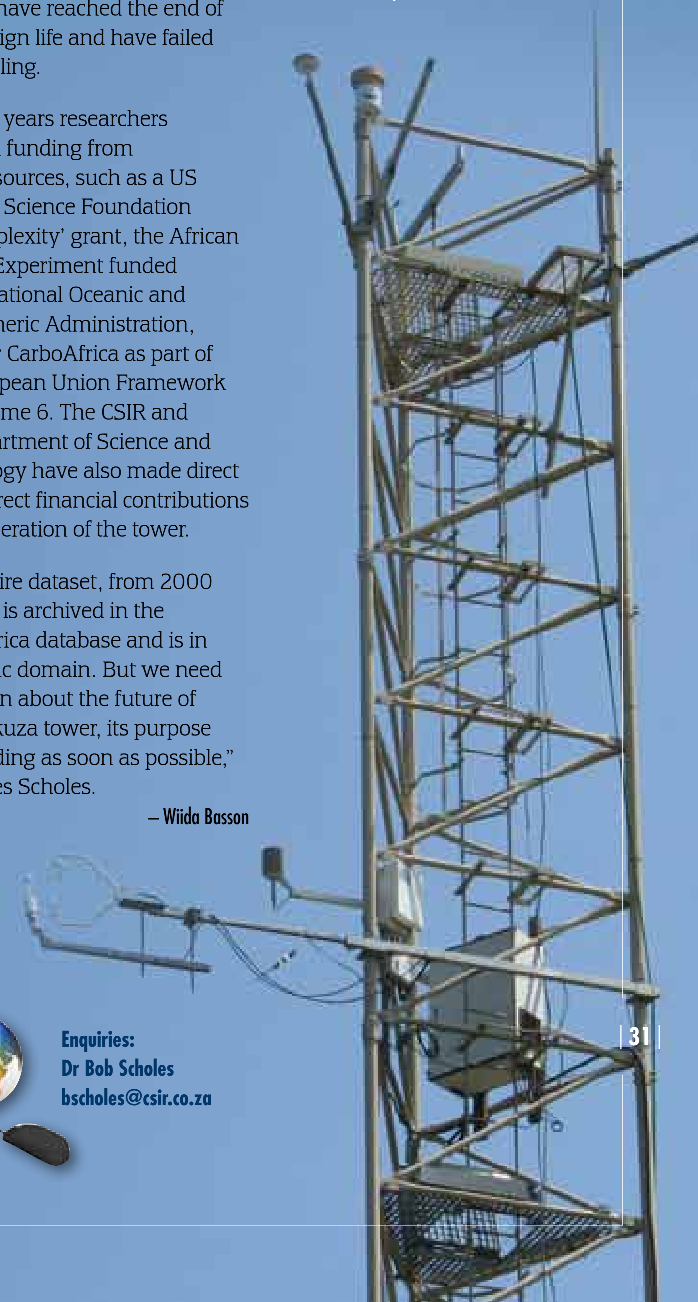
Originally installed as part of the SAFARI 2000 project on fires and associated emissions to the southern African atmosphere, the 22-metre-tall flux tower was used as part of the calibration and validation infrastructure for the about-to-be-launched Terra and Aqua Earth observing satellites. An unusual feature of the research site is its location on an ecotone – the transition point between Combretum savannas on the ridge and Acacia savannas in the valley.

However, at the end of 2010, the longest-running flux tower in Africa, and one of only a few in savannas anywhere, needed a serious overhaul as many of the sensors have reached the end of their design life and have failed or are failing.

Over the years researchers obtained funding from various sources, such as a US National Science Foundation 'Biocomplexity' grant, the African Carbon Experiment funded by the National Oceanic and Atmospheric Administration, and later CarboAfrica as part of the European Union Framework Programme 6. The CSIR and the Department of Science and Technology have also made direct and indirect financial contributions to the operation of the tower.

"The entire dataset, from 2000 to 2009, is archived in the CarboAfrica database and is in the public domain. But we need a decision about the future of the Skukuza tower, its purpose and funding as soon as possible," concludes Scholes.

– Wiida Basson



The flux tower at Skukuza in the Kruger National Park is the longest-running flux tower in Africa, and one of only a few in savannas anywhere.

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WORLD POPULATION:
6 999 999 999
AND STILL GROWING

Adapting THE WAY WE LIVE

The Earth's human population is predicted to rise to nine billion by 2050. The twin challenges of reducing people's impact by reducing their levels of consumption and waste generation on the one hand, while still being able to raise the average standard of living to an acceptable level, will require us to make radical changes to the way we live.

(DST, 10-year Global Change Research Plan for South Africa, 2010)

The impacts of climate change are not evenly distributed – the poorest countries and people will suffer earliest and most. And if and when the damages appear it will be too late to reverse the process. Thus we are forced to look a long way ahead.

The Stern Review on the Economics of Climate Change, October 30, 2006

New project to help catapult ecosystem services onto SA development agenda

"We can plan far better, more productive landscapes by using our knowledge of ecological infrastructure and the ecosystem services it produces." – Dr Belinda Reyers

Ecosystem services infrastructure, such as wetlands and dunes, help reduce our vulnerability to climate change. Dunes form a natural buffer against erosion during sea-storms and play an important role in protecting coastal areas while wetlands soak up rain like sponges. Where development does not heed this, the consequences can be devastating. Researchers now hope to help decision makers gain access to tools and capacity that will help them manage this important ecological infrastructure.

ECOLOGICAL INFRASTRUCTURE like wetlands, coastal dunes, rivers and estuaries play as crucial a role in a country's development as built infrastructure such as roads and railways. South Africa's wealth of ecological infrastructure – viewed as a nice to have for decades – is increasingly proving to be the cornerstone that underpins urban and rural economies. This ecological infrastructure provides us with many benefits (called ecosystem services) including fertile soil for agriculture, fresh water, food, fuelwood, pollination of our food crops and tourism, but also things like protection from extreme events – floods, droughts and fire. This is increasingly relevant in the face of the mounting risks of climate change.

Bringing science and policy together

This dawning realisation by many sectors is central to a new project which is seeing the Global Environment Facility – through the United Nations Environment Programme as implementing agency – invest $1.6m in South Africa over the next four years. The Project for Ecosystem Services' (ProEcoServ) main aim is to better integrate information on this ecological infrastructure and the benefits it provides to society into national sustainable development planning.

Dr Belinda Reyers and Dr Luthando Dziba, CSIR chief and principal scientists respectively and co-leaders of the ProEcoServ project, point out that in the past, many projects have been directed at either science or policy development, but hardly ever at the interface between the two. As a consequence, the rich knowledge generated on South African ecosystem services does not make it onto the radars of policy and decision makers, especially those outside of the environmental sector. This is the gap that ProEcoServ aims to fill.

Making the most of ecosystem services

"We can plan far better, more productive landscapes through the use of our knowledge of ecological infrastructure and the ecosystem services it produces," says Reyers. While these services are often taken for granted, they are important to economies and societies, and even more so in times of difficulty, like during a drought. Climate change is increasingly placing this ecological infrastructure and its services in the foreground. For example, wetlands soak up rain like sponges, slowing down the water and preventing floods; coastal dunes buffer coastal communities from sea storms. Communities in South Africa have in recent times

About ProEcoServ

- South Africa is one of five participating countries: Chile, Trinidad and Tobago, Vietnam and Lesotho.
- The project is a partnership between the CSIR and the South African National Biodiversity Institute with the Department of Environmental Affairs chairing the project steering committee.
- The project will involve public and private partners from sectors such as agriculture, urban development, water management, business and mining during its four-year duration.

"Just like municipalities are trying to find better ways to manage their infrastructure for better service delivery, this partnership aims to better manage our ecological infrastructure – also under future conditions of change."

NOSIPHO NGCABA, DIRECTOR-GENERAL, DEPARTMENT OF ENVIRONMENTAL AFFAIRS

"Lessons learnt from this project on the interface between science and policy will benefit a broad spectrum of our research. This project has the CSIR's unequivocal support."

DR SIBUSISO SIBISI, CHIEF EXECUTIVE OFFICER, CSIR

witnessed floods as a result of increased rainfall in tandem with degraded wetlands unable to slow the waters, coastal homes washing away as a result of sea storms and eroding dunes unable to protect beaches as they normally would, and fires leaping out of control as a result of dense infestations of alien invasive trees in urban landscapes. It is clear that increased incidents of extreme events like floods and storms as a result of climate change make us vulnerable, a vulnerability that is increased because we have not looked after ecological infrastructure. But the solutions are readily at hand to reduce this vulnerability by blending human ingenuity with an increased awareness of the ingenuity of nature: "Ecosystems have been built over millennia to be able to cope with change," she says.

It is against this background that ProEcoServ seeks to assist scientists and policy makers to work together to find ways to better manage South Africa's ecological infrastructure. The project hopes to develop knowledge, tools and capacity and to place these in the hands of decision makers to make informed choices about the use and management of South Africa's ecological infrastructure and ecosystem services.

Project work programmes

In South Africa, the project will focus on three scales.

Municipal management

At a municipal scale, the project will look at development planning and disaster management in the Eden District Municipality in the southern Cape, where the effects of climate change are already evident as increased floods, droughts, fire frequency and intensity, as well as sea storm surges.

The Risk and Development Annual Review (RADAR) for the Western Cape, published by the University of Cape Town, highlights that between 2003 and 2008, the Western Cape government departments and parastatals incurred direct damage costs exceeding R2.5 billion in eight severe weather events associated with cut-off lows. For these eight cut-off low events, Eden District incurred 70% of the damage costs for all Western Cape municipalities. Damage per capita in rural areas was 3.5 times more than annual household income in some instances.

"This is an increasingly unpredictable part of the world, but an engaged private and public sector have created the right 'climate' to find solutions for improved management of ecosystem infrastructure," says CSIR principal scientist, Dr Jeanne Nel, who has been working with the insurance and food and beverage sector in the area.

Catchment management

At a catchment level, the project will look at water and land use management in the grasslands of the Olifants River catchment in the Witbank area. "This is an area where many in the environmental sector would rather not venture because there is very little 'nature' left," says Reyers.

Mining, agriculture and failing infrastructure have left their mark on the landscape with heavy metals, excessive phosphates and untreated sewage seriously threatening water quality and human health in this area.

But at the same time the area is important for agriculture, for urban and rural livelihoods

"There is value in ecological infrastructure. There is a clear link between a country's development state and its biodiversity state."

DR TANYA ABRAHAMSE, CHIEF EXECUTIVE OFFICER, SANBI

"Countries consider their human capital, social capital, and man-made capital but often their natural capital is invisible. This factor is missing in countries' development models."

ERSIN ESEN, PROECOSERV PROJECT MANAGER, UNEP

and for economic development. Solutions have to be found to reduce the very real threat to water quality in the area, which could have devastating knock-on effects to the agricultural and urban economies in the area, not to mention the health of people.

"Bringing our knowledge of the role of ecological infrastructure in cleaning water and the air, as well as our knowledge of the very dangerous and imminent water and air quality thresholds, we can work with business, industry and the public sector in understanding the impacts of such intensive land use and looking for solutions offered to the area by its ecological infrastructure and their services," says Reyers.

"We will look, for example, at the impact of restoring the functioning of wetlands and riparian vegetation in the region – plants are fantastic at cleaning water.

"We can also look at more optimal designs of the landscape, blending ecological and built infrastructure in a matrix of agriculture, mining, settlements and areas of critical ecological infrastructure within safe operating thresholds. This also provides some real job creation options in restoring and managing this infrastructure," she says.

National policy

At a national policy scale, the project will be investigating the kind of policies needed to make ecosystem services central to poverty alleviation and socio-economic development.

It will build on the very progressive environmental policy frameworks as well as the strong partnerships between science and policy in this sector, to expand these frameworks into areas important for the management of ecological infrastructure and their services. These areas include the evolving green economy where in reality ecosystem services are the foundations upon which any economy rests.

Recognising the role of ecological infrastructure in job creation, poverty alleviation and economic growth is key to ensuring a prosperous, equitable and resilient green economy.

The project will help in turning the world's attention beyond the negative impacts and uncertainties related to climate change, to a more positive message of hope and practical solutions in which ecological infrastructure helps societies adapt to climate change.

In addition to these green economy and climate change adaptation engagements, ProEcoServ will be supporting outreach, networking, incentive schemes and capacity building activities assisting scientists and policy makers to work together to understand the importance of ecological infrastructure and ecosystem services to society and to find ways to better manage this infrastructure, especially in the face of the increasing risks from climate change.

– Alida Britz

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More bang for your conservation bucks – a structured approach to real world decision making

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report cites 28 586 studies demonstrating significant biological changes in terrestrial ecosystems. Already high extinction rates, driven primarily by habitat loss, are predicted to increase under climate change. Yet there is little specific advice or precedent in the literature to guide adaptation investment for conserving biodiversity within realistic economic constraints.

IN A LETTER to the newly launched and prestigious journal *Nature Climate Change*, CSIR chief ecologist Dr Brian van Wilgen and others present a systematic ecological and economic analysis of a climate adaptation problem in one of the world's most species-rich and threatened ecosystems: the South African fynbos.

The letter addresses the question of how a limited adaptation investment budget should be most efficiently invested, given an objective to maximise net species persistence in the fynbos over the next 50 years.

According to the authors, investment decisions so far have been made with "imperfect information about conservation values, existing and future threats, and costs and efficacy of the management options at hand, making the demand for a sound analytical framework acute".

Add to that the fact that most climate adaptation strategies will have to be developed under severe uncertainty, and you have the perfect case study for decision science: "The complexity of adaptation decisions increases with increasing numbers of options, with uncertainty about expected benefits and with the number of decision criteria. Dealing with complexity and uncertainty is the domain of decision theory, and tools exist to help, ranging from simple cost-effective analysis, to sophisticated optimisation and uncertainty analysis techniques."

In the case of fynbos, the authors identified two competing actions for maximising species persistence for fynbos: fire management to avoid excessive reduction below current return intervals of around 15 years; and habitat protection, including invasive alien plant control.

They then used a simple cost-effectiveness analysis to identify optimal allocations to fire management and habitat protection:

- With a limited budget – ranging from 0 to 120 million US$ per year – it is most efficient to invest almost solely in fire management.

Why? If climate change drives fire return intervals to levels lower than every eight years, there is a high probability of extinction for the species. This is because a large portion of the fynbos shrub flora is 'obligate seeders'. Obligate seeders are killed by fire and can regenerate only from seed. If fire frequency increases, it may lead to the destruction of adult plants before they reach sexual maturity and hence local extinction.

- When the available budget exceeds US$43 million, marginal returns from fire management decrease relative to those from invasive alien plant control habitat protection, suggesting that a mixed investment strategy would be more effective.

What is decision science?

Decision science provides the tools necessary for rational decision making under uncertainty and complexity. Decision science has been discussed in the IPCC assessment reports as conceptually and practically relevant to mitigation and adaptation choices. Like all decision theory problems, climate adaptation will include a problem formulation phase in which broad goals and a set of specific, measurable objectives are defined. This is followed by the identification of a set of candidate management actions, the construction of a system model that characterises system dynamics and predicts expected benefits of investment options, and the implementation of a decision model that identifies the best portfolio of actions in light of information at hand.

- At around US$105 million, no further gains in expected minimum abundance can be made with further investment in invasive alien plant control, suggesting that remaining budget should go into fire management.

According to the authors, this illustrates a key result: "That the optimal investment strategy depends on the available budget, in this case in a highly nonlinear fashion. The preference for fire management at low budgets arises because every dollar invested in fire delivers a relatively large increase in fire return intervals and therefore population persistence, and if fire return intervals are too low to maintain species, habitat protection is irrelevant."

– Wiida Basson

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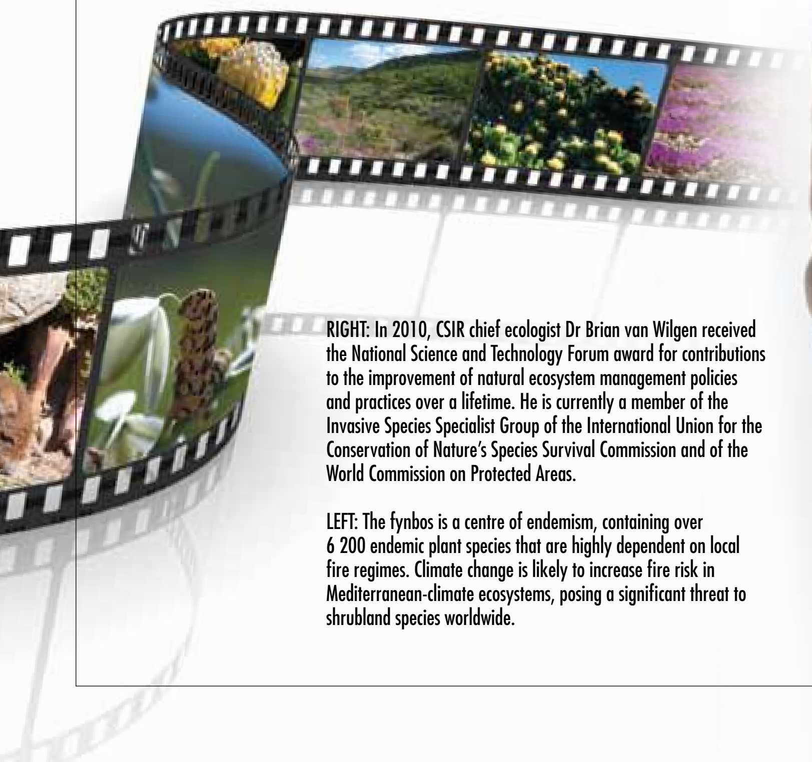


RIGHT: In 2010, CSIR chief ecologist Dr Brian van Wilgen received the National Science and Technology Forum award for contributions to the improvement of natural ecosystem management policies and practices over a lifetime. He is currently a member of the Invasive Species Specialist Group of the International Union for the Conservation of Nature's Species Survival Commission and of the World Commission on Protected Areas.

LEFT: The fynbos is a centre of endemism, containing over 6 200 endemic plant species that are highly dependent on local fire regimes. Climate change is likely to increase fire risk in Mediterranean-climate ecosystems, posing a significant threat to shrubland species worldwide.

Green supply chains
towards environmental sustainability

Pressure to reduce the environmental impact of logistics operations has increased over the past number of years. Freight transport is estimated to contribute about 8% of energy-related CO_2 emissions worldwide; however, making logistics 'sustainable' in the longer term will involve more than just reducing carbon emissions.

THE ADVERSE EFFECTS of distributing goods are diverse, including impairing air quality, generating noise and vibration, causing accidents and contributing significantly to global warming. The focus on logistics and supply chain management and their impact on climate change have increased mainly because of the realisation that global warming presents a much greater and more immediate threat than previously thought.

The most recent State of Logistics™ survey published by the CSIR records that in 2009, 23 million tons of greenhouse gasses were emitted in South Africa due to land freight transport activities. This amounts to 49% of transport emissions and just over 5% of total emissions for the country. Road freight contributed 23 million tons, and rail 2.7 million tons. This translates into R4.6 billion and R0.6 billion, respectively, in costs to the environment.

Supply chain management, or logistics, has become a key business activity. Reducing costs while satisfying customers has been an overriding objective in this area for many years.

In addition, supply chains have become more dynamic, resilient, agile and adaptable, while there is increasing emphasis on adding value to the process.

A recent World Bank report emphasises the importance of efficient logistics for trade and growth. It is now widely acknowledged that better logistics performance is strongly associated with trade expansion, export diversification, ability to attract foreign direct investment, and economic growth.

Green supply chains, or green logistics, are defined as efforts to reduce the externalities and achieve a more sustainable balance between economic, environmental and social objectives.

Given the pressure around reducing the impact of logistics and supply chain operations on the environment, and specifically on climate change, there are numerous ways to address these, including:

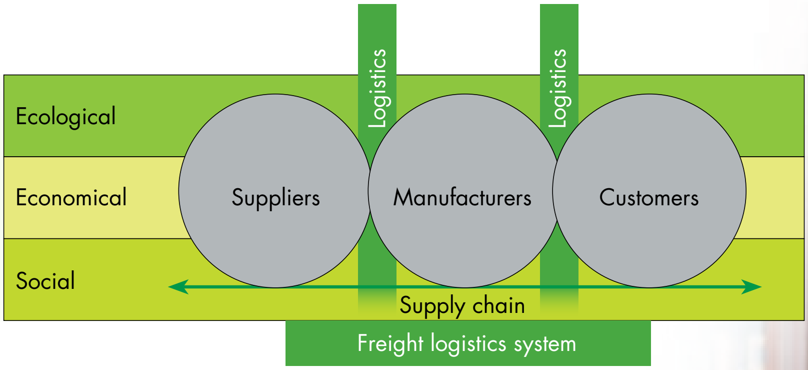
- Re-assessing and restructuring supply chains to incorporate environmental issues and factors;
- Transferring freight to greener transport modes. Worldwide, the growth in freight has mainly been on roads, which are not very 'green-friendly'. There are renewed efforts to move some types of freight from road to rail;
- Developing greener vehicles, aircraft, ships, etc. Much has already been done in this regard, especially regarding heavy-duty diesel vehicles;
- Reducing the impact of warehousing by, e.g. improving energy efficiency;
- Improving vehicle utilisation, including optimising the routing of vehicles;
- Increasing the fuel efficiency in the road freight sector; and
- Aiming initiatives such as city logistics and reverse logistics at environmental sustainability.

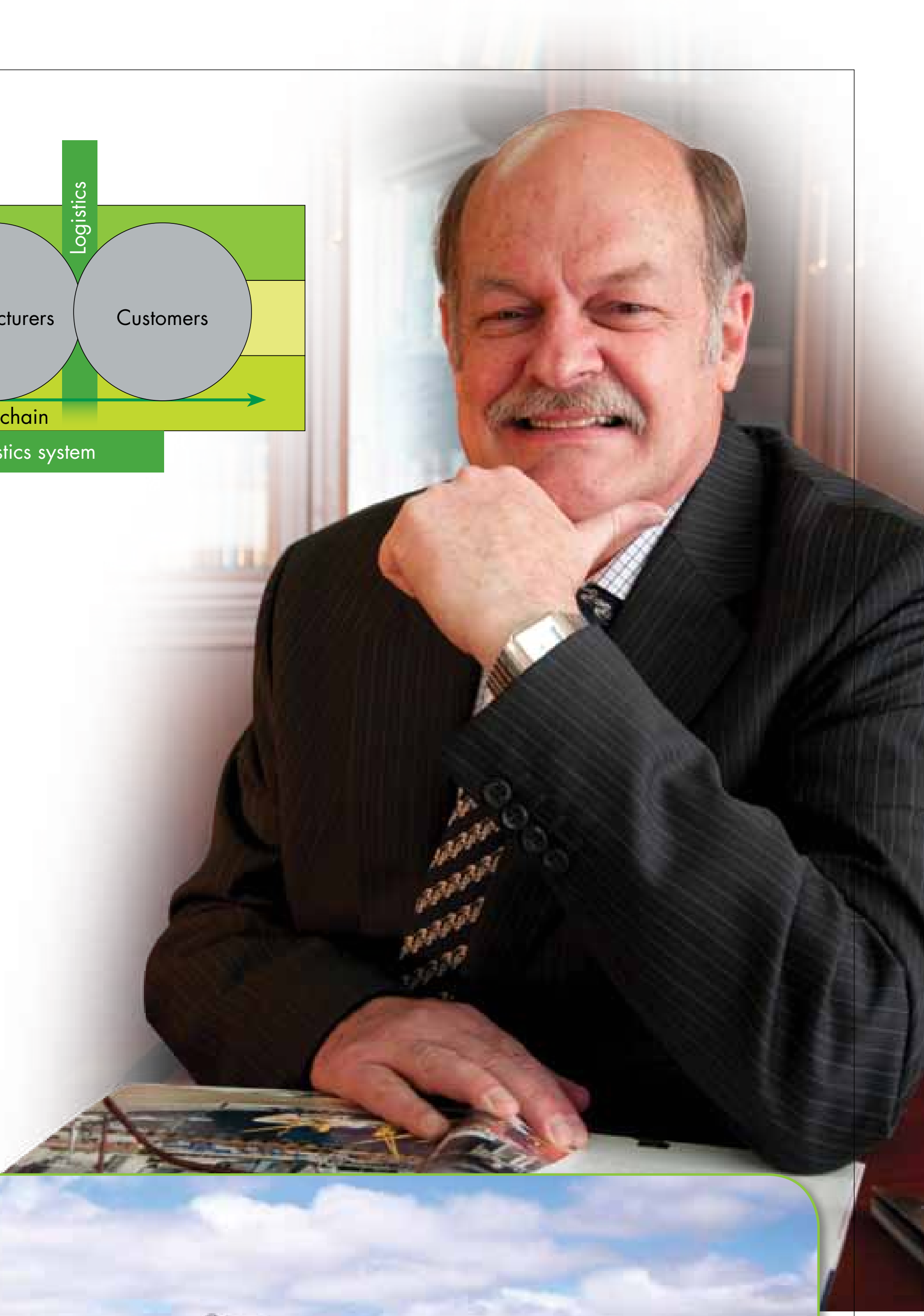
These efforts aimed at reducing the impact on the environment reiterate that sustainable green logistics and green supply chains will be a prerequisite in future. Environmental pressures and concerns around climate change will grow, thus increasing the emphasis that governments and consumers will place on this critical aspect. It must therefore become a priority for supply chain managers.

BRICS countries: CO_2 emissions from fuel combustion by sector with electricity and heat allocated to consuming sectors in 2008 (in million tons of CO_2)

Country	Total CO_2 emissions from fuel combustion	Other energy industries	Manufacturing and construction	All transport	Road transport	Other sectors
Brazil	364.6	27.9	128.2	149.7	134.6	58.8
Russian Federation	1 593.8	193.9	536.0	274.0	131.9	589.9
India	1 427.6	50.7	652.8	147.4	121.1	576.7
China	6 550.5	467.4	4 143.4	482.2	334.4	1 467.5
South Africa	337.4	16.2	163.1	49.5	42.3	108.6

Source: International Energy Agency 2010





The outcome of a five-year research programme in the USA found that supply chains of the future must deliver on six outcomes, namely, cost, responsiveness, security, sustainability, resilience and innovation. Of these six, sustainability is defined as 'green', environmentally-responsible supply chains that eliminate waste, reduce pollution and contribute in a positive manner to improving the quality of the environment through eco-friendly processes, sub-assemblies and finished goods. Carbon footprint reduction along the supply chain is but one example.

– Hans W Ittmann

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Renewed efforts are underway to move some types of freight from road to rail.

Helping business respond to risk in a changing world

Global change can significantly compromise the economic performance of business by heightening the consequences and unpredictability of risks. Therefore, no business can afford to reduce only its negative impacts on the receiving environment. More and more businesses are realising that all their activities are embedded within an inter-connected and fast-changing social-ecological landscape.

A MULTIDISCIPLINARY GROUP of CSIR researchers have been working with two major South African corporations – Santam (in collaboration with the University of Cape Town – UCT) and South African Breweries (in collaboration with WWF) – to help them gain a systematic understanding of how global change impacts on their natural resources risk profile.

According to sustainability specialist Dr Lorren Haywood, failure to understand the linkages between the bio-physical Earth systems, ecological, socio-economic and external governance systems within which business operates, can spell disaster for even the most robust business.

"Within the financial sector, the global insurance sector is facing unprecedented claims due to a recent increase in 'natural catastrophes' associated with global change (see Figure 1). This is having significant adverse impacts on the affordability and availability of insurance, potentially slowing growth in the industry and transferring more of the burden to governments and individuals," she explains.

When Dr Jeanne Nel, ecosystem services specialist, engaged with South African business and industry, she found a similar trend: "Take short-term insurance, for example. In certain areas, an estimated 75% of 'special peril' claims over the past 15 years were paid out in the last five years to cover climate-related events such as floods, wind and storm surge damage. In some instances, a single district municipality accounted for over 50% of these private and public claims."

Against this backdrop, Santam, the CSIR and UCT's Centre of Criminology undertook a collaborative project to develop a 'proof of concept' to understand how both global change and human-induced changes are likely to affect the insurance industry. With a clear understanding, insurance companies can improve their risk assessment capability, and proactively manage the risk profile by, for example, working with key stakeholders to improve their social ecological resilience, Dr Nel explains.

How can a business improve its social-ecological resilience?

To understand the likely effect of global change, the project team modelled climate change projections for the southern Cape and the social-ecological risk landscape. This included risk factors such as flooding, wild fires and coastal storm surges, as well as the drivers of these risks, coupled with related ecological and social vulnerabilities.

Based on these, they compiled different scenarios of change, and identified those

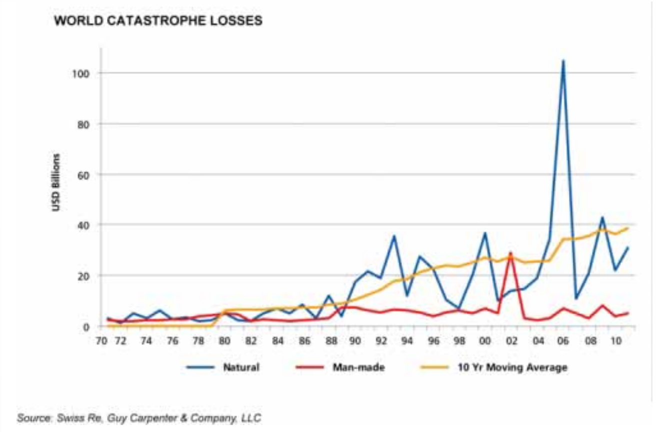

Figure 1: Trends in insured claims due to natural catastrophes and man-made disasters 1970 to 2010 (Carpenter 2010)

interventions that can mitigate future risk.

"We found that by better understanding the socio-ecological landscape within which it operates, the insurance industry can play a very influential role to ensure that regulations are followed, and that the costs and benefits of different land management options are correctly considered in land use planning and decision-making processes," Dr Haywood and Dr Nel explain.

Another sector that has been at the forefront of grappling with the impacts of changing Earth systems is the food and beverage industry. One of the largest global companies in this sector, SAB, found that more than 95% of its water footprint lay in the growth of crops like hops and barley in the drought-stricken southern Cape region. Working with the company to understand the dynamics of the water risk in the hops growing region of George, the CSIR and the World Wildlife Fund for Nature identified three ultimate drivers of water risk: climate change, water-intensive alien trees, and competition for water from urban development.

By means of a scenario of change exercise based on these drivers, they determined two core response strategies which should mitigate the majority of future water risk to SAB's hop farm operations: "We found, for example, that the rehabilitation of the hydrological and ecological functionality of the catchments will yield water and economic benefits that far outweigh future threats from climate change. Similarly, future threats from competition for water in this region are likely to be greatly reduced through SAB Hop Farms taking a leadership role in the development of a groundwater monitoring framework and institutional structures that are able to engage effectively with decision-making processes from an informed and science-based position," Dr Nel explains.

Thinking out the box and addressing risk assessment from a social ecological perspective could better enable business to effectively inform management actions that are intended to build resilience of the systems on which the business depends, and help the business mitigate and withstand risks associated with unpredictable global change.

– Wiida Basson

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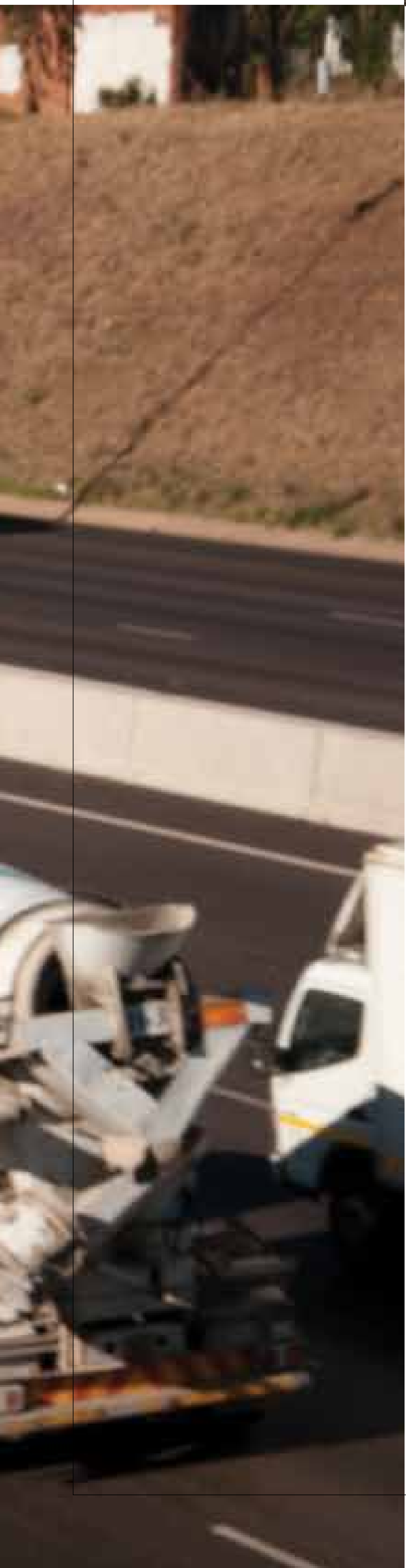
What is the difference between resilience and sustainability?

Sustainability refers to an organisation's goals and contribution to the principles of sustainability, i.e. reducing its impact on the environment, having a positive impact on society and, of course, maintaining a positive bottom line. Resilience, on the other hand, is a measure of the ability of the organisation and the system (social, economic and environmental) on which it depends, to adsorb and adapt to disturbances before losing its current structure and functions. It implies that the business needs to understand its impact, dependencies, and the dynamics within the system, in order to understand how to influence and respond appropriately to change.

Dealing with the effects of **global climate change on roads**

Benoit Verhaeghe,
CSIR Infrastructure Engineering Manager



The performance of transportation infrastructure is affected directly by environmental changes relating to global climate change.

THESE RANGE FROM rises in average surface temperature, more severe heat waves and prolonged droughts; reduced ice and snow coverage and changes in freeze-thaw cycles; rising sea levels and more frequent and intense storms.

"If significant climate change impacts are projected and the risk profile justifies it, processes should be initiated to adapt road design, maintenance and construction guidelines, and standards. In addition, planning, design, construction and maintenance operations may have to be adjusted to reduce risks and protect the long-term serviceability of road infrastructure," says Benoit Verhaeghe, Infrastructure Engineering Manager at the CSIR.

"Rising ambient temperatures may cause bituminous-bound road materials to become susceptible to permanent deformation in the form of road rutting. Increased rainfall in certain parts of the world may result in flooding and higher groundwater levels, which in turn may lead to erosion, slope instability and reduced structural strength and bearing capacity of road structures," he warns.

Verhaeghe serves on an international committee that concentrates on roads within the broader scope of PIARC (the World Roads Association). The committee has produced a document to sensitise the road sector to the likely impacts of climate change on roads and to provide guidance on how to go about:

- Assessing the vulnerability of roads to the direct impacts of climate change; and
- Identifying and prioritising possible adaptation measures for roads that could be applied immediately, or phased in over time, to avert the negative consequences of climate change on the serviceability of road networks.

Climate change is expected to have various environmental, social and economic effects, the severity of which may vary by geographic location, country and region. The committee conducted a survey by sending a questionnaire to PIARC members.

"From the response we received from 21 countries, overall concern was expressed about the uncertainties associated with the nature and extent of climate change, and the lack of understanding of the vulnerability of transport networks to extreme weather events, as well as the risk exposure to both road owners and road users. Linked to those were the uncertainties associated with the indirect impacts of climate change, such as the potential changes in traffic volumes due to shifts in population and relocation of industrial activities as a consequence of climate change, which may impact on the demand for road infrastructure," adds Verhaeghe.

The PIARC document provides guidance on how to conduct risk and vulnerability assessments, and on how to deal with the effects of climate change on roads.

Adaptation strategies should be sustainable and consider appropriate mitigation strategies and policies aimed at reducing greenhouse gas emissions. This can be achieved by, for instance, design and maintenance strategies that focus on the technical quality. "One could also adopt long-life road design concepts to minimise materials used for road construction; the amount of road construction material used during the lifetime of a road has a greater impact on the carbon footprint than, for instance, the construction and maintenance methods adopted," observes Verhaeghe.

Short and long-term effects of climate change may require more frequent maintenance, rehabilitation and reconstruction of roads, which has direct cost implications for road owners. "Overall, climate change is expected to increase the cost of road maintenance and rehabilitation," he concludes.

– Hilda van Rooyen

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CSIR research architect Naa Lamkai Ampofo-Anti recommends the application of life-cycle assessment principles to reduce the contribution of buildings to climate change.

Assessing the impact of buildings on climate change

The operation and maintenance of buildings in South Africa, residential as well as non-residential, contribute to almost 25% of all greenhouse gas (GHG) emissions in the country.

TYPICALLY, buildings have five life-cycle stages, from raw material extraction and processing, to material manufacturing, on-site construction, operation and maintenance, and, finally, disposal. Some 80% of their GHG emissions are linked to how people use energy (mainly electricity) in buildings during the 'operation and maintenance' life-cycle stage which lasts 50 years and more.

The intent of both global and local 'green' building efforts is to drastically reduce the energy demand of this dominant life-cycle stage, leading to a major, global reduction in building-related GHG emissions.

"However, with climate change high on the agenda, and mounting evidence of the construction industry's contributions to this phenomenon, the life-cycle assessment (LCA) 'cradle-to-grave' approach to buildings may hold the key to greenness in the construction industry," comments Naa Lamkai Ampofo-Anti, a CSIR research architect.

"Practically, this means that the remaining 20% of GHG emissions, plus a broad range of environmental problems associated with building materials' life cycles, would need to be factored into all investigations. Examples of such problems are the depletion of non-renewable resources, habitat destruction and toxic emissions," she notes.

"LCA, a well-established approach followed in many industries, has only recently been introduced in the construction industry as a way of minimising environmental impacts while maximising performance of products constructed," explains Ampofo-Anti.

Using LCA, she has investigated the possibility of substituting common building materials such as clay brick with a natural fibre composite (NFC) in construction, to be developed from South African-grown flax, hemp or sisal. The proposed NFC in construction is expected to have important environmental advantages for the South African building and construction sector. These include reduced dependence on non-renewable resources such as metals and fossil fuels; and the ability to withdraw CO_2, the key GHG, from the atmosphere during the growth phase.

"Growing such fibres has other environmental consequences that are as important as climate change. In particular, the use of fertilisers and pesticides in crop production processes is a key driver for eutrophication (poor water quality). This is, of course, a 'no-no', given that South Africa already faces major challenges around water salinity and scarcity. As NFCs hold promise for more environmentally-sound construction materials, we should use LCA principles to conduct more research in this field, before giving any consideration to construction applications," she adds.

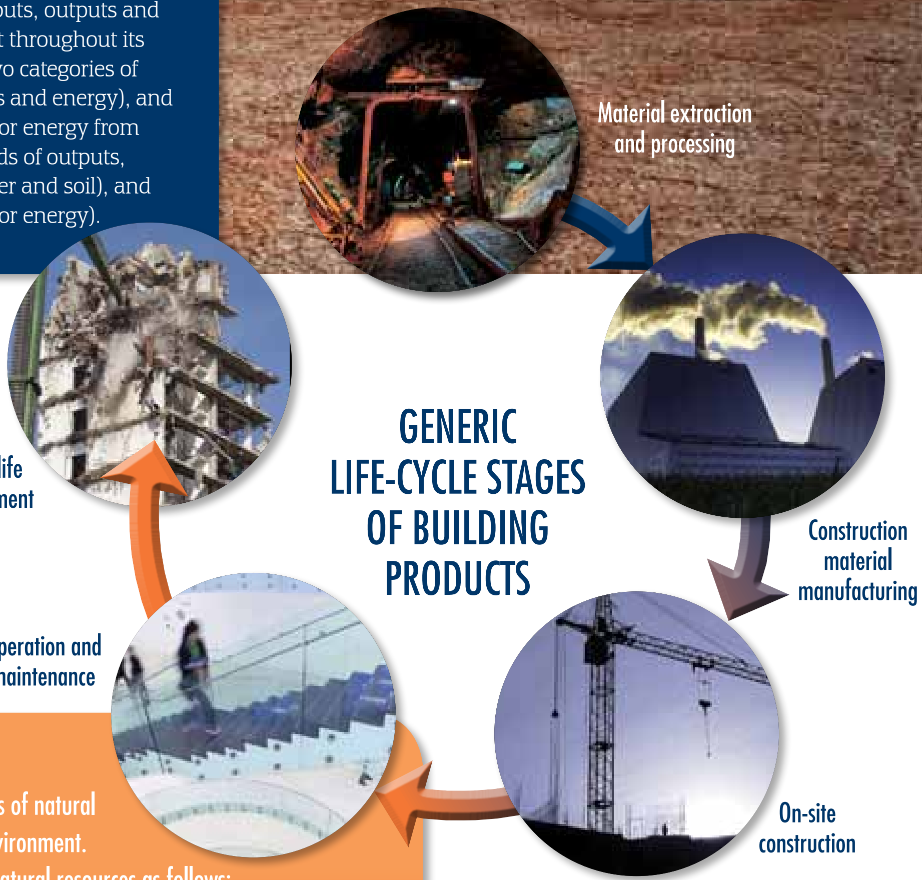
Several types of tools have been developed for incorporating LCA into the 'green' building agenda. "These include tools for whole building design, building

What is LCA?

Life-cycle assessment (LCA) is an environmental management tool for compilation and evaluation of the inputs, outputs and potential environmental impacts of a product throughout its life-cycle (SANS 14044, 2006). It involves two categories of inputs, namely environmental (raw materials and energy), and economic (products, semi-finished products or energy from other processes). Similarly, there are two kinds of outputs, namely environmental (emissions to air, water and soil), and economic (products, semi-finished products or energy).

material and component specification, and building rating and certification. While these tools are commercially available, they are backed up by data that are specific to the nation or region for which they had been developed. To obtain credible results locally, we need appropriate data, which are not yet freely available," she concludes.

– Hilda van Rooyen



The construction of buildings and other physical infrastructure results in the use of large volumes of natural resources, which leads to degradation of the environment.

The construction industry worldwide consumes natural resources as follows:

- 50% of all material resources globally;
- 45% of energy generated is used to heat, light and ventilate buildings and 5% to construct these;
- 40% of water used globally is for sanitation and other uses in buildings;
- 60% of prime agricultural land is lost to farming for building purposes;
- 70% of global timber products end up in building construction.

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Grass-fed *versus* feedlot – **does it matter to the climate?**

Jokes about cow-farts are always good for a snigger around the braai, but what is the reality? The manure-slinging between feedlot-based meat producers and graziers has become furious in recent years. Both sides claim they are better for the environment and seek to promote their product in climate-conscious markets.

FEEDLOTTERS POINT OUT that when cattle are fed on concentrates they emit half the methane than animals grazing low-quality winter forage, and put on mass twice as fast.

Range supporters counter with 'What about the greenhouse gasses produced growing and transporting the concentrate? And what about methane from the manure piles?'

Both are partly right, but ending the argument with scientific facts turns out to be much more complicated. You can't just quote from European or North American studies, because the climate, management systems, breeds and feeds are quite different in South Africa. If you really do care about the effects of livestock-sector emissions on the climate and not just scoring points, you have to do the calculation right: using local data, over the full production cycle and for all the greenhouse gasses.

Adding it up

With support from WWF (the World Wildlife Fund) I recently did the sums for farmers in the escarpment grasslands of Mpumalanga and KwaZulu-Natal. The answers challenged all my preconceptions.

The first thing to note is that in South Africa, all beef cattle spend the majority of their lives on the veld. At 15 to 18 months, some are fattened in feedlots for about three months before slaughter. The breeding cows and bulls remain on the veld. So the difference between feedlot and rangefed is not that great, and comes down to what happens to the heifers and steers in those few months. During that period the methane generated from the rumen per kilogram of dressed carcase produced is substantially lower for feedlot cattle. This is thanks to the optimal quality of the diet and the lack of activity of the animals.

In Mpumalanga and KwaZulu-Natal, finishing concentrate feeds are mostly made from the byproducts of the milling and brewing industries, with some minerals, urea and vegetable protein added. Greenhouse gasses – carbon dioxide and nitrous oxide – are produced

during the growing of the mielies and soybeans and manufacture of urea, but less so than in many other parts of the world. The feed is generally produced only a few hundred kilometres away from the site of consumption, so the emissions from road and rail transport are not very large. Nevertheless, the feed-production emissions partly offset the gains from lower enteric emissions. So in the end, it depends on how the wastes are handled.

Manure and urine deposited on the veld produce almost no greenhouse gasses, because they dry out quickly. Animal wastes that accumulate in deep piles, or worse still are washed into pits or lagoons, become waterlogged and generate both methane and nitrous oxide, cancelling the methane-reducing benefits of concentrate feed. On the other hand, if the wastes are mucked-out daily and dry-spread, very little methane is given off. If the waste slurry is put into a digestor, and the methane is burned in place of diesel in a generator, then you actually get a greenhouse credit, and feedlots come out better overall in terms of climate effects than meat produced purely on the range.

On the other side of the fence

Graziers can also do some things to reduce their climate footprint. Surprisingly, eliminating veld fires is not one of them. From a purely climate point of view, when grass is burned it produces less of a global warming effect than if it is eaten by a ruminant or a termite. Producers of free-range beef can supplement the diet of their animals, especially in the winter months, on the veld where the manure does not matter. If they use locally-grown high-protein forages or feeds without artificial fertilisers, they will get some of the mass gain and methane-reducing benefits achieved in feedlots, but can still claim to be an organic and animal-friendly product.

– Dr Bob Scholes

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CLUVA:
Preparing Africa for climate change

Coordinator:
AMRA Scarl, Italy

Participating organisations:

- Addis Ababa University, Ethiopia
- Ardhi University ARU, Tanzania
- Centro Euro-Mediterraneo per i Cambiamenti Climatici Scarl CMCC, Italy
- CSIR, South Africa
- Helmholtz-Zentrum für Umweltforschung UFZ UFZ, Germany
- Københavns Universitet KU, Denmark
- Norsk Institutt for By-Og Regionforskning NIBR, Norway
- Technische Universität München TUM, Germany
- Université de Ouagadougou UO, Burkina Faso
- Université de Yaoundé I UY1, Cameroon
- Université Gaston Berger de Saint Louis UGB, Senegal
- The University of Manchester UM, United Kingdom.

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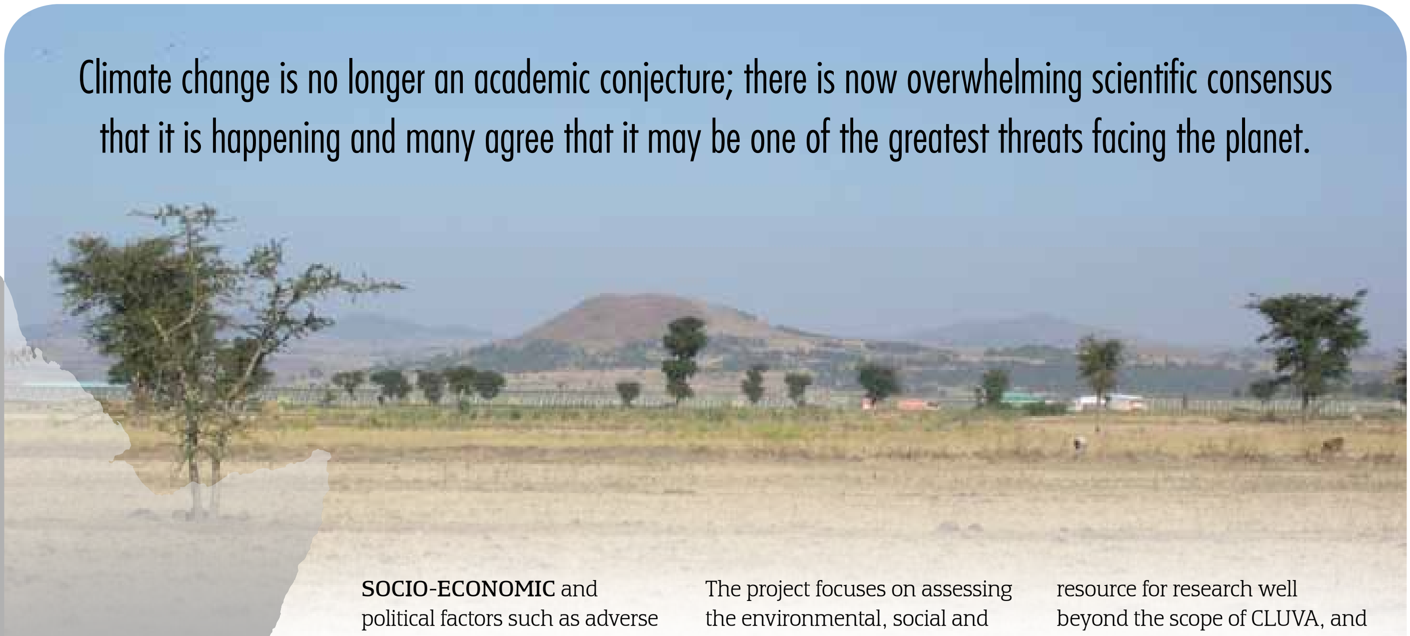
Climate change is no longer an academic conjecture; there is now overwhelming scientific consensus that it is happening and many agree that it may be one of the greatest threats facing the planet.



SOCIO-ECONOMIC and political factors such as adverse policies, extreme poverty, inadequate services and infrastructure, and lack of access to resources, especially natural resources such as water and food, exacerbate the threat posed by climate change.

Although Africa is particularly vulnerable to the effects of climate change, its real impact on a local scale is still poorly understood. CLUVA (Climate change and Urban Vulnerability in Africa) is an initiative funded by the European Union's Seventh Framework Programme (FP7) and brings together experts in information technology, climate, risk management, urban planning and social science from 13 European and African academic and research institutions. The CSIR is one of these African research institutions.

The overall objective of CLUVA is to develop methods and knowledge relevant to African cities. The aim is to manage climate risk, thereby reducing their vulnerability and improving their capacity to cope with climate change.

The project focuses on assessing the environmental, social and economic impacts and risks of climate change-induced hazards likely to affect urban areas. Such hazards include floods, sea-level rise, droughts, heat waves, desertification, storms and fires. Scenarios in five geographically and climatically-different African cities, namely, Addis Ababa in Ethiopia, Dar es Salaam in Tanzania, Douala in Cameroon, Ouagadougou in Burkina Faso and Saint-Louis in Senegal, will be explored as case studies.

The CSIR's contributions focus on three pivotal CLUVA tasks and draws on expertise in climate change, sensor web enablement, geoprocessing tools, and data analysis and experimentation.

The first of these entails the downscaling (to a resolution of approximately 50 km) of an ensemble of four global projections of future climate change over the entire African continent, for the period 1961 to 2050. These projections will be downscaled further to a resolution of about 8 km for regions that cover the selected African cities. This information constitutes a novel and unique resource for research well beyond the scope of CLUVA, and will be hosted at the Very Large Database (VLDB) repositories, housed at the Centre for High Performance Computing.

The CSIR will also develop web-based technologies that provide access to these data sets and derived information. These include climate change maps and statistical indices for the percentage of days with extreme temperature, rainfall intensity, the maximum length of dry or wet spells, and other variables. This information is key to more informed development of climate change adaptation strategies and policy.

Thirdly, the CSIR leads the capacity building work package, aimed at strengthening African research capability in climate change and related fields. Three summer schools and workshops are planned, aimed at fostering knowledge generation and exchange among researchers at Master's, doctoral and post-doctoral levels. The first of these summer schools will be held in Ouagadougou in January 2012, and the second event is planned for South Africa early in 2013.

– Dr Anwar Vahed

Profiling the vulnerability of South Africa's cities and towns to global change risks

Urbanisation of humanity is seen as one of the greatest social, cultural, economic and environmental transformations in history, with African urban growth (3.3%) the highest in the world. This is according to the UN Habitat's State of the World's Cities 2008/2009 report.

CSIR researchers in urban and regional planning, climate studies and modelling and sustainability science are spearheading the *South African Risk and Vulnerability Atlas*. Team members include (from left): Dr Emma Archer van Garderen, Elsona van Huyssteen and Alize le Roux.

DEVELOPMENT TRENDS in Africa reflect the critical role that towns and cities play in addressing basic needs such as food, water and safety; and providing access to formal and informal networks, services, and employment opportunities.

Towns and cities in South Africa are estimated to be home to almost 70% of the national population and responsible for the generation of 85% of all economic activity. An analysis of functional urban areas suggests that in 2007, the Gauteng city region and the coastal city regions of Cape Town, eThekwini and Nelson Mandela Bay were home to more than 39% of South Africans; and they comprise less than 3% of the land area of the country.

Complex socio-environmental factors and risks such as climate change, surface and groundwater availability, ecosystem vulnerability, land capability and food security, all have an influence on the vulnerability and resilience of cities and towns.

In the South African context, socio-economic factors also contribute to increased risk and vulnerability of cities, towns and settlements. These factors include population growth, increased poverty and demands on services and resources, inequalities, violent crime, lack of employment, service delivery protests, as well as xenophobic attacks.

The key temporal and spatial trends influencing socio-economic factors are also imperative when considering possible impacts of natural and human risks and hazards on socio-ecological systems, the vulnerability of such systems, and coping capacities of different towns, regions and communities.

The vulnerability and resilience of South Africa's settlements are impacted and influenced by a magnitude of multi-stressors. However, very few of these have been explored in terms of what and where the impact would be, and how government, civil society, communities and science and technology could be pro-active in mitigating these stressors.

A need has been identified by key role players, such as the National Disaster Management Centre, provinces and municipalities, the private sector, as well as various research institutions, to understand the complex relationship between the multi-stressors through science-based investigations.

Within the platform of the South African Risk and Vulnerability Atlas, CSIR researchers in urban and regional planning, climate studies and modelling and sustainability science, are spearheading an initiative to understand what makes regions and settlements in South Africa either more vulnerable or resilient to global change risks.

The CSIR's planning support systems group combines various information sets (e.g. population growth patterns, migration trends, population densities, economic dependencies and inequalities) by making use of its innovative, updated geospatial analysis platform (GAP, 2011). Researchers then apply advanced spatial analysis and integrated planning concepts and tools to understand, determine and quantify South Africa's socio-economic patterns, pressures and multi-stressor areas. Some preliminary graphics represented in Figure 1 illustrate South African settlements susceptible to projected extreme rainfall events.

The first step in planning for resilient communities and addressing high levels of susceptibility is to profile and understand the social and economic risks, vulnerabilities and coping capacities of different areas, regions and settlements. As such the CSIR's planning support systems group provides the Atlas with updated information on South Africa's human settlements and socio-economic pressure areas.

Areas that are socially vulnerable are typically identified in communities with disparities in income, high levels of poverty, high illiteracy rates, age dependencies, political instability, high population concentrations, ethnic minorities, single-headed households and limited access to livelihoods and services (see Figure 2).

Economically pressurised areas are usually grant-dependent areas, with declining economies, service delivery backlogs, high unemployment and inequalities. Indicators and information in this regard published through the Risk and Vulnerability Atlas will support researchers and decision makers to anticipate and mitigate risks in vulnerable settlements. This will provide a start in answering pertinent questions about the country's economic assets and socio-economically distressed areas.

– Alize le Roux and Elsona van Huyssteen

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THE SOUTH AFRICAN RISK AND VULNERABILITY ATLAS PROJECT is being implemented by the CSIR on behalf of the Department of Science and Technology, with key inputs from South African research institutions and groups. Dr Emma Archer van Garderen and Dr Bob Scholes of the CSIR are the Atlas project leaders. Based on a shared platform, the Atlas provides access to a large collection of scientific data and knowledge in and about South Africa, in addition to the basic Atlas data sets (see http://www.rvatlas.org/).

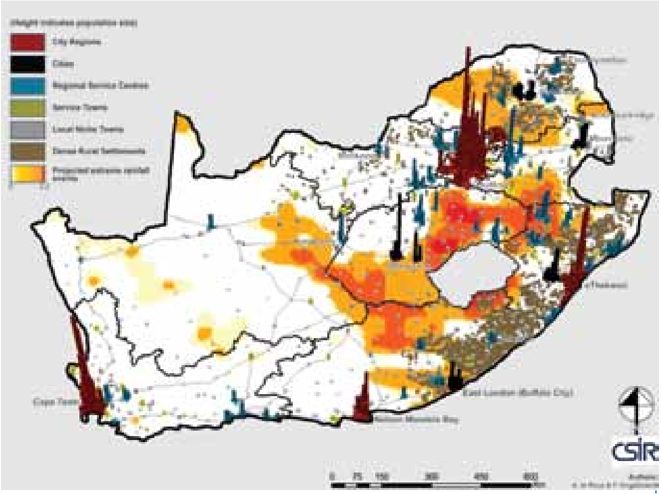

Figure 1: A map depicting the total population in 2007 (height of bar graphs) of various South African settlements (source: CSIR mesoframe 2010) and the projected change in the frequency of extreme rainfall events. Such events are defined as 20 mm of rain or more that occurs within a 24-hour period per 50 x 50 km² grid box, for the near-future period, 2011-2040, relative to 1961-1990 (source: CSM&EH). Units of the rainfall variable are the number of rainfall events per grid box per year.

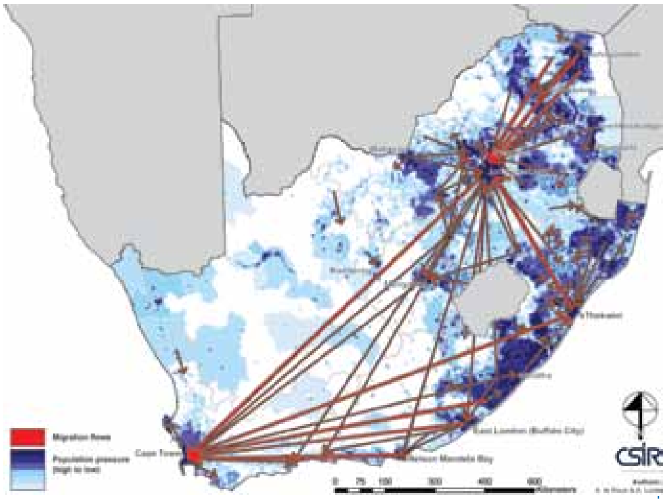

Figure 2: South Africa's biggest areas of population pressure, based on high population growth from 2001-2007 and current population densities (source: CSIR mesoframe 2010 & StatsSA 2007). The red arrows indicate the internal migration/movement of registered voters during the period 1999 to 2009 (source: IEC 2010 & IPDM 2010).

Building the resilience of vulnerable coastal areas against climate change impacts

Southern African states have very little adaptive capacity and their ability to halt coastal impacts on a large scale is virtually non-existent. Simple adaptation practices, implemented sooner rather than later, can reduce the potential impact by factor 10 to 100, and at a fraction of the cost compared to damage avoided.

HOWEVER, West Indian Ocean countries need to understand the adaptation options available, and that these are considerably different from typical first-world approaches, according to CSIR coastal engineering researchers André Theron, Marius Rossouw and Laurie Barwell.

Having worked on a number of projects along the southern and south-eastern Africa coastline, they assessed and mapped those areas most vulnerable to climate change. Combining coastal engineering skills with geographic information systems (GIS) and numerical wave modelling (Figure 1), they then identified sustainable as well as environmentally friendly adaptive and cost-effective protection measures for vulnerable areas in the context of future hazard scenarios.

What can these vulnerable coastal areas expect over the next 50 to 100 years?

The coastal zone of the southern Western Indian Ocean region is particularly vulnerable to the expected impacts of climate change. Contributing factors include vast low-lying coastal plains such as delta coasts; high population concentrations in close proximity to the sea; poverty; and little capacity to defend infrastructure, says Theron.

This situation is aggravated by direct exposure to high wave energy regimes in some parts and a potential increase in cyclone activities. Large numbers of the local populations also rely heavily on goods and services and economic benefits provided by the coastal zone.

When looking at the previous few decades, observations show that, since 1993, global sea levels have risen by about 3 mm per year. Looking to the next 50 to 100 years, projections for 2100 are in the 0.5 to 2 m range. Also, a potential 10% increase in ocean wind strength may lead to a potential increase of 26% in wave height, resulting in potential increases in sediment transport rates of 40 to 100%, impacting on coastal stability. Furthermore, while about two cyclones per year currently enter the Mozambique Channel, a possible southward shift of the cyclone belt, due to climate change, would mean an increase in the occurrence of cyclones in south Mozambique and the north-eastern parts of South Africa's coastal regions.

Safeguarding vulnerable coastal areas

Applying realistic scenarios of future coastal conditions (winds, waves, currents, extreme events and sea level rise) under climate change and the potential effects, the researchers developed specific adaptation measures and coastal protection options for developing countries to mitigate the physical impacts of climate change.

While some of these measures involve straightforward management options, others

Adaptation measures

Right: Example of hard engineering and armouring: constructing sloping, vertical or curved concrete seawalls.

Right: Example of 'local knowledge accommodation' – increasing resilience by raising property and building structures on pillars. Soft engineering or restoration options include:

- Sand nourishment – pump extra sand onto the beach to build it up and reduce wave impacts and flooding
- Manage dunes by establishing or reinstating the dune vegetation
- Manage and rehabilitate mangroves, corals and wetlands as natural protection.

focus on a soft engineering or restoration approach, and hard engineering or armouring options.

Management options include:

- Accept and retreat – this means repositioning of infrastructure that is at risk; preventing future developments by instituting zoning or set-back lines; and resettlement of vulnerable communities.
- Abstention – this is the 'do nothing' option if the risk of loss of property or human life is very minimal.
- Alternative coastal developments that will be 'safe' from climate change impacts.
- Accommodation – increasing the resilience of existing infrastructure by, for example, raising property or building structures on pillars.

Where the potential impacts of high energy waves are going to be less, options include protecting the shore with sand-filled geotextile containers, or rock-filled wire basket and mattress structures.

– Wiida Basson

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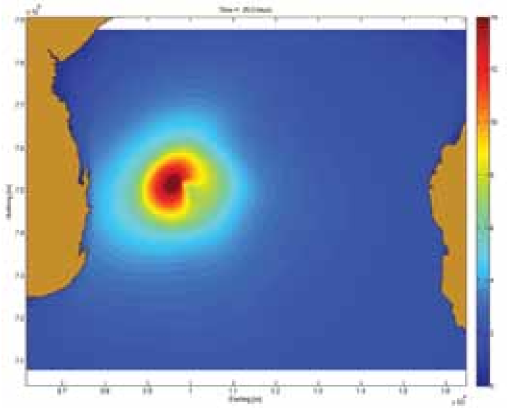

Figure 1: Cyclone-generated wave field in the Mozambican Channel approaching the Mozambican coast

"For us living on small islands and on the coast, climate change is not an academic exercise – it is a clear and present danger. In fact it could well become the most dangerous weapon of mass destruction because it could wipe us out as nations."

– Dr Nirmal Shah, President of Western Indian Ocean Marine Science Organisation (WIOMSA)

CSIR coastal engineering researchers André Theron and Marius Rossouw. Insert: Laurie Barwell.

Hard engineering and armouring options include:

- Sloping, vertical or curved concrete seawalls
- Concrete/rock revetments
- Dikes
- Perched beach structures – this is an artificial option to keep the upper part of the beach profile in place
- Shore-parallel structures, for example artificial surf zone reefs, detached breakwaters, rock berms
- Groynes to trap sediment
- Beaches of very coarse sand, gravel or cobbles to dissipate wave energy and erosion
- Coastal flood control gates in 'enclosed' areas such as river mouths and small bays.

Right: Example of hard engineering option where the potential impacts of high energy waves are going to be less: rock-filled wire (Gabion type) basket and buried Reno mattress structures.

Members of the CSIR's urban and regional planning team involved in the EnerKey project (from left): Alize le Roux, Maria Coetzee and Tsepang Leuta.

Exploring the correlation between Gauteng's urban form and its carbon footprint

South Africa has to find ways to address the needs of urban dwellers in large, rapidly-growing and mainly poor cities in such a way that the interdependence between cities and their ecosystems is taken into account. A key research focus is to investigate how a city's physical form and infrastructure affect its sustainability.

THESE CONCEPTS have been identified by the Department of Science and Technology (DST) as some of the greatest challenges facing urban planners and developers in the 21st century. Furthermore, South African cities are exceptionally dispersed in comparison to urban forms in most developed and developing countries.

Maria Coetzee of the CSIR comments: "The 'energy hungry' Gauteng is regarded as the engine of the South African economy. It generates 33.6% of all economic activity in the country on 1.5% of the land area and is home to 22.4% of South Africa's population. Urban mobility is critical for securing livelihoods, but is also a key factor in environmental damage. Transport accounts for more than 35% of energy consumption in Gauteng."

"Reducing energy consumption in the Gauteng City Region as well as other metropolitan regions is thus imperative," stresses Coetzee, who heads urban and regional planning at the CSIR. Spatial planning is widely acknowledged as a critical instrument for impacting urban form and related sustainability.

The move towards cities with a lower carbon footprint is on the agenda of a number of South African entities, including the National

Planning Commission, the Gauteng Green Inter-Ministerial Committee, the National Department of Transport and the CSIR.

CSIR researchers are using synergies between the DST-funded Integrated Planning and Development Modelling (IPDM) project, and the Gauteng-focused EnerKey project to generate quantitative evidence on the relationship between urban form and the energy demands of Gauteng. This enables the CSIR to make well-grounded assessments of the desirability of different land-use and transportation scenarios.

EnerKey is a joint venture between Germany and South Africa aimed at developing and implementing innovative pathways and projects in urban energy supply and use. The focus is on improving the sustainability of the Gauteng City Region by reducing its energy demand and resultant CO_2 footprint.

"EnerKey and the IPDM have specific strategies and implementation frameworks. It is imperative to integrate the research and modelling elements of these two initiatives, especially with the EnerKey project concluding in 2013," says Coetzee.

The urban dynamics laboratory (UDL) of the CSIR will be used to simulate and model spatial policy scenarios for EnerKey. "The results will demonstrate the impact of future urban form on the energy consumption and carbon emission patterns for Gauteng," explains Dr Louis Waldeck, who heads the UDL and manages the CSIR's planning support systems.

The UDL facility equips trans-disciplinary teams of researchers and stakeholders with tools and methodologies to numerically model and simulate cities and regions as complex systems. The CSIR will develop two spatial scenarios for Gauteng, to evaluate future implications of compact versus sprawling urban form, and the transportation needs associated with such city forms.

"Our German peers will add their energy-related information to our socio-economic information to determine the energy footprints of different spatial scenarios over a 30-year period. The CSIR should ensure that its urban simulation is able to evaluate policy proposals and add value to existing policy and research endeavours," Coetzee notes.

Coetzee has been serving on EnerKey's long-term perspective working group for the past two years. The group has representation from Germany and South Africa, including research and academic institutions, implementing agents like energy providers and distributors, as well as industry and commerce. Key local players represented are the Gauteng provincial government, the city administrations of the Johannesburg, Ekurhuleni and Tshwane metros, and NGOs active in the energy field. Dr Ludger Eltrop of the University of Stuttgart is the German lead partner of the EnerKey project. Professor Harold Annegarn of the University of Johannesburg is his South African counterpart.

"The transformation to a lower-carbon future requires many changes of a technical and political nature, but passion is a key ingredient for the people who will see it through. It is my opinion that, without passion and enthusiasm, not even the best science or the most progressive political changes can or will be 'sold'," concludes Coetzee.

– Hilda van Rooyen

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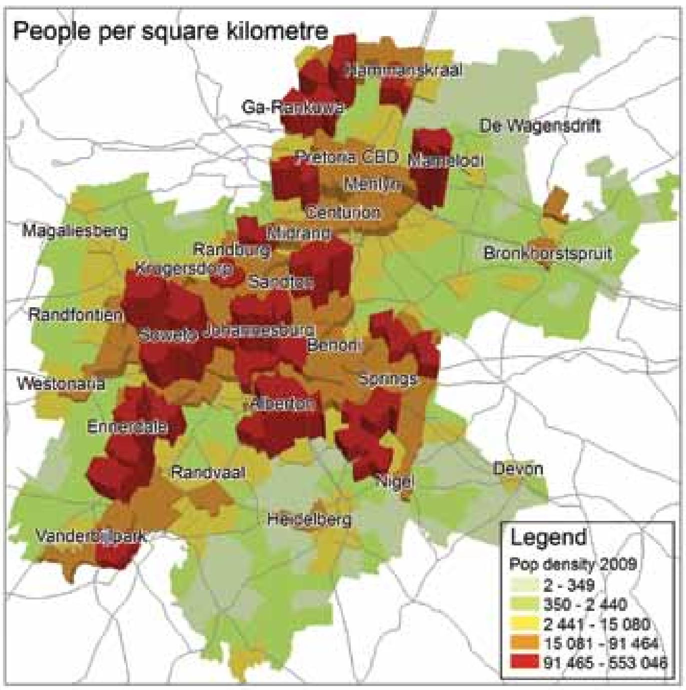

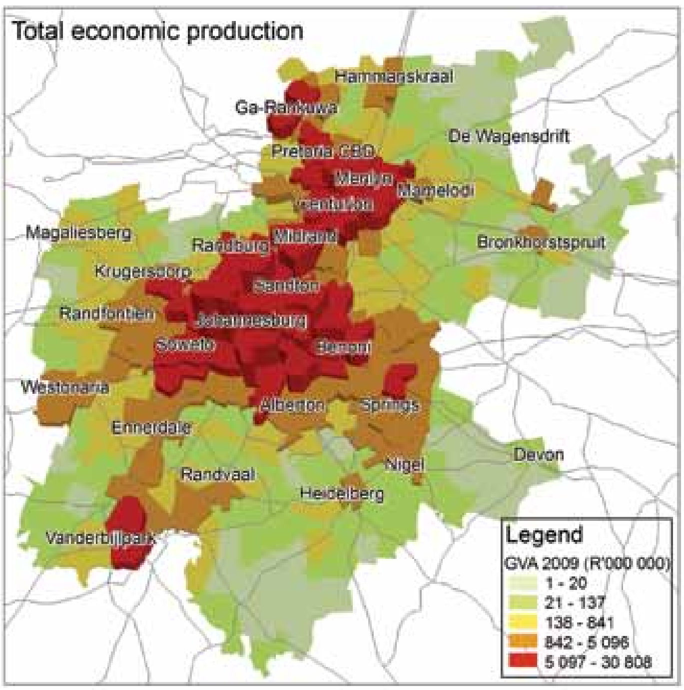

Understanding the science of the kalabash – empowering local rural communities to weather the impacts of climate change

The CSIR has been working with VhaVenda communities in the Vhembe Biosphere Reserve in Limpopo since 2009 as part of a European Union Seventh Framework Programme project called LiveDiverse. Research focuses on the interface between biodiversity and the livelihoods of communities who live in or close to a biodiversity hotspot. More specifically, the CSIR has been involved in understanding the role of beliefs, perceptions and attitudes towards the natural environment, and the influence these have on people's day-to-day activities.

THE VHEMBE Biosphere Reserve has a relatively large and rapidly growing human population, most of whom rely heavily on their close relationship with natural resources for their livelihoods. This close relationship, coupled with a high unemployment rate, results in negative impacts on natural resources which are used for energy, food, medicinal and other purposes.

A cultural understanding of climate change

Our interaction with rural VhaVenda communities has given us valuable insights into how people understand the change in their climate (if they see such change), what they think the reasons for this are, and how they respond to it. For some, especially the elderly, the reasons for climate change do not necessarily echo western scientific explanations or solutions. For example, Gogo Muntshieka from Mbahela explains why she thinks rivers are running dry:

"*In the old days the river did not run dry and the trees were very big. These days the river gets dry and the trees are not as big. These days there is less rain but I do not know why there is less rain. The rivers are running dry because people are using the wrong vessel to draw water from the river – they should rather use the kalabash. In the old days we were taught that you must use the kalabash; if not, then the river will run dry. These days people use plastic jugs and things like that, it's easier. Or the clay pot, some people also use a clay pot but many don't use the clay pot anymore because it breaks easily.*"

While Gogo Muntshieka may be talking about ideas and beliefs foreign to the scientific mind, she does give us some very significant information.

As a young girl her grandmother would teach her how to prepare the kalabash or make the clay pot so that she could draw water in the correct and culturally appropriate way. These life lessons have, however, faded into insignificance as cell phones and satellite television became important. Gogo Muntshieka tells us that she sees the climate is changing by telling us that the river is getting drier more often and it rains less and less.

A Mbahela woman draws water with a pot and plastic bucket from a local spring in the village.

The Mutale River flows a few hundred metres from Mushithe Village. As the village has poor water supply, many villagers use the river water for everyday household activities such as washing clothes.

Families in Thondoni and Beleni rely on firewood for fuel to cook food and to keep warm. Children often help to fetch the wood, although this is usually the women's task.

Mbahela women sorting mielies (maize).

But, not only does she talk about the fact that the climate is changing, she also speaks about a changing society where ways of dealing with a changing natural environment are no longer shared between generations.
It is important for us as scientists to understand this, especially in relation to rural communities' resilience to these changes.

Impacts of climate change on rural communities

Since rural communities often depend in a very direct way on cash crops, unimproved water sources and other natural resources, they are highly vulnerable to change and extreme events. Changes in the climate directly affect their sources of livelihoods, for example:

"*There is less rain now than what there used to be, which means people can grow fewer crops. People used to grow spinach, now they can only grow maize and beans. There are also fewer cattle because of drought, and many cattle die because of drought. The number of trees has also decreased and some trees are dying because there is not enough rain and because people cut them down" (Anonymous, Thondoni Village).*

For many community members the change in their natural environment, be it more or less rain, the increased incidence of natural disasters, or just a more pronounced lack of food, is expressed through a growing need for help. For example, communities' dependency on government is increasing:

"*Given that there are fewer food crops now, people go to other communities for help. We also depend on child and pension grants. Community members do not help each other because they do not trust each other and because they do not have enough food even for themselves and therefore find it difficult to help others" (Anonymous, Beleni Village).*

Community members' capacity to help one another is also decreasing:

"*When there is a drought we cannot do anything. If you have run out of food you cannot go to another house and ask for food. That food belongs to that house... enough for them, if you give to others then you won't have enough for yourself" (Anonymous, Mbahela Village).*

These vulnerabilities can be reduced through a combination of scientific knowledge and local knowledge. Local crop types and cultivars as well as livestock may not always have the production potential of genetically modified commercial options, but are often resistant to disease and resilient in extreme conditions. Local knowledge about when and how to plough, which fruit and firewood to harvest and which areas are sacred, is not always explained in scientific language, but often underpins sustainable harvesting and production. In this context, it is important to understand local customs and practices, as well as vulnerabilities before development options and adaptation mechanisms can be suggested.

Local knowledge combined with science can underpin sustainable harvests

In Mbahela we found a good example of how local and scientific knowledge can work together. In this village a group of emerging farmers, together with scientists from the Limpopo Department of Agriculture, worked to produce a drought-resistant maize seed. By combining local knowledge and scientific know-how the community can now not only respond to drought in a better way, they can market this knowledge, sell it and thus supplement the village income.

Climate change is a very real fact of life for rural communities, emphasising the necessity to equip them with the skills and knowledge to respond effectively. These skills and knowledge not only refer to better science regarding how we monitor the changes in the environment; but also how these impacts will affect communities; how one can better inform communities about these impacts; and how science can contribute to preparing communities to respond to these changes in sustainable ways. This is indeed a multi-dimensional and complex challenge for scientists.

– Karen Nortje and Dr Marius Claassen

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Climate change and human health: **how vulnerable are we?**

"Climate change affects every aspect of society, from the health of the global economy to the health of our children. It is about the water in our wells and in our taps. It is about the food on the table and at the core of nearly all the major challenges we face today." – UN Secretary-General Ban Ki-moon

INCREASING TEMPERATURES, rising sea levels, changing patterns of precipitation and more frequent and severe extreme weather events are expected to have a significant impact on key determinants of human health. These include clean air and water, sufficient food and adequate shelter.

Climatic changes over recent decades have probably already affected some health outcomes. According to the World Health Organization (WHO), climate change is claiming over 150 000 lives annually. The extent and nature of climate change impacts on human health vary by region, by relative vulnerability of population groups, by the extent and duration of exposure to climate change itself, and by society's ability to adapt to or cope with the change.

Who are the most vulnerable?

Potentially vulnerable regions include the temperate latitudes, which are projected to warm disproportionately, such as sub-Saharan Africa, and sprawling cities where the urban heat island effect could intensify extreme climatic events. Sub-Saharan Africa is particularly vulnerable to health effects from climate change as a result of poverty, a high pre-existing disease burden, fragmented health services, and water and food insecurity.

Local health risks

In South Africa, the most talked-about climate change-related risk to human health is a changing pattern in the distribution and severity of malaria. This is understandably so since malaria is a life-threatening disease. However, there are other important risks requiring our urgent attention if we are to protect the health of our population in a changing climate.

Too much exposure to solar ultraviolet radiation can be harmful to our eyes, skin and immune system. For example, if the temperature increases beyond what is normal, the body is unable to cool itself and heats up, resulting in heat stress. Affected people may suffer heat cramps, heat exhaustion and ultimately a stroke, which could, without proper treatment, lead to death.

Near-surface ozone is a harmful pollutant and exposure to low levels is known to cause respiratory problems and worsen asthma attacks. Exposure to high amounts of ozone can cause permanent lung damage and increases the risk of death from heart or lung disease.

Mitigation and adaptation

CSIR scientists are working to address the current lack of long-term, high-quality data on climate change and health, which hampers our predictive capability, and the implementation of mitigation and adaptation measures. A project team is currently preparing maps to describe environmental health risks in southern Africa. These maps will assist decision makers to make informed choices to safeguard the lives of the region's people.

The maps will soon be available on the website of the *South African Risk and Vulnerability Atlas* (www.sarva.org.za)

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Water governance

Dr Harrison Pienaar recently joined the CSIR as competence area manager of the Ecosystems Services research group after having played a major role in putting together an integrated response to the challenges facing the water sector while serving as chief director at the Department of Water Affairs.

In Africa, climate change is impacting within the context of an already stressed continent. While these impacts are continent-wide, the location, magnitude, quality and duration will vary from region to region. This implies a flexible approach, prioritising vulnerable and sensitive spots such as coastal areas, tropical forests, wetlands and those regions that are already experiencing food insecurity.

THE VARIABILITY of impacts facing Africa will necessitate variable and flexible policies and measures. Apart from improving our understanding of climate change issues, water will have to be at the core of any development strategies. This implies inter and intra institutional cooperation, and making good quality data available on climate change drivers such as water availability (hydrology, groundwater, infrastructure and water quality) and water requirements (demand, hydropower and environmental in-stream flow requirements) at trans-boundary and regional levels.

Water governance in the South African context

There is general consensus that, apart from a few uncertainties, climate change science is sound. The challenge is to translate the science into useful information, particularly around areas of impact. People need

and climate change

to know and understand the spatial or geographic impacts affecting them; how the impacts will manifest; who is likely to be the most vulnerable and what needs to be done.

The South African government has set in motion a framework which presents an overall strategic intent and direction for the water sector, covering at least 30 years. However, the desired outcomes of this framework will only be realised through the implementation of the national water resource strategy (currently being revised by the Department of Water Affairs, DWA) which outlines how water demand and supply must be reconciled at national level, as well as the development of catchment management strategies to assist with water management at catchment level.

The dreaded 'I' word – implementation – across the different sectors is critical. In this regard communication is crucial, as different key sector role-players all have equally strong mandates (which often overlap with one another), enabling them to give effect to the concept of integrated water resources management (IWRM).

Four key phases of water management

The overall approach towards achieving IWRM in South Africa illustrates the importance and consideration of four key phases of water management. Firstly, the determination of the water balance through an assessment of the current water availability which also take into account the ecological water requirements. At the same time, water user requirements are being considered, though with limited stakeholder involvement as part of this phase.

Secondly, the detailed evaluation and activities linked to water resource classification, with much greater public participation compared to the limited consultation exercise in the preceding phase. Information on water resource management options, including future water use projections, will inform how stakeholders deliberate and agree on water classification scenarios and subsequent water management plans.

Important source documents on water, such as the national water resource strategy (NWRS), and catchment management strategies (facilitated by DWA), will serve as a good basis for more informed stakeholder participation during this phase, including biodiversity overlays such as the national freshwater ecosystems protections areas (NFEPAs) that are being established through the Department of Environmental Affairs.

The outcome of this phase would be a water allocation schedule (in consultation with stakeholders) comprising a water resource management class, which outlines how much water can be allocated to different water users and how much water must be kept in the system to maintain ecological sustainability.

Thirdly, intervention measures such as compulsory water use licensing, water conservation and water demand management (among others) are necessary to achieve the recommended water resource management class and allocation schedule, particularly in areas that are water stressed. During this phase, various additional mechanisms can also be considered to realise the water allocation schedule that has been determined following a vigorous water resource classification process.

These mechanisms can include new water resource development (i.e. water resource infrastructure), the setting of

resource quality objectives and decision-support tools such as water resource modelling systems.

The final phase is an adaptive management approach whereby ongoing monitoring, evaluation, compliance and enforcement activities provide for sound management of the entire process. The effective application of key activities such as the conducting of resource quality audits and the application of source-directed controls will eventually result in continuous improvement of the water balance (phase one).

Facing the implementation challenge

It is obvious that the effective operationalisation of these key IWRM elements will require considerable time and resources, including close collaboration between various key water sector role-players. All four phases would also require a great deal of research and development support as water management often depends on innovative solutions (such as water supply and water treatment technologies), especially in a country like ours where available water is scarce.

A concerted effort from various sectors is required to respond to climate variability and climate change impacts. While various IWRM elements consider certain intervention measures, the establishment and rollout of a climate change water sector response strategy (currently being developed by DWA) makes provision for a focused, comprehensive and proactive response to climate change and variability. However, sector-specific recommendations outlined in the Working for Growth and Development framework already pave the way for climate change response action plans. Lastly, buy-in of stakeholders in finalising the water sector response strategy is critical.

Already there appears to be consensus among key water sector role-players that adaptation and mitigation should be the cornerstone of a water sector response strategy with adaptation issues likely to be the predominant forms of intervention for the water sector. This response strategy would therefore aim to understand risks, vulnerability and implications for ways in which demand and supply issues need to be balanced in the overall water management system.

It is also recognised that climate change has implications for future costs and investments in either existing infrastructure or the development of new infrastructure. Therefore, the implications need to be quite substantial for appropriate finances and investments to be mobilised. Early decisions now will save significant costs in the future.

Lastly, some research gaps that require immediate attention would be to identify the best entry points for adaptation and mitigation measures, including the assessment of socio-economic impacts of climate change, especially on the livelihoods of the poor.

– Dr Harrison Pienaar

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Overcoming complexity and sustainability issues key to SA's water future

Even without climate change, South Africa faces critical water issues, especially with regard to institutional capacity and regulation. What do current scenarios predict South Africa might look like by the year 2025, when faced with added complexities such as climate change and increased demand for water for development?

FUNDED BY the Water Research Commission, CSIR water resource governance specialists identified the most critical drivers that will play a role in the way we handle the impacts of climate change, and developed a scenario game board for the country's water sector institutional landscape by 2025.

The key, and pivotal, uncertainties were identified as complexity and sustainability:

- Complexity: the ability of the decision-making paradigm to deal with complexity versus failing to deal with it by milling around in circles. This factor is determined by the number of factors, the rate of change of those factors, and the ease of identification of the factors in any situation.
- Sustainability: being keenly sensitive to sustainability issues versus exploitation regardless of sustainability, where sustainable development is defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs.

Based on these key uncertainty factors, researchers developed four scenarios, each with its own story to tell:

Decision-making paradigm deals with complexity

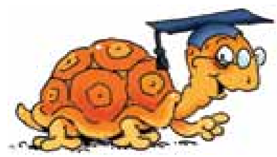
Exploitation regardless of sustainability

Keenly sensitive to sustainability issues

GREEDY JACKAL SCENARIO

This represents a landscape where the decision-making paradigm deals with complexity but exploitation continues regardless of sustainability.

WISE TORTOISE SCENARIO



The decision-making paradigm deals with complexity, and is keenly sensitive to deal with sustainability issues.

IGNORANT OSTRICH SCENARIO

There is exploitation regardless of sustainability and the decision-making paradigm fails to deal with complexity.

BUSY BEE SCENARIO

There is a keen sensitivity to deal with sustainability issues but the decision-making paradigm fails to deal with complexity.

Decision-making paradigm fails to deal with complexity

The story of the Greedy Jackal

In this scenario water is scarce. Resources are running dry in a country that is still in the process of development and addressing backlogs. As such, the government is chiefly concerned with pandering to the social and economic demands placed upon it, and, as a result, represses any pressures for environmental responsibility.

However, the prevailing mindset is anything but fatalistic. Something must be done, and a multidisciplinary approach is agreed upon. Learning is not through testing, but by doing. This is evident in increasing discourse around trade-offs, such as the sharing of resources, efficiencies and co-operations.

Conflict increases between competing users, and the ideal has to be compromised at times to satisfy specific interests, be they economic, social, agricultural or even political.

There is little agreement among stakeholders, and any decision making is fragmented further by the vocal interference of lobby groups who seize the opportunity to pressurise malleable components of the decision-making process towards satisfying specific interests.

South African citizens are confronted with tough decisions and are forced to rethink their former cavalier attitude towards water. This is indeed a bitter way to learn about the critical nature of this limited resource.

In frustration they turn to the government, who they see as the ultimate authority in the management of water. The government in turn centralises control and, in frustration, and unable to implement preferred measures, suspends the Water Act.

The story of the Ignorant Ostrich

The driving feature of this scenario is the government's incapacity to prioritise water as central to development and the rush to implement short-term and imbalanced solutions to the ever-growing challenges of a developing nation.

In this scenario the forces entrusted with the management of water (the government) have a poor understanding of the concept of sustainability. They have 'more important issues' on their plate. There is frustration around general delivery.

Around water, people want taps, and they want them quickly. Little concern is afforded to the security, maintenance, quality and longevity of the supply. As a result, the government has been forced to make quick, and often rash, decisions surrounding water issues, hoping to secure quick results. The concept of sustainability is lost in the rush.

Political and social imperatives for job creation and social and economic growth take precedence, with a view to 'improving the quality of life'; and when decisions are made they are designed to secure as much as possible as quickly as possible.

In an attempt to accelerate delivery, work is going to the private sector (often via costly tender processes), which in turn increases complexity in the system and, subsequently, leads to higher transaction costs.

The combination of a weak understanding of intergenerational equity and a lack of common vision, combined with an unyielding quest for short-term benefit has placed a stranglehold around any considerations of sustainability for the water sector; and as what water is left in the system bleeds out, the ostrich that has not seen the danger signs, takes its last breath.

The story of the Wise Tortoise

A paradigm shift has occurred. There is no isolated and singular 'water sector'. Instead, it is a multi-layered and diversified composite of different sectors all actively engaged in water as a resource of strategic importance.

This has been achieved through the increased harmonisation of legislation and is guided by a shared, principle-based vision. This means a reduced transaction cost, and more tools are used other than just command and control.

There is now a state of institutional maturity and stability, one that recognises legal plurality and alignment with a confidence to embrace flexibility; it is, in essence, an enabling environment that allows informal governance to work. Moreover, it harnesses indigenous knowledge, values and decision-making processes. Strong decentralised systems allow for local regulation, and for local impacts to be addressed.

As people become more empowered to make choices and decisions, a strong citizens' voice starts to emerge. Combined with successful incentives, this has encouraged accountability by all stakeholders, from individuals through corporations and up to government.

A tortoise will prosper when it has a complete understanding of its environment, and allocates the correct resources timeously, with great thought, and with conviction. In this scenario, a common understanding and awareness by all stakeholders has led to the appreciation of the true value of water to self and to others. It is recognised as both a social and an economic resource, but more importantly a finite one, which should therefore be protected and carefully managed. The environment flourishes, providing a sustainable resource of clean and re-usable water.

The outcome of this scenario is a happy and prosperous people.

The story of the Busy Bee

This scenario is characterised by noble intentions but a failure to correctly execute requisite actions. Part of the reason for this is a distorted perception of the state of affairs.

The country has enough water – or so it seems – and there is a genuine zeal on the part of the government to ensure that it remains so, and that the supply and management, of water is sustainable. The right words are used; suggestions are enthusiastically embraced and there is clear evidence that sustainability is considered a priority. In fact, there is almost an obsession towards developing and displaying a sensitivity towards sustainability at all costs.

Unfortunately, the real picture is not so rosy. There is little economic growth, and social development is slow. The demand for water is growing quickly and problems are hiding just around the corner.

Without any systems thinking in place in management, the levels of dealing with the inherent complexity are low and the consequences of actions are not clearly understood. There is an increasing inability to deal with the unknown, and people within the management system operate in silos with little co-operation or sharing of knowledge.

Similarly, any research that is encouraged is poorly directed, without any clear focus. The passion is there, but it is dispersed and diluted in effect. The resultant knowledge is not internalised; no time is left to reflect on decisions, and there is little in the way of innovation that is, no new ideas to address pressing problems.

The sustainable management of water as a critical resource requires a clear, focused head and a complete picture of the complexity of the system.

This is an extract from *The Water Sector Institutional Landscape 2025*, edited by Dr Marius Claassen. It will be available as a Water Research Commission publication.

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Producing food in a

"The agricultural sector in southern Africa needs long-term planned adaptation strategies to build climate change resilience and ensure that initiatives to address climate change reach all farmers, including the poorest and most vulnerable."

– Dr Constansia Musvoto, CSIR

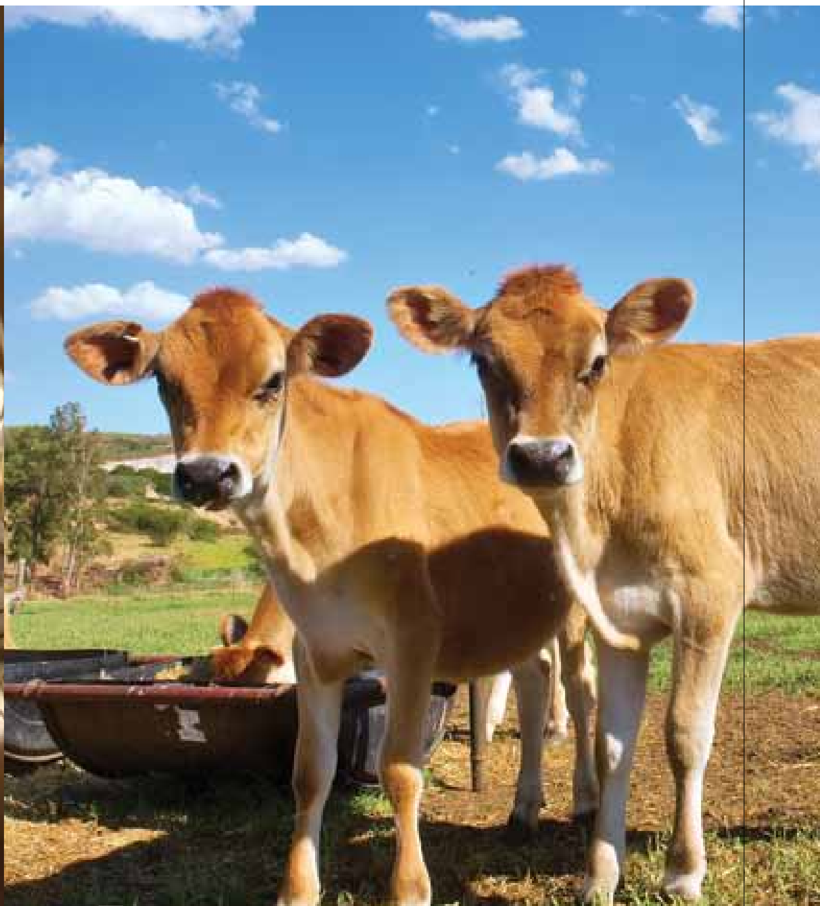
ENVIRONMENTAL RESEARCHERS predict that southern Africa will be severely affected by climate change over the next 70 years, with the possibility of critical impacts on food production in the region. Mounting evidence indicates that growth in food production has already begun to slow due to a range of factors, of which climate stress is one. In 2006, for example, the production of maize, the staple food for the region, fell short by 2.18 million metric tonnes.

Local impacts

Researchers are currently working in a range of locations throughout South Africa to monitor and measure the impact of climate change on food production. A recent study indicates that crop net revenues are expected to fall by as much as 90% by 2100, with small-scale farmers being the most severely affected. Climate change is expected to result in additional price increases for the most important agricultural crops such as wheat and maize.

Research has also pointed to changes in rainfall patterns, such as the likelihood of our rainy season getting shorter. These changes are likely to seriously affect farmers dependent on rain-fed agriculture. Of all the regions in South Africa, the Western Cape has shown some of the most significant impacts in recent times. Farmers are already starting to notice the effects of quicker soil drying and the effects of warming on apple and pear production.

Researchers have found that increased temperatures also impact cattle farming in a variety of ways, most particularly in the area of heat stress. Heat stress can affect feed intake, fertility and pregnancy outcomes, liveweight gain and, under certain conditions, mortality. Different breeds have different



changing climate

thresholds above which they experience heat stress. Locally adapted breeds, often used in more traditional extensive farming systems, tend to be more resilient in higher temperatures.

Access to information

It has become imperative for policy makers to create an enabling environment to support adaptation by increasing access to information and making a particular effort to reach small-scale subsistence farmers with limited resources to confront climate change. Farmers should be advised to start planning for the long term to increase their resilience in responding to climate change.

To assist policy makers in creating this enabling environment, environmental researchers are developing and applying multiple analytical procedures to assess, quantitatively, how climate affects current agricultural systems in southern Africa. The procedures will enable them to predict how these systems may be affected in the future by climate change under various global warming scenarios, and suggesting what role adaptation could play.

The latest research findings are available on the website of the *South African Risk and Vulnerability Atlas* (www.sarva.org.za), as well as in the Department of Agriculture, Fisheries and Forestry's *Atlas of Climate Change and the South African Agricultural Sector: A 2010 perspective.*

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Five main climate change-related drivers

5

– temperature, precipitation, sea level rise, atmospheric carbon dioxide content and incidence of extreme events – may affect the agriculture sector in the following ways:

- reduction in crop yields and agriculture productivity;
- increased incidence of pest attacks;
- limited availability of water;
- exacerbation of drought periods;
- reduction in soil fertility; and
- low livestock productivity and high production cost.

Africa's environmental challenges in the 21st century: **Current and emerging issues**

Vulnerability to climate change varies according to individual countries, geographical positioning and the capacity to mitigate or adapt to the changes.

THE REASONS FOR THIS are not far-fetched: two thirds of Africa is classified as deserts or drylands. These are concentrated in the Sahelian region, the Horn of Africa and large parts of southern Africa, including the Kalahari. Africa is especially susceptible to land degradation and bears the greatest impact of drought and desertification. The majority of the populations in most African countries live on marginal lands in rural areas practising rain-fed agriculture. The current situation of almost unprecedented human suffering in Somalia and large parts of the Horn of Africa due to famine provides stark reminders of these realities.

Impacts of climate change aggravated by land degradation

Desertification threatens agricultural production on these marginal lands exacerbating poverty and undermining economic development. In a recent report, the United Nations Convention to Combat Desertification (UNCCD) estimated that some six million hectares of productive land was being lost in Africa every year since 1990, due to land degradation.

With two-thirds of arable land expected to be lost in Africa by 2025, land degradation currently leads to the loss of an average of more than 3% annually of agriculture GDP in the sub-Saharan Africa region.

Dr Jimmy Adegoke is executive director, CSIR Natural Resources and the Environment.

Both drought and desertification influence water availability, which is projected to be one of the greatest constraints to economic growth in the future.

United Nations Economic Commission for Africa (UNECA), in a 2008 *Africa Review Report on Drought and Desertification* estimated that by the year 2025, nearly 230 million Africans will be facing water scarcity and 460 million will live in water-stressed countries.

Foreign acquisition of agricultural land

While climate-induced drought and desertification continue to pose serious threats to sustainable livelihoods of communities and the economic development in Africa, an equally insidious and potentially dangerous development is the current wave of agricultural land acquisition across Africa by foreign interests.

Seeking new ways to meet the food needs of their populations, a wide range of countries – including China, Kuwait, India and South Korea – have invested heavily in land outside their borders, mostly in sub-Saharan Africa. In the past six years, as global food and oil price increases made it more expensive to import food, Saudi Arabia and other Gulf states began investing in earnest in Ethiopia and Sudan – in excess of $75 billion from 2005 to 2009, according to the Arab Organization for Agricultural Development. These deals are part of a land grab taking place all across Africa, a transfer of control unprecedented in the post-colonial era.

According to a World Bank report released in January 2011, 48% of all land deals struck worldwide between October 2008 and August 2009 involved land in sub-Saharan African countries. The pace of acquisitions has been stunning. The World Bank report revealed that in 2009, some 111 million acres of farmland was acquired globally by foreign investors – nearly 75% of it in sub-Saharan Africa. Prior to 2008, foreign investors only acquired an average of 10 million acres per year.

Reporting in an online news media forum, Ashwin Parulkar disputes the claims by governments and their investing partners that the deals will bring employment, food surpluses and economic growth to impoverished rural populations. He argues that investor interest has been directed primarily at countries with weak recognition of land rights and that local communities are usually excluded altogether from the negotiations.

Reaction from African institutions

African governments are not unaware of these issues or their ramifications for the future of the continent. In 1999 seven Central African nations, hosted by Cameroon's President Biya, produced an agreement over the proper management and stewardship of one of Africa's most fragile ecosystems and the world's second largest rainforest, the Congo Basin Region, to minimise the effects of pollution and climate change.

The development and implementation of National Environmental Action Plans, which were formulated under the auspices of the African Union, were intended to provide the broad policy framework for coordinated management and protection of the environment. They articulate among other things, policy interventions for conservation and sustainable utilisation of natural resources, including land management and integrated resource planning. To support and complement country level efforts, the New Partnership for African Development (NEPAD)/Comprehensive Africa Agricultural Development Program (CAADP) was developed and endorsed by African heads of state and governments as a framework for the restoration of agricultural growth, food security and rural development in Africa.

Lastly, the AU-ECA-AfDB Initiative on Land Policy in Africa sought to address the lack of comprehensive national land policies in most African countries which has been recognised as one of the major factors contributing to many land-related problems such as inequitable distribution of land, mismanagement of land resources, continued existence of land laws that are inconsistent with current needs and delay in transactions as a result of lack of well-coordinated land information system.

In conclusion

Throughout the continent there is growing recognition among Africans that the continent needs to chart its own course in protecting itself against the threat of environmental and economic degradation. The research community also has an important role to play in helping to catalyse, sustain, and strengthen national and regional efforts aimed at managing or mitigating the adverse impacts of these threats.

– Dr Jimmy Adegoke

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recapping

Visit: http://www.csir.co.za/publications.html for previous issues of the ScienceScope

All set for a Battery Research Centre

A BATTERY RESEARCH CENTRE is being set up at the CSIR, edging South Africa one step closer to playing a meaningful role in the advancement of battery research and innovation. The centre aims to find ways of producing batteries that last longer, store more energy, are cheaper to manufacture, and environmentally friendly to dispose of. "We want the centre to be a leading world-class characterisation, testing and battery materials development laboratory that provides state-of-the art research facilities. I believe that the establishment of this centre is just one step closer to the ideal of becoming an energy-efficient country," concludes Dr Mkhulu Mathe, who heads up the CSIR's research group for energy and processes.

• *Read the full story on page 8 of the Energy ScienceScope.*

Exploring a clean development mechanism methodology for biodiesel

FUNDING AND BACKING of the clean development mechanism (CDM) of the Kyoto Protocol could help the biofuel industry to reach maturity and form a sustainable part of the world energy landscape. The CSIR, in collaboration with the Graduate School of Technology Management of the University of Pretoria, undertook an investigation into biodiesel production and how the CDM could enable such production. The study identified six typical embedded CDM projects in the larger biodiesel production process. The study further investigated the CDM regulatory environment for the biodiesel value chain and aimed to propose a consolidated methodological approach for CDM biodiesel projects.

• *Read the full story on page 23 of the Energy ScienceScope.*

Clean coal technology: gasification of South African coals

THE GASIFICATION of coal is only one type of clean coal technology being developed for power generation as a potential answer to reduce its role in global warming. The CSIR has identified integrated gasification combined cycle (IGCC) technology as a potential clean coal technology that could be applied in South Africa to increase efficiency and achieve near zero emissions of greenhouse gasses, which is likely to be a requirement for electricity producers towards the middle of the 21st century. Another reason why the CSIR is concentrating its research efforts on this particular clean coal technology is because IGCC holds the advantage of reduced water consumption and the potential for coproduction of liquid and gaseous fuels and chemicals.

• *Read the full story on page 30 of the Energy ScienceScope.*

Is renewable electricity a sustainable solution for rural South Africa?

WORLDWIDE, renewable energy as a sustainable alternative to 'carbon-intensive' energy sources is a hot topic. The post Kyoto 2012 commitments to low carbon technologies, to mitigate the effects of climate change, are based on renewable energies that are to be supported by a carbon tax. At the same time, the objective of South Africa's Millennium Development Goals is to reduce widespread poverty between 1990 and 2015. This includes the provision of access to energy for all South Africans. In 2003, the Department of Minerals and Energy embarked on a project to test the viability of renewable energy for locations not accessible to the national grid. CSIR researchers tested 'sustainability science thinking' on this project, with the objective of understanding how to speed up the research and implement new energy technologies.

• *Read the full story on page 36 of the Energy ScienceScope.*

Natural fibre composites for construction applications

AS THE WORLD becomes more environmentally aware, the drive towards eco-friendly materials and products has gained momentum. One of the projects that form part of the new strategic investment areas within the CSIR deals with the use of natural fibres in construction products. This initiative seeks to make a meaningful contribution to the concept of bio-based housing. As part of this project, a prototype natural fibre-based insulated sandwiched panel was developed at the CSIR under the leadership of Dr Rajesh Anandjiwala. The project has a strong focus on both materials and application-oriented product development. The roof panel in question is nothing more than a sandwich-type of structure. The structure consists of an expanded polystyrene centre and outer layers consisting of a natural fibre polymer composite.

• *Read the full story on page 62 of the Built Environment ScienceScope.*