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Science for a
sustainable
earth

CSIR

our future through science

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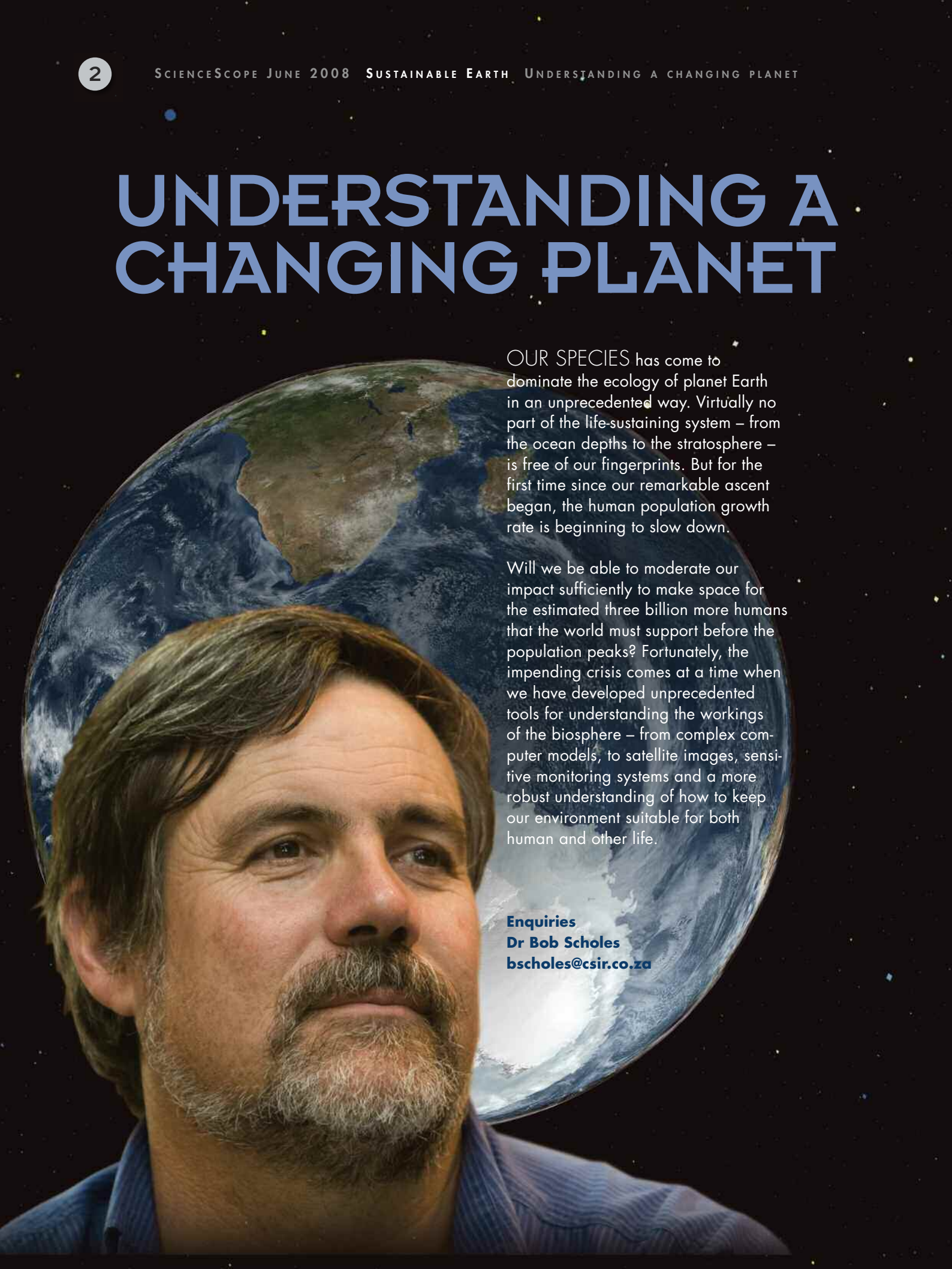
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UNDERSTANDING A CHANGING PLANET

A composite image featuring a man's face in the foreground and a view of Earth from space in the background. The man has brown hair and a beard, looking upwards and to the right. The Earth is shown as a large, curved horizon with blue oceans and brown/green continents, set against a black space background with small white stars.

OUR SPECIES has come to dominate the ecology of planet Earth in an unprecedented way. Virtually no part of the life-sustaining system – from the ocean depths to the stratosphere – is free of our fingerprints. But for the first time since our remarkable ascent began, the human population growth rate is beginning to slow down.

Will we be able to moderate our impact sufficiently to make space for the estimated three billion more humans that the world must support before the population peaks? Fortunately, the impending crisis comes at a time when we have developed unprecedented tools for understanding the workings of the biosphere – from complex computer models, to satellite images, sensitive monitoring systems and a more robust understanding of how to keep our environment suitable for both human and other life.

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Automated land-cover change detection

by Dr Konrad Wessels and Seare Araya

LAND-COVER CHANGE often indicates land use change with major socio-economic impacts. The transformation of vegetation cover (e.g. deforestation, agricultural expansion and urbanisation) has significant impacts on hydrology, ecosystems and climate.

Researchers at the Meraka Institute of the CSIR have taken on the challenge of automated land-cover change detection by applying novel signal processing, time-series analyses and machine learning methods to the problem, using high-performance computing resources. The multidisciplinary research involves computer scientists, electronic engineers, ecologists and remote sensing specialists.

Mapping national land cover with high-resolution satellite imagery takes years to complete, at great cost. The 1995/96 National Land Cover (NLC) and 2000 NLC studies were based on single-date Landsat TM and ETM imagery (30 m pixel resolution) and is frequently used for various spatial planning purposes.

Unfortunately, the 1995 and 2000 versions of the NLC were compiled using very different methods. As a result, land-use and land-cover change cannot be

deduced reliably from a map-to-map comparison of the two dates. An alternative or complementary approach is to use an extended time-series of daily coarse-resolution satellite images (e.g. the moderate resolution imaging spectroradiometer (MODIS) at 500 m pixel resolution), to identify areas of potential land-cover change, which can then be further investigated using high-resolution satellite images.

Despite the coarse resolution of MODIS images compared to Landsat TM and ETM imagery (500 m versus 30 m), the temporal profile of the pixels of various land cover and/or uses provides a distinctive temporal signature or signal. For example, the natural seasonal patterns of green grasslands during the rainy season versus the senescent, brown grasslands in the dry season are very different from the seasonal patterns of irrigated croplands or expanding rural settlements.

For regional applications, these change detection methods need to be sufficiently automated to process very large volumes of data and minimise time-consuming, expert human interpretation. As daily, regional coarse-resolution datasets become more accessible and computational resources become more

affordable, such automated change-detection systems should become more attainable.

Monitoring land-cover change in such an automated fashion has nevertheless remained an elusive goal in environmental remote sensing, as two previous NASA-funded research initiatives have been unable to develop operational systems for the MODIS sensor. It is clear that this can be achieved only through crossdisciplinary research benefiting from the advancements in machine learning, statistics, database technology, high-performance computing, data visualisation and image processing.

Project leader, Dr Konrad Wessels, summarises the team objective as "Interpret the present in the context of the past, in near-real time!" Researchers are collaborating with the Department of Electrical, Electronic and Computer Engineering of the University of Pretoria, the School of Computer Science at the University of the Witwatersrand, the ecosystems and earth observation research group of the CSIR and the CSIR Cluster Computing Centre (C4).

The team was recently joined by Dr Amandine Robin, a postdoctoral researcher from France.

Methods previously limited to the fields of telecommunications and human language technology are now being applied to environmental monitoring, using a time-series of satellite images. The data (or signal) from each image pixel are analysed through time to identify changes within a seven-year period (2000 to present). This requires that very large image archives (in the order of two terabytes) be restructured for efficient per-pixel time-series analyses, initially a daunting feat in itself. Various time-series classification and clustering methods are then used to detect change whenever a pixel's spectro-temporal characteristics changes to that of a different land cover type.

Adapting these techniques to work with remotely-sensed time-series data presents a new challenge to the research community. Moreover, change detection across the entire South Africa has the added challenge of scale and can only be achieved in a high-performance computing environment.

The system has been dubbed 'HiTempo', touting its ability to rapidly perform time-series analysis of hyper-temporal satellite data.

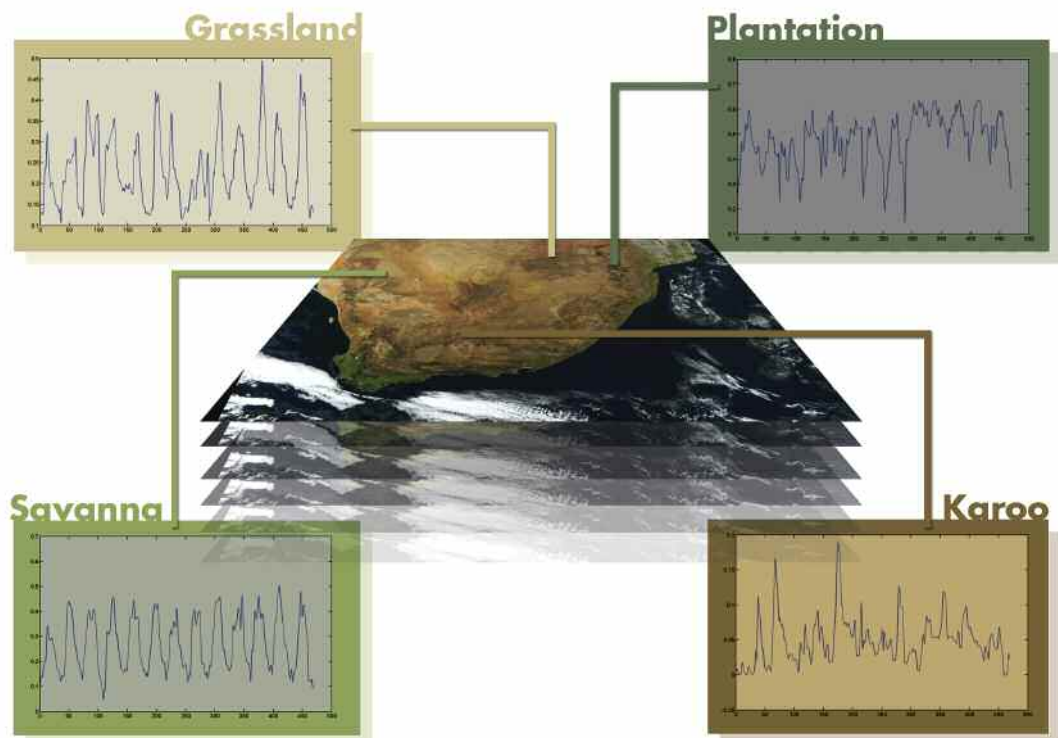
Two major challenges have emerged: Distinguishing human impacts on the land surface from inter-annual rainfall variability; and determining the accuracy of change detection methods, given limited regional validation data, i.e. well-documented examples of known land-use land-cover change.

The issues are being addressed partially by simulating land-cover change, such as informal settlement or cultivated field expansion, by blending the signals

Meraka Institute researchers (front) Waldo Kleynhans and Dr Frans van den Bergh with Professor Corne Olivier (University of Pretoria) (middle left), Dr Konrad Wessels and Brian Salmon, and (back) Seare Araya, Albert Gazendam and Asheer Bachoo



REPRESENTATION OF A MULTI-TEMPORAL IMAGE ANALYSIS



from near-by pixels of contrasting land use from a specific point in time. A database of known examples of land-cover change is also being compiled.

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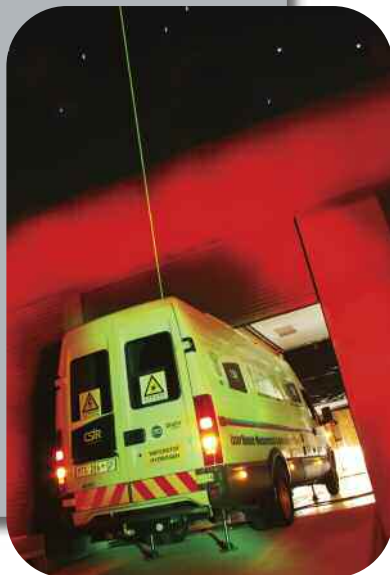
Global climate change

Laser technology for a better understanding of the atmosphere

THE LASER RADAR, more popularly known as lidar (light detection and ranging), is becoming one of the most powerful techniques for active remote sensing of the earth's atmosphere. Using advanced techniques and instrumentation, a mobile lidar system is being designed and developed at the CSIR. Although lidar has been exploited for atmospheric measurements in many countries, lidars in the African continent are limited to two, including the mobile lidar system at the CSIR. This system is primarily designed for atmospheric studies, such as the monitoring of various pollutants in the lower atmosphere that contribute to global climate change and global warming. The initial results conclude that the system is capable of providing aerosol/cloud backscatter measurements for the height region from ground to 20 km with a 10 m vertical height resolution. The measurements will elucidate the aerosol concentration, optical depth, cloud position, thickness and other general properties of the cloud that are important for a better understanding of the earth-radiation budget, global climate change and turbulence. Future plans include qualitative industrial pollutant measurements, 3D measurements using an XY scanner, a two channel lidar system, water-vapour measurements, the implementation of differential absorption lidar (DIAL) and ozone measurements. The CSIR lidar system comprises a laser transmitter, an optical receiver and a data acquisition system.

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Mobile lidar van



Climate change: SA's top technology transfer needs

INTERVENTIONS LINKED to achieving sustainable development goals, such as access to water and sanitation, food security and health are among South Africa's top technology transfer needs in the face of climate change. This is according to a study conducted by the CSIR in which more than 100 mitigation and adaptation technologies were selected by stakeholders and a project team responsible for the compilation of a Climate Change Technology Needs Assessment. The report forms part of South Africa's obligations as a developing country to the United Nations Framework Convention on Climate Change (UNFCCC).

Technology transfer in this context refers to a broad set of processes covering the flows of know-how, experience and equipment for mitigating or adapting to climate change. Stakeholders in this process include governments, private sector entities, financial institutions, non-governmental organisations and research/education institutions.

Methodology for prioritising the technologies was developed specifically for the report and was used to identify the most important technologies appropriate for technology transfer from developed countries. As a result, a prioritisation matrix was compiled with scoring and weighting factors for all technologies.

The relevant role-players and stakeholders are currently engaged in action plans aimed at implementing the recommendations provided in the report.

This information is included in a comprehensive report, titled: *Climate Change Technology Needs Assessment*, available on the web site of the Department of Science and Technology – www.dst.gov.za.

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The carbon cycle: South Africa, the future and beyond

SOUTH AFRICA'S fast-growing economy constrains our ability to mitigate the climate change crisis. Moreover, our country has one of the highest greenhouse gas inventories per unit productivity in the world.

This is according to CSIR archaeologist and carbon isotope expert, Dr Stephan Woodborne. "Carbon gasses are the biggest contributor to global warming and climate change, with carbon dioxide (CO₂) being the main culprit. The dilemma is, however, that CO₂ is the main driver of the world economy through its link to energy production." When load shedding struck the country in late 2007, very few South Africans were relieved to be contributing to lower carbon emissions and to increased productivity, i.e. doing the same or more work with less electricity.

Earth's reservoirs

The distribution of the world's carbon has evolved into a fine balance over a very long time - the entire existence of our planet. This balance sustains life as we know it. In this natural state, carbon exchanges spontaneously between the ocean, the atmosphere, the biosphere (all living entities on earth) and the lithosphere (earth's solid surface and

below) – also known as reservoirs. Since a mere century ago, our post-industrial economy had become reliant on fossil fuels to produce energy. Alas, the burning of fossil fuel accelerates the exchange of carbon from the lithosphere (in the form of coal) to the atmosphere (in the form of greenhouse gases). Small changes in other carbon reservoirs make a big difference in the atmosphere, and the problem lies in the greenhouse effect of atmospheric carbon, Woodborne warns. "The earth is gradually warming and the heat distribution in the ocean and atmosphere is changing with tangible signs such as changing weather patterns. Today fossil fuel has become indispensable to the economy, but devastating to our planet."

CSIR research

Scientists in the natural resources environment, use isotopes to trace carbon exchange processes. "Isotopes of carbon are atoms that are chemically equivalent, but that contain different numbers of neutrons. CO₂, in the atmosphere, for example, will contain the isotopes ¹²C, ¹³C and ¹⁴C, and the ratio between the different isotopes will depend on the source of the carbon," he explains.

Using isotopes to study the carbon exchange between plants and the atmosphere, and plants and the soil, the CSIR is contributing to global climate change modelling by better constraining this part of the carbon budget. It is a complicated business because carbon exchange has an inherent feedback: Changing atmospheric CO₂ affects rainfall and temperature, while rainfall and temperature affect ecosystem carbon exchange with the atmosphere.

Role of the oceans

"Other global-scale processes need to be studied, such as the exchange of gases between the ocean and the atmosphere," Woodborne says.

"Among others, the oceans are absorbing carbon-based gases faster than they belch these out." The ocean is a slow turnover reservoir, which means that some carbon dissolved in the ocean was absorbed thousands of years ago.

Because of the huge amount of carbon in the ocean, any changes in the ocean circulation would be profound. The melting of sea ice at the poles is an indication that something is happening, but exactly what this will do to the atmosphere, is unclear.



A sample carousel for the measurement of isotopes in liquid samples. It is used to measure isotopes of hydrogen and oxygen in water as well as the measurement of carbon isotopes in alcohol



Woodborne agrees with other researchers that the current loss of sea-ice cover at both poles has alarming implications for the carbon budget. "Our research 'looks back into the past' to understand these processes. Radiocarbon is the indicator isotope that gives us the clues. While there is a high level of consensus about the global atmospheric radiocarbon cycle as far back as 26 000 years ago, prior to that time period some interesting contradictions exist. A key event was the release of melt-water into the North Atlantic about 13 800 years ago that led to climatic cooling and a significant disruption of the carbon cycle for the following 2000 years."

Cango caves

The CSIR, through its association with the Department of Science and Technology's Africa Centre for Climate and Earth System Science (ACCESS) project, is involved in carbon science. One component of this focuses on a 50 000-year old Cango speleothem (stalagmite). "It is producing a very



high-resolution atmospheric radiocarbon record for the critical time period between 50 000 and 26 000 years ago," Woodborne says. "The fact that we know the outcome of these past changes will help us understand the relationship between atmospheric carbon, ocean circulation and climate change."

Another component of the ACCESS project involves a more direct look at the functioning of the ocean. The Southern Ocean is poorly studied despite the fact that it is one of the most productive regions of the world. The biogeochemistry of the Southern Ocean considers the relationship between the energy inputs such as nutrients and the impact of these on other cycles such as nitrogen, iron and carbon. Biological productivity is possibly as important as inorganic carbon exchange, and it is suggested that models of carbon absorption in the ocean should focus on the biological processes with as much detail as the physical processes.



Archaeologist and carbon isotope expert, Dr Stephan Woodborne



Climate change: what is it all about?

For billions of years, the struggle for survival on earth was like a dance between the earth system that perpetually changed the environment, and life that coped and evolved, sometimes in response to the environment, and sometimes taking the lead and driving the change. The result is a particular harmony in which life and the environment co-exist in a state that we call nature. It is the fine-tuned relationship between survival and the complex earth system.

This natural ecological state of affairs changed dramatically over the past 200 years. Humanity discovered the economic power of natural resources – coal, crude oil, gas and minerals. To drive the fast-growing world economy, these resources became the energy-producing commodity of choice. The inexpensive and relatively easy extraction of coal and oil (fossil fuels) became indispensable ingredients of anything that uses electricity: The manufacture of vehicles, cement, your personal comfort in the form of hot running water and light to read at night.

The benefits are seductive: Improved health and poverty alleviation through the production of better medication, better housing, advanced education and scientific breakthroughs. However, the lasting footprint of these endeavours had a devastating effect on the complex and delicate earth systems and the future of the planet. The threat lies in what it is doing to the atmosphere.

The changing earth system is once again being led by one of its parasitic life forms, i.e. humans. The climate is changing, and climate change science is our crystal ball to see the outcomes of our actions.

Finding ways of reducing the negative effects on the planet, its fragile atmosphere and its inhabitants, will require massive changes in the established behaviour of humankind. Achieving this goal will demand scientific wisdom and vision to govern humanity.

Among many international efforts to combat the distressing future of the planet, South Africans from many spheres of scientific knowledge have established the Africa Centre for Climate and Earth System Science (ACCESS). The CSIR is an active participant in this endeavour.

South African obligation

Coal burning is a current reality, and so is the ongoing rise in atmospheric CO₂. "Our handle on the pending impact of atmospheric carbon lies in our ability to model its effect on the heat distribution of the world, as well as our ability to forecast the extent to which carbon will exchange between the atmosphere on the one hand, and the ocean, biosphere and lithosphere on the other," Woodborne says.

"The complexity of carbon budget science is a challenge," Woodborne concludes, "but it has produced a new form of global science. Observations are required around the world, and so everyone can contribute, although not everyone has the means to synthesise the observations. I believe that South Africa, in facing its obligation to mitigate climate change, should mediate in particular the optimisation of our economical growth needs and environmental impacts to ultimately have a handle on our carbon footprint."

Woodborne believes that, through mathematical models and hard science, climate change and global warming will be unravelled in our lifetime.

– Renatè Janse van Vuuren

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World-famed fauna destroying the Karoo?

THE LITTLE KAROO is a semi-arid region lying in the rain shadow of the Outeniqua mountains of the southern Cape. This region stretches roughly from Montague in the west to Uniondale in the east and is further walled in by the impressive Swartberg mountain range in the north.

The Little Karoo has a unique biological and physical character, which has attracted people to this region for the past 2 000 years. It is also rich in biodiversity, particularly with regard to plant species, with more than 1 325 species found here, 182 of which are found nowhere else in the world. The biodiversity of the region is internationally recognised as it falls within two global biodiversity hotspots, the Succulent Karoo and the Cape Floristic Region.

When one thinks of the Little Karoo, one typically thinks of dry scenic vistas, dried fruits and a baking hot sun. But, perhaps more than anything else, it is the ostriches that stick in people's minds. We have a fascination with the size of ostrich eggs, the elegance of their feathers, and the taste of an ostrich steak. Unfortunately, ostrich farming – as it has been practiced in the region – and biodiversity don't mix.





Ecologist, Dr Patrick O'Farrell

We have a fascination with ostriches, but regrettably ostrich farming – as it is practiced in the Little Karoo – and biodiversity don't mix.

"The CSIR has studied the Little Karoo area for the past three years, undertaking a number of projects, which have focused on sustainable land and resource use, and developing a better understanding of the ecosystem services of this arid landscape," says ecologist Dr Patrick O'Farrell. "One of our studies investigated the financial feasibility of restoring areas that have been used for ostrich farming. This study showed just how expensive it is to return natural capital back to its original state, particularly in arid areas, as seedling survival is very low. The message that emerged is, don't destroy or damage natural capital because you can't easily get it back.

"We also found that if land-use practices degrade the environment, multiple different ecosystem services can be lost. These include reductions in the volume of water that can be captured; the amount of carbon that can be stored, both in plants and in the soil; the recharging of ground water is reduced; and soil is not well-held, resulting in erosion. Our studies really highlight the consequences of land-use decisions; consequences we have been trying to communicate to farmers through the Gouritz Initiative, a forum that links scientists with society.

Vision

The work that the CSIR undertook in the Little Karoo has also sought to develop an understanding of the resilience of the region. "We have tried to achieve this by looking at the natural and socio-economic systems as a single, integrated social-ecological system. Here we investigated the ecological and production history of the region, understanding past land-use practices, so as to better interpret what we are seeing on the ground now. We also engaged with stakeholders in understanding their vision of the future, and we broadly identified potential future scenarios for the region. We believe that this holistic approach is the most appropriate way of trying to steer the region towards a more sustainable trajectory," O'Farrell says.

"The Little Karoo has provided scientists with an interesting study region, and one which could be seen as a microcosm of what is going on in much of South Africa now and into the future, given climate change and the predicted reduction in rainfall over the western areas, increasing water scarcity, and worsening agricultural conditions," O'Farrell concludes.

– Renatè Janse van Vuuren

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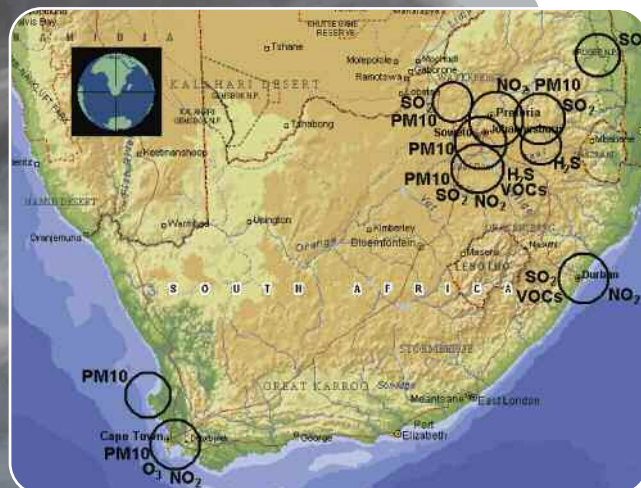
Erosion of this scale is becoming a common sight in the Little Karoo

Ostrich farming here has an extremely destructive effect on the ecosystems of this area. While most ostriches are kept in small pens; breeding flocks range freely, trampling a myriad pathways across the veld, as they perform territorial and breeding displays. This amorous behaviour not only crushes much of the irreplaceable plant biodiversity, but affects the soil surface, compacting it, and forever changing its potential. This seems like a misuse of the natural capital on which the agricultural economy of the region was built.

This region is well known for drought as well as occasional floods. Compounding this dryness is the fact that the evaporation rates here are 10 times higher than the annual rainfall, so like all semi-arid agricultural areas, water resources are in high demand. Most of the water captured in the surrounding mountains or that flows into the area, is used to irrigate lucerne. This treasured wet commodity is being translated into food for ostriches.

First State of the Air Report sheds light on the seemingly invisible

The first State of the Air Report in South Africa provides insight into sources of emissions and associated health, welfare and broader environmental impacts. The CSIR was instrumental in the compilation of this report.



Identification of some of the regions where elevated air pollutant concentrations in excess of health thresholds have been measured

SOUTH AFRICA faces the challenge of addressing a range of persistent air pollution problems in addition to proactively positioning itself to deal with emerging issues. The first State of the Air Report deduced that high ambient sulphur dioxide (SO₂) and fine particulate concentrations due primarily to fuel burning within the household, industrial and power generation sectors represent persistent air pollution challenges in many areas.

Human health impacts related to household coal and wood burning remain the most serious and pressing national air pollution problem. Further, the co-location of heavy industries and communities presents a continued source of health risks and consequent conflict, currently exacerbated by increased pressure to place residential areas within former industrial buffer zones.

Emerging air pollution issues are closely associated with the transportation sector, particularly road transportation. In South African cities, a notable increasing trend in the concentrations of transport-related pollutants is apparent. Volatile organic compound releases from fuel filling stations and nitrogen oxide and hydrocarbon releases from major airports have also served to highlight the air quality implications of transportation policies.

CSIR researcher in environmental modelling and climate change, Rina Taviv, says, "The database of ambient air quality monitoring created as a part of the first State of the Air Report will

become the most comprehensive source of information for decision-makers, air quality managers and other interested and affected parties. It will be incorporated in the South African Air Quality Information System (SAAQIS), which is being developed and will be hosted by the South African Weather Service. Now that pollution levels have been quantified and a baseline status set, the results of the air quality management efforts initiated after promulgation of the Air Quality Act, 2004, can be monitored."

In compiling the report, air quality monitoring data were obtained from a number of agencies for over 120 stations and all available data for the period 1994 to 2004 were collected.

Compliance with air quality standards and long-term trends were assessed for all air pollutants, including greenhouse gases (GHGs), volatile organic compounds, metals (Cr⁶⁺, Mn and Hg), hydrogen sulphide (H₂S) and total reduced sulphur (TRS). The level of exceedance was quantified by identification of locations and periods when pollutants exceeded air quality standards. High levels of SO₂, particulate matter, ozone (O₃), oxides of nitrogen (NO₂), H₂S and volatile organic compounds were found in many urban and industrial locations (see map). Prior to the report, no national statistics were available for ambient air quality.

The qualitative analysis of significant sources, pollutants and impact areas represents an important first step in air

quality management.

The report identifies the most significant combustion-related sources as:

- Electricity generation
- The industrial and commercial fuel-burning sector
- Vehicle emissions
- Domestic fuel burning
- Biomass burning.

Breathe a little easier

The good news is that the recommendations for further improvements in air quality monitoring and data collection were provided to the Department of Environmental Affairs and Tourism (DEAT) and since then DEAT has instituted various other projects and measures to address air pollution.

These include the official launch of the Vaal Triangle Airshed Priority Area Air Quality Monitoring Network and the installation of six air quality monitoring stations; the first generation National Framework for Air Quality Management has been published; the Highveld Airshed was declared as the second Air Quality Priority Area; and potential sites for DEAT's five ambient air quality monitoring stations were identified in the Highveld Airshed.

Further information on these and other projects is available on the SAAQIS web site: www.saaqis.org.za/Links.aspx.

– Chiara Lincoln

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Biogeochemist and oceanographer,
Dr Pedro Monteiro

Southern Ocean CO₂ Observatory Programme: new base for climate change research

OF THE CARBON DIOXIDE (CO₂) that we release into the environment by burning fossil fuels, approximately one third remains in the atmosphere, which contributes to the long-term trend of increasing CO₂. The balance is taken up evenly by the ocean and terrestrial biosphere.

Of the fraction of ocean uptake, approximately 50% is taken up in the Southern Ocean. A significant adjustment to this service to the planet could have a major impact on global CO₂ emissions mitigation targets. The basic problem is that not only is the variability of this uptake not well understood, but also, and perhaps more seriously, its likely response to global warming is unknown at this stage.

South Africa has a unique geographical advantage in respect of observing, understanding and eventually predicting changes in the Southern Ocean. This opens the possibility of both making an impact on global knowledge of our changing planet as well as reducing the uncertainties of the likely impact of these changes on the climate of southern Africa.

New areas of Southern Ocean research

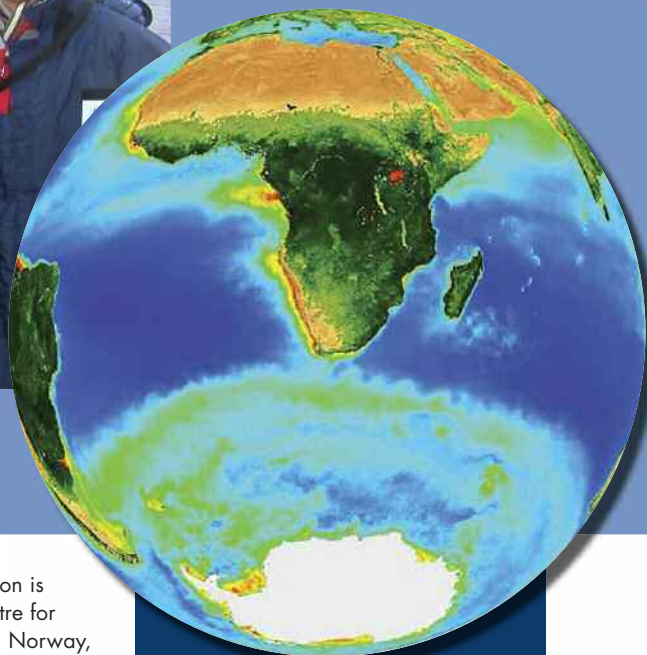
"Southern Africa is a 'peninsula of land' projecting into a very large surrounding ocean characterised by extreme contrasts from tropical through temperate to polar, which interact with the atmos-

phere to define our climatic characteristics. The dependence of our climate on the surrounding oceans remains one of the least understood areas of science and the main source of uncertainty in respect of global warming. The waters around South Africa provide a wealth of information and is a natural laboratory offering a special opportunity to research oceanographers to study a range of different mechanisms impacting on regional and global biogeochemistry," says CSIR biogeochemist and oceanographer, Dr Pedro Monteiro.

Monteiro leads the CSIR's ocean systems and climate research group. "We are interested in understanding how and why CO₂ and oxygen are



The South African biogeochemistry team, Dr Pedro Monteiro (CSIR), Dr Sandy Thomalla, Dr Howard Waldron and Warren Joubert (CSIR), in front of the light incubations systems used to measure productivity from water samples collected daily



A view of the planet from a southern African perspective, highlighting the extent to which the southern African system can be seen as a 'peninsula' in the southern hemisphere Atlantic, Indian and Southern oceans. Southern African climate is shaped by all three oceans and it is there that we have to look for the clues for regional climate change. It also shows the extensive areas of elevated productivity in the Southern Ocean where much of the atmospheric CO₂ uptake occurs

changing in the thermocline* waters of the South East Atlantic and Southern Oceans. These changes are important not only in respect of constraining the rate of global warming, but also as indicators of the rate and the way the regional system is adjusting to climate change. In addition, the biogeochemical characteristics of the Southern Ocean are thought to play an important role in, among others, modulating global ocean productivity," he adds.

Most of the large-scale modelling is undertaken at the CSIR-affiliated Centre for High Performance Computing (CHPC) in Cape Town.

International collaboration

In 2007, a four-year multiproject international initiative – the Southern Ocean CO₂ Observatory Programme – was initiated to establish a CSIR climate-centred oceanographic research and development (R&D) capability for the Southern Ocean.

"The intention is that it will make a significant contribution to ACCESS (see text box on next page) and the Department of Science and Technology's (DST) long-term climate research and education plans and grow to become a globally-recognised centre of Southern Ocean science in Africa."

The international collaboration is centred on the Bjerknes Centre for Climate Research in Bergen, Norway, and the School of Atmospheric and Ocean Science at Princeton University for the modelling and the productivity variability aspects. Both contribute significantly to the South African graduate training programmes, either through student exchange or through ACCESS. At least 12 South African scientific and tertiary institutions participate in ACCESS. "One of our stated goals is to also use this programme to develop links with the Australian programme for comparative studies," Monteiro adds.

Research expedition

"The focus of our research is on the ocean-atmosphere exchange fluxes of CO₂ in the Southern Ocean south of Africa," Monteiro says. "Through modelling and observation we want to understand the basis for the important CO₂ sink in the sub-Antarctic Zone (40-50 °S) and how this may be modified through global warming. This is to be undertaken through the integration of modelling, remote sensing and *in situ* observations."

The first *in situ* process study was undertaken as part of the Bonus GoodHope expedition, which was part of International Polar Year. This French-led inter-

national collaboration on the research ship *RV Marion DuFresne* hosted a six-week-long study of the physics and biogeochemistry of the Southern Ocean south of Africa during February and March 2008.

"The focus area for our work spanned the sub-Antarctic and Antarctic systems between 40-60 °S. The purpose was to explore the coupled nature of carbon export fluxes, carbonate changes, pre-formed nutrients and remineralised nutrients, and ocean physics in regulating the carbon system.

*Thermocline: the middle layer of water in a lake or the ocean where heat decreases rapidly as the depth increases



Image: NASA

Rosette used on the RV Marion DuFresne to profile the water column continuously down to 5 000 m for temperature, salinity, chlorophyll, currents and to collect 24 discrete water samples for on board sampling and analysis



"Our French colleagues also undertook detailed studies of trace metal co-limitation to try to unravel the major puzzle of the Southern Ocean being rich in nutrients, but low in chlorophyll concentration," Monteiro adds.

"We believe our research makes a significant contribution to the strategies defined by the South African National Antarctic Programme (SANAP)," Monteiro says. "A key purpose of the project is to develop new South African graduates (PhD and MSc) and in so doing, support local efforts to build a centre of excellence in oceanography in Cape Town.

"The local and international relationships leave little doubt about the important role of the Southern Ocean in regulating climate in the short term and in the long term through adjustments in the ocean-atmosphere balance of CO₂," Monteiro concludes. "We want to make an impact on better understanding and fill the knowledge gaps in the CO₂ sink dynamics of the sub-Antarctic zone."

– Renatè Janse van Vuuren

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ACCESS: One of the most significant initiatives in southern Africa is the formation of the Africa Centre for Climate and Earth System Science (ACCESS), an institution launched in early 2007. It is an interinstitutional initiative to stimulate an understanding of climate through a coupled systems approach (e.g. coupled ocean-atmosphere) supported by advanced high-speed computing facilities and providing a new space within which a new generation of South African scientists can develop.

The ACCESS initiative is strongly supported and funded by the Department of Science and Technology (DST) in South Africa and forms part of the DST's climate change research and development policy. Furthermore, both the CSIR, through its natural resources and the environment research strategy, and the University of Cape Town, through the marine science partnership, are closely aligned with ACCESS and the DST's national priorities.

ACCESS's key impact areas are:

- Research, with the prediction of changing climatic conditions on time-scales from seasons and decades as its main goal. Here the key outcome is the reduction of uncertainties in seasonal, interannual and decadal climate projections
- Knowledge transfer to the public, business and state institutions to understand regional and global environmental problems. The intention is to ultimately improve adaptive management of coastal zone, fisheries, shipping, agriculture, energy, water use and urban areas
- Career advancement, including making the public at large – also scholars and students – aware of developments and opportunities in earth sciences. In this regard, the core of ACCESS is a postgraduate degree in earth system science offered through the main participating universities.

Promoting earth observation and data democracy for developing countries

THE GROUP ON EARTH

OBSERVATION (GEO) emphasises the importance of earth information for global sustainable development: "Understanding the earth system is crucial to enhancing human health, safety and welfare, alleviating human suffering including poverty, protecting the global environment, reducing disaster losses, and achieving sustainable development. Observations of the earth system are critical to advancing this understanding."

In support of these objectives, the Committee on Earth Observation Satellites (CEOS) serves as the global umbrella body for civilian space agencies with specific emphasis on remote sensing. Earth observation (EO) satellites are specifically designed to observe earth from orbit. Data from these satellites are used for environmental monitoring, meteorology, map making and various other applications.

The exotic location of Kohala Coast, Hawaii, was the backdrop for the CEOS plenary during November 2007, where leadership by the United States Geological Survey (USGS) was transferred to the CSIR.

The CSIR is the CEOS chair for 2008 and is responsible for the oversight role of CEOS over this period. Funding from the Department of Science and Technology (DST) assists the CSIR in ensuring that local CEOS activities as well as CEOS chair obligations are met.

Pontsho Maruping, CEOS chair, explains, "Our role is to promote the goals of CEOS through proper international coordination of EO programmes and the maximum utilisation

"Our role is to promote the goals of CEOS through proper international coordination of EO programmes and the maximum utilisation of their data."



Pontsho Maruping, current CEOS chair

of their data." This ranges from the development of detailed technical standards for data product exchange to the establishment of high-level interagency agreements on common data principles.

Free data for Africa

As its special project, the CSIR has committed to lowering access to remote sensing data from the China-Brazil Earth Resources Satellite (CBERS) programme to African countries. The CSIR is also exploring to replicate this model with space agencies from other countries such as CONAE in Argentina, ISRO in India, CSA in Canada and ESA in

Europe. CBERS will be the pilot to demonstrate a model to realise the special project.

Availability of CBERS images to African countries is possible through the willingness of international partners such as Brazil and China. INPE in Brazil and CRESDA in China have committed to support the CSIR in its initiative to lower the barriers to developing countries in accessing satellite imagery data.

This will enable the CSIR to focus on disseminating country coverage initially to countries in the region, followed by the African countries that fall within its footprint. These include Angola, Botswana, the Democratic Republic of Congo, Lesotho, Madagascar, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

The CSIR's Alex Fortescue, who is a member of the CEOS chair team, explains the philosophy that underlies this decision, "The CSIR is committed to the concept of data democracy for developing countries. It is our view that only by broadening data access and capacity to end users in developing countries, will the full potential of EO data be exploited successfully worldwide."

The CSIR Satellite Applications Centre, being one of the ground stations identified for CBERS direct reception and onward distribution, is finalising negotiations to use spare capacity on GEONETCAST of EUMETSAT (the European Organisation for the Exploitation of Meteorological Satellites), which allows simplified downlink over Africa through geostationary communications satellites.

The CSIR's CEOS team: Raoul Hodges, Asanda Ntisana, Wabile Motswasele and Alex Forstescue (not present)



EUMETSAT delivers weather and climate-related satellite data, images and products – 24 hours a day, 365 days a year.

The CSIR is exploring various models of disseminating data relevant and appropriate for suitable categories of end users. In as far as GEONETCAST is concerned, the technical requirements for a potential end-user recipient are reasonably simple: A personal computer (PC), receiving antenna (parabolic) and PC-compatible DVB satellite receiver card or a DVB set-top box. Potential use of the received images ranges from capacity building to the monitoring of natural disasters and land-cover changes as a result of drought, desertification and deforestation. Other possible applications include the use of such images in the mitigation of threats to agricultural production and to public health.

In parallel, the CSIR recognises that training of end users is as important as the ability to receive data and is also a major participant in the CEOS Working Group on Educa-

tion and Capacity Building (WGEdu) committee. During the WGEdu workshop held in Brazil towards the end of April 2008, the CSIR highlighted the need for introducing more structured and focused training programmes, including material and tools. CEOS representatives at this workshop expressed support and cooperation in light of the CSIR's CEOS special project.

SA on global stage

The global EO stage centres on GEO and its specific 10-year implementation plan of the Global Earth Observation System of Systems (GEOSS). CEOS is a member of GEO and addresses the space segment-related aspect of GEOSS.

At the South African EO workshop held in April 2008, local EO players committed to participate and contribute to CEOS and GEOS efforts in a coordinated manner. More significantly, the workshop fostered deeper understanding of the need to conduct remote sensing in a complementary fashion in terms of space-segment and *in situ* observations.

– Biffy van Rooyen

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Image: NASA

The CSIR is committed to the concept of data democracy for developing countries. It is our view that only by broadening data access and capacity to end users in developing countries, will the full potential of EO data be exploited successfully worldwide.



Dr Anthony Turton



Is the glass half full or half empty?

Water quenches a thirst, nourishes plant life; we use it to clean, transport goods and generate energy, we even use it for recreation. It is therefore easy to understand that an inextricable link exists between water and the economy. "The time to reflect on the way we manage our water resources is now," says Dr Anthony Turton, a CSIR researcher who is shifting water management paradigms and changing the way we think about water.

To stimulate and promote social development, South Africa requires rapid economic growth: We need to create new jobs, eradicate poverty, build houses and improve the basic living conditions of all citizens. What many do not realise is that water may well be the divide between achieving this goal and stunted economic growth.

A dependable water supply is critical for economic development, from primary sector activities such as agriculture and mining, to industry, energy and basic services. Good management of water resources brings certainty and efficiency in productivity across economic sectors and contributes to the health of our citizens and the environment. These interventions lead to immediate and long-term benefits for the economy, the environment and the lives of millions of people.

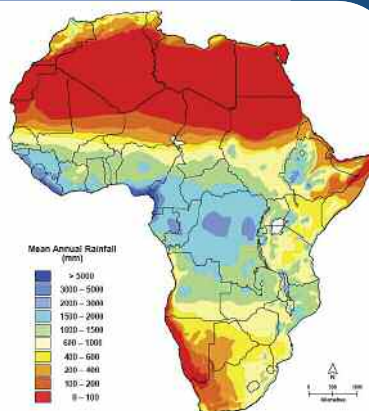
The challenges

Certain geographical, historical and cultural factors make Africa's water profile different from most, a uniqueness that requires a special approach to the way we manage our water resources.

Africa is severely water constrained. The ratio of rainwater that eventually becomes river water is the lowest in the world – on average a paltry 20% at continental level. "It is this poor conversion ratio that is a fundamental development constraint in Africa, giving the continent a specific risk profile that is generally misunderstood," says Turton. This is what the World Bank describes as being 'held hostage to hydrology', as it translates into uncertainty and risk that need to be appreciated and managed if industrial development is to be viable and sustainable over time.

Another unique, yet significant, factor that complicates the problem is that the geographical location of several centres of development in Africa was dictated by the availability of mineral deposits, not the availability of water. This means that major cities such as Johannesburg, Pretoria, Bulawayo, Harare, Gaborone, Francistown and Windhoek have been built on or near major watershed divides. "This is totally at odds with the rest of the world, where most major centres of development are located on rivers, lakes or the seashore," says Turton.

This gives rise to another problem: the management of effluent return-flows. As these major centres of development are located upstream of their water storage infrastructure, the management of return-flows becomes a major challenge. This is compounded by the fact that by



Rainfall (mm/yr)

World Average = 860

Africa Average = 652

SADC Average = 947

RSA Average = 498

The key lies in asking the right questions, challenging existing paradigms and ultimately, changing the way we think about water.

2004, around 98% of the total national resource had been allocated, with a number of areas being over-allocated by as much as 150%.

Looking ahead

"The key," says Turton, "lies in asking the right questions, challenging existing paradigms and ultimately, changing the way we think about water." The first fundamental question we have to ask is: "How do we manage water as a flux instead of a stock?" And it is this concept that lies at the heart of research work underway in a consortium consisting of the CSIR, the Stockholm International Water Institute (SIWI) and Phillips Robinson and Associates (PRA), based in Namibia.

Stock versus flux

Traditionally, water has been viewed as a stock with known volumetric magnitude, which is then distributed much like the slices of a pie. "However, our research suggests that if managed correctly, water can and should be a renewable resource," Turton adds.

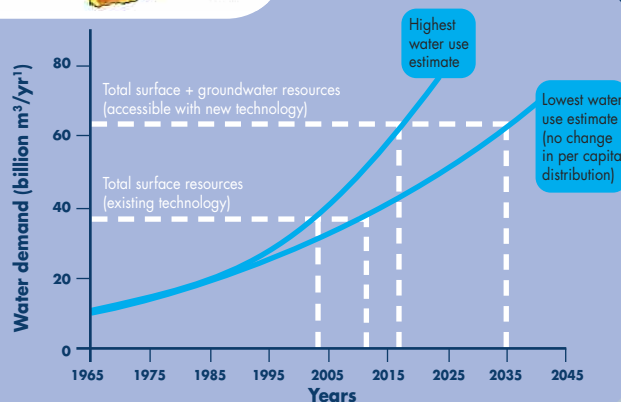
Unlike other natural resources such as gold, coal, oil and iron ore, water is

fugitive in nature. It can be cascaded around a given system – theoretically an infinite number of times – restrained only by the level of technological solutions available and affordable at the time.

Therefore, if water can be used twice – for example first as a generator of hydro-power in the upper reaches of the system and later as irrigation water in the floodplains along the lower basin – then in effect, the 'pie' is twice as large as when viewed through the lens of the traditional paradigm of water as a stock.

SA's water resources

South Africa is a world leader in water research. As far back as the 1966 Commission of Enquiry into Water Matters, researchers grasped the extent of the



challenge and determined that future economic development would be curtailed unless the country invests heavily in water research; regards water as a strategic resource and manages it as such; develops peaceful relationships with neighbouring states so that external sources of water can be explored; and reviews the energy mix so that water constraints are taken into consideration. "If we subscribe to these simple yet significant wisdoms already outlined in 1966," says Turton, "the glass needn't be half full or half empty; it can be filled to the brim. When water resources are treated as a flux, the options are almost infinite, dictated only by our technological innovation as a nation."

– Cat van Rooyen

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Meandering towards a better understanding of our rivers

WATER IS A SCARCE AND PRECIOUS

commodity in South Africa. Efficient management of our water resources has a direct bearing on our social well-being, our standard of living and the country's economy. The CSIR has been actively involved in the development and implementation of the River Health Programme (RHP) since 1994. The RHP is a national monitoring programme that measures and reports on the ecological state of rivers in South Africa. Its main objectives are to measure, assess and report on the ecological state of aquatic ecosystems; detect and report on spatial and temporal trends; identify and report on emerging problems; and ultimately educate the public at large regarding the health of the country's rivers.

Wilma Strydom, a CSIR researcher, says, "It is the onus of every citizen of this country to take responsibility for the protection of our rivers. Informed and inclusive decision-making requires frequent communication to ensure that scientifically-accurate information is provided to the broader stakeholder community." As a result, the reports and posters produced by the RHP are presented in easy and understandable formats. Posters and activity books for use in schools have also been produced. To date, 13 reports on the state

of rivers, and more than 10 posters have been produced, several of which in the dominant local languages. In addition, the reports have been referenced in several journal and conference papers.

Current ecostatus of rivers

An excerpt from *Achievements of the River Health Programme 1994 - 2004: A national perspective on the ecological health of selected South African rivers*, compiled by the Department of Water Affairs and Forestry, the Department of Environmental Affairs and Tourism, the Water Research Commission and the CSIR, reports how the ecological status (EcoStatus) of a river refers to its overall condition or health.

"EcoStatus incorporates a range of features and characteristics of a river and its riparian areas (riverbeds), and summarises these data into a single assessment condition. The health of a river indicates its ability to support a natural array of species and relates directly to the ability and capacity of a system to provide a variety of goods and services to society. After initial investigations, the RHP now applies this approach.

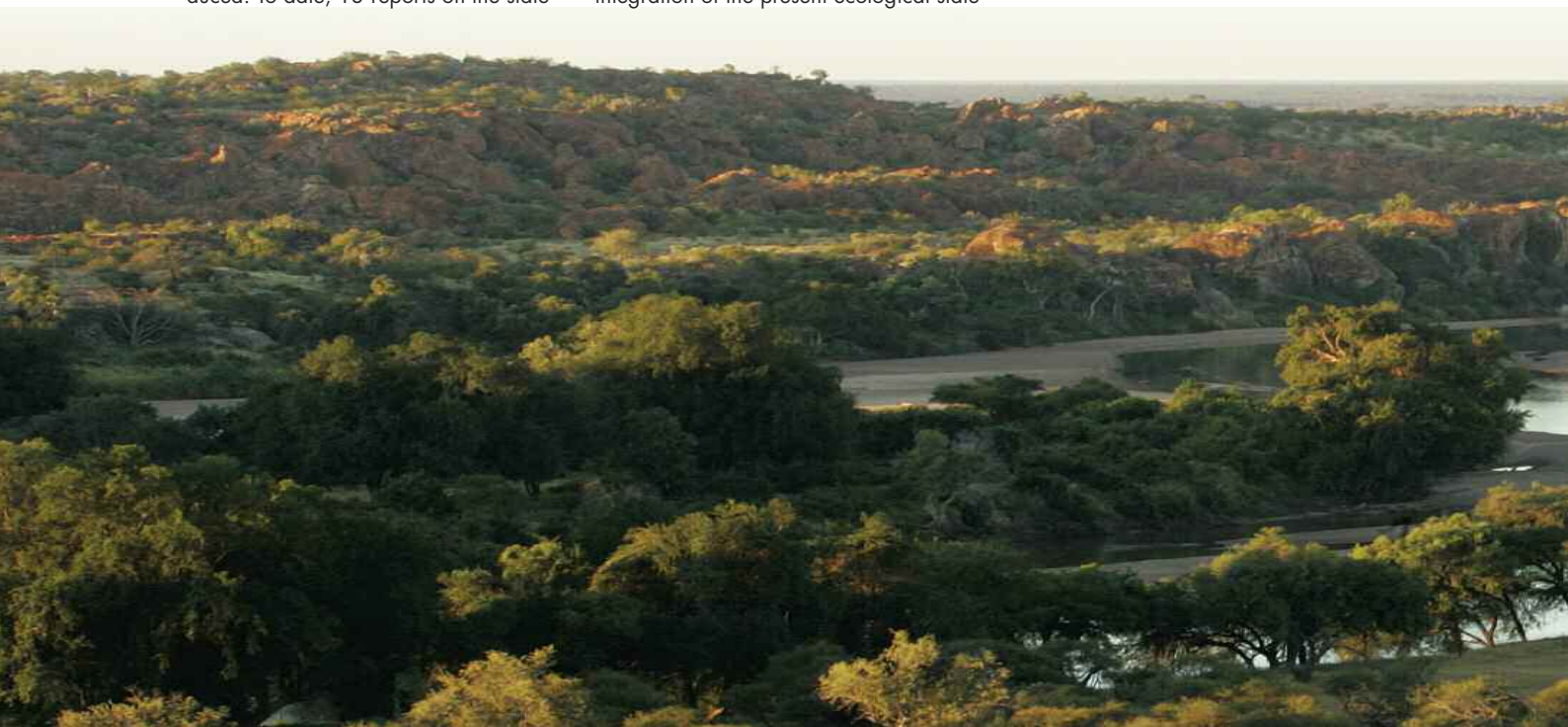
"EcoStatus is interpreted through the integration of the present ecological state

of the system drivers (geomorphology, hydrology and water quality), the resulting habitat integrity in terms of specific biological groups (fish, macro-invertebrates and riparian vegetation) and the responses of these biological groups. EcoStatus is thus an integrative measure that determines the response of the habitat to modifications.

The response of the biota to the change in habitat determines the health of rivers. Since the RHP focuses on the assessment of biological responses of aquatic ecosystems, the EcoStatus approach was adopted and applied as part of river health assessments."

Benefits of initiative

Strydom explains, "Through comparison of environmental performances in different areas, the effects of different impacts or drivers will be substantiated. By conducting continued biomonitoring and reporting, trends in river health will become available, which will in future allow comparison of data and interpretations. The availability of this river health information will show whether appropriate decisions have been taken and will contribute to informed decisions in future."



In 2007, a study was conducted in randomly-selected schools to determine whether communication materials on the state of rivers contained sufficient information, in the appropriate format, to improve learners' understanding of the benefits that healthy rivers provide; increase their awareness of adverse impacts on rivers; and change their attitudes towards river conservation.

Further, a survey amongst the residents of the Buffalo, Hartenbos and Klein Brak catchments determined the extent to which state of the rivers reports have been distributed; people's attitudes towards river conservation; their awareness of general water issues in South Africa; and their understanding of river ecosystem services and human impacts on river ecosystems.

The results are being analysed and findings will be published in scientific peer-reviewed journals.

Strydom says, "Through sufficient intervention at school level, children will grow up becoming more responsible citizens who understand the importance of and care for our river ecosystems."

More information is available on the South African River Health Programme web site:

www.csir.co.za/rhp.

Enquiries

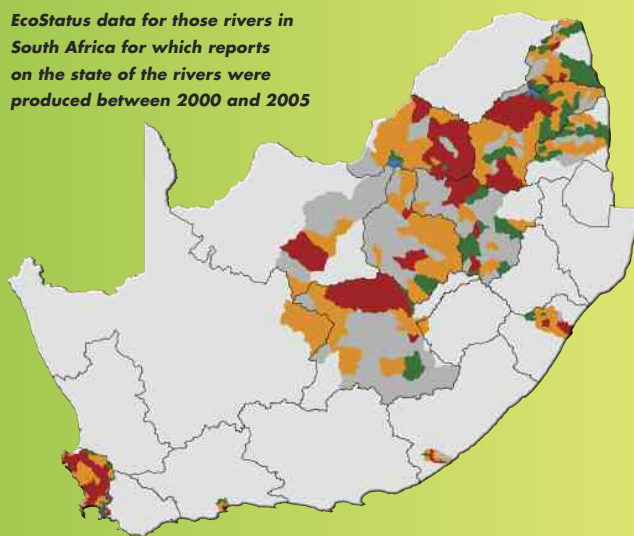
Wilma Strydom

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The River Health Programme

The RHP was initiated in 1994 by the Department of Water Affairs and Forestry (DWAF). The National Water Act (Act 36 of 1998) also stipulates that DWAF, as the national custodian of South Africa's water resources, is responsible for the monitoring and assessment of these water resources (RSA 1998). DWAF, the Department of Environmental Affairs and Tourism and the Water Research Commission are the programme's national partners. As a result of the programme, unique partnerships have developed, which have seen the sharing of resources and technical expertise across various organisations to monitor, report and communicate information on the state of rivers in South Africa.

EcoStatus data for those rivers in South Africa for which reports on the state of the rivers were produced between 2000 and 2005

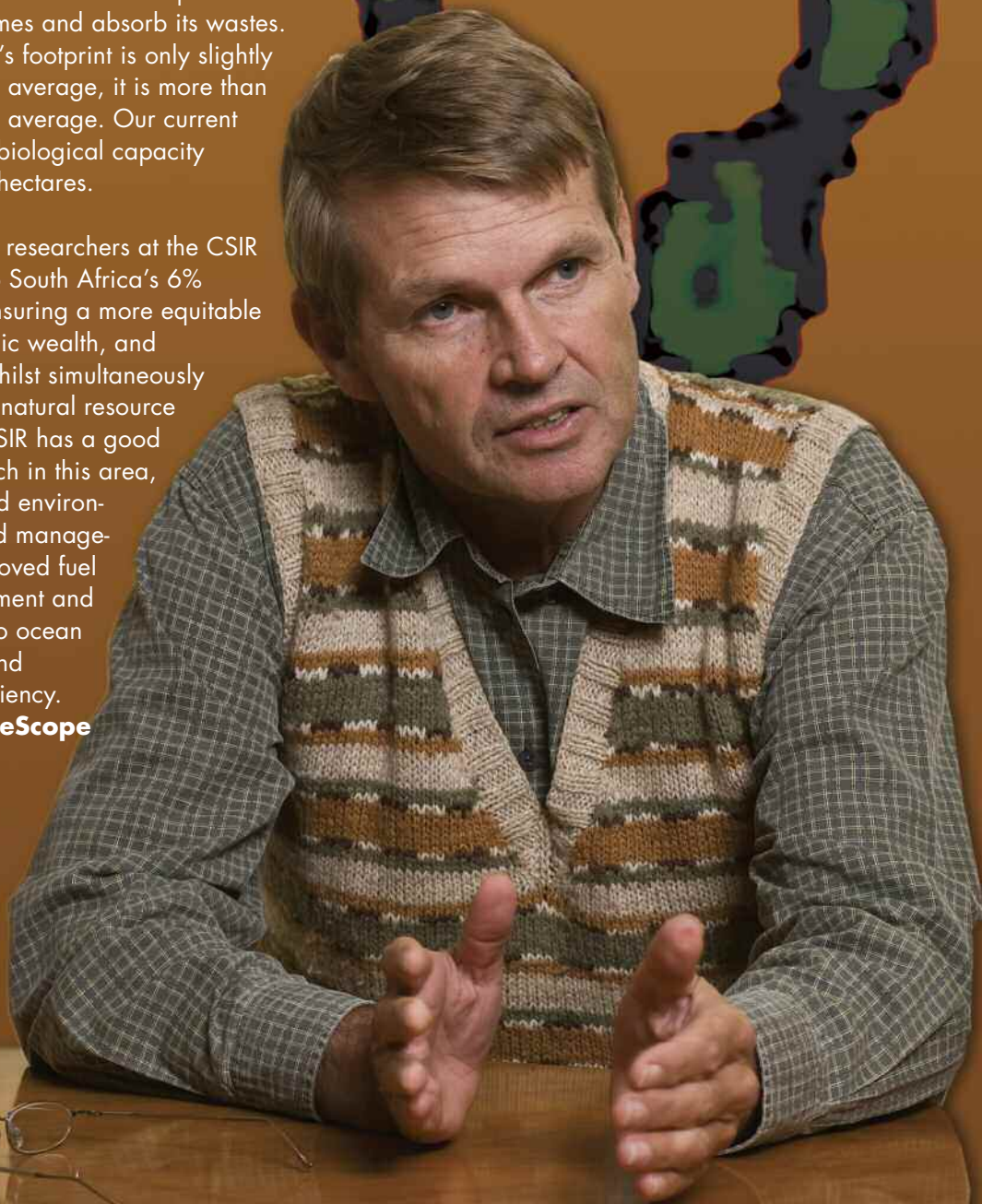


REDUCING THE HUMAN FOOTPRINT

THE 'HUMAN FOOTPRINT' is used as a metaphor for mankind's demands on the earth's ecosystems and natural resources. It is an expression of the amount of land a population needs to produce the resources it consumes and absorb its wastes. Although South Africa's footprint is only slightly higher than the global average, it is more than double that of Africa's average. Our current footprint exceeds our biological capacity by 3,5 million global hectares.

Key challenges facing researchers at the CSIR include contributing to South Africa's 6% growth aspirations, ensuring a more equitable distribution of economic wealth, and eradicating poverty whilst simultaneously lowering our levels of natural resource use and waste. The CSIR has a good track record of research in this area, ranging from improved environmental assessment and management techniques, improved fuel efficiency, water treatment and water use efficiency, to ocean outfall management and increased mining efficiency. This section of **ScienceScope** provides insights into some of the CSIR's current research initiatives aimed at reducing South Africa's human footprint.

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Aiming for sustainability of South Africa's abalone industry

Abalone produced by aquaculture. Researchers are developing a probiotic to enhance abalone growth. Ultimately it is hoped that this will decrease illegal natural harvesting



On 1 February 2008 all commercial fishing of wild abalone (also known as perlemoen) was officially suspended in South Africa. This was the result of a direct instruction by the country's Minister of Environmental Affairs and Tourism, Mr Marthinus van Schalkwyk, in a bid to ensure the survival of the threatened mollusc and to allow stocks to recover.

Despite the demand for this niche-market connoisseur food currently exceeding 20 000 tons per annum, the South African government has boldly reduced the total allowable catch from 615 tons in 1995 to a low of 125 tons for the 2006/07 season and an all-time emergency low of 75 tons for 2007/08.

Much of the concern about the South African abalone stocks stems from rising illegal poaching often resulting in the premature harvesting of these sea creatures before they can reach a substantial size. The abalone industry has meanwhile progressed from natural harvesting of abalone to a steady increase in production of abalone by aquaculture – a change influenced by antipoaching laws and regulation of natural harvesting to protect the natural abalone level in South African waters.

A new collaborative research project between the CSIR and the University of Cape Town (UCT) aims to stimulate competitiveness in the local abalone industry in an environmentally-conscious manner. Bioprocess development researchers under the leadership of the CSIR's Raj Laloo are investigating the use of biotechnology, in particular fermentation and product development technology, to shorten the growth period of abalone in an effort to provide a solution for the sustainability of the abalone industry.

"Abalone takes four years to grow before it is suitable to sell. Therefore, it's a more lucrative product if you can

make it grow faster," explains Laloo, whose project stems from long-lasting collaboration with UCT, established to develop a probiotic for inclusion in abalone/mariculture feed products. It is expected that the product will enhance abalone growth rates significantly, reduce current losses associated with culturing abalone and reduce negative environmental impact on marine systems.

The project took off about 10 years ago when Professor Vernon Coyne of the Molecular and Cell Biology Department at UCT began isolating micro-organisms from the gut of abalone to characterise these for probiotic effect. This would allow abalone to digest food quickly and improve their resistance to disease. His work resulted in an internationally-competitive concept technology that was patented. Lack of sufficient funding for commercialisation of the probiotics characterised and patented in Coyne's laboratory, prevented research necessary to develop processes for large-scale production until recently when the private company Benguela Aquaculture Technologies joined the project, which costs in the region of R6 million.

Laloo and his team are developing Coyne's small-scale demonstration into a commercial production process resulting in lower cost production and a stable abalone probiotic product. "We are investigating organism growth and the maximisation of biomass productivity in fermentation, to minimise the variable cost of production," says Laloo. Downstream processes such as cell harvest-



ing, product formulation and stabilisation of the product also feature on their radar. The team endeavours to deliver an integrated process package to ensure robust commercialisation of this innovative technology.

Coyne's research group at UCT will conduct field trials to test the feed product prototypes on abalone farmed at Hannesbaai and will continue to develop new probiotics that will improve all aspects of the abalone farming process.

South Africa has about 12 abalone farms with an estimated capital investment of R70 million and is known for its abalone availability. It is also an international player in terms of abalone growth technology. The product under development is aimed at increasing the growth of abalone by approximately 40%, reducing the time span to maturity.

Perhaps this attractive option for the viability of abalone culturing could see a decrease in illegal natural harvesting.

– Asha Speckman

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Novel biotechnology processes to reduce waste

Methods to upgrade waste products are generally poorly addressed and manufacturers have few options from which to choose. This results in large quantities of food processing wastes being discarded and used for landfill, or as bulking products with a very low value. The trend worldwide is to 'go green' and use natural resources conservatively and smartly. The CSIR has engaged in several 'green' projects where biotechnology is applied for the beneficiation of industrial wastes.



separates protein effectively from residual grain material. The new protein-enriched material was then used in the formulation of aquaculture feeds for various South African finfish species as well as for Mozambique tilapia.

Value for brewery waste

The beer brewing industry is one of the biggest sources of food processing wastes worldwide, generating more than 300 000 tons of spent grain annually in South Africa alone. Brewers' spent grain has a relatively low energy and protein value, which together with the high fibre content, makes it unsuitable as a food adjunct.

A group of CSIR bioscience researchers joined forces with scientists from 13 internationally-acclaimed research institutions in 10 countries for the REPRO project. The aim is to develop novel hybrid processing methods to deconstruct and modify spent grain by tailored bioprocesses. The modified waste coproducts were then evaluated in several value-added applications to determine the technological feasibility, economic viability, environmental impact, safety and societal and regulatory acceptance.

The CSIR's contribution focused on improving the protein content of the brewers' spent grain. This was achieved by a patented mechanical separation process, which

Plant-based proteins can be used successfully in fish feeds, but highly unsaturated fatty acids essential in fish diets only occur in marine animals and are usually added in the form of fish oil and fish meal. This places pressure on fragile natural marine resources. In the search for sustainable alternatives, CSIR scientists have produced these vital fatty acids by fungal fermentation of the protein-enriched spent grain. Inclusion of modified spent grain as well as fermented spent grain in fish feed did not affect the fish negatively during feeding trials conducted in Pretoria and Cape Town.

The project has come to an end after three years and has resulted in several scientific outputs: a patent and several publications are in progress. The development of fish feed is but one of the many applications of this technology, another of which includes an anti-oxidant-rich health drink.



Results of uncoated (top) and coated strawberries (bottom) stored open. The coating is based on kafirin extracted from sorghum brewers' spent grain. The fruit at the top was observed after five days under refrigerated conditions (4 °C) and the fruit at the bottom after five days ambient humidity at 21 °C.

Edible film from brewers' waste

The NovelQ project, funded by the European Commission within the Sixth Framework Programme, was established two years ago and culminates in 2009. In this project, the CSIR investigates the extraction of purified cereal proteins from sorghum brewers' spent grain, millet and oats.

The CSIR is scaling up the protein extraction protocols from laboratory scale to bench (16 l) and ultimately to pilot (75 l) scale to generate sufficient amounts of protein for use as edible coatings for vegetables (carrots and broccoli) and fruit (tomatoes and strawberries). The coatings are formulated to extend the storage life of the products without reducing their fresh appearance and texture. Coating trials are underway.

In the NovelQ project the proteins are also investigated for the ability of these to form part of packaging materials that can be used in novel processing technologies such as high hydrostatic pressure processing (a non-thermal process) to extend the storage life of food products without destroying their fresh characteristics. The aim of using proteins in the packaging material is to produce strong materials from more eco-friendly sources that will conform to the required packaging specifications for the novel technologies.



Maximising value of Karoo tequila plant

Agave americana, a fibrous plant, belongs to one of several families of plants containing fructans as a reserve for storing carbohydrates. The plant grows well in the Karoo and its pina is currently used for tequila production, while the rest of the plant is left to decompose on the veld. This waste material (mostly leaves and offcuts) has the potential to supply many other raw materials of economic value that could lead to the creation of new industries in inulin, fructose syrup and fibres (textiles, paper).

Inulin is a valuable component widely used in the food industry as an additive, sugar substitute and prebiotic agent. In 2005 a multidisciplinary study on local agave was launched by the CSIR. The objective of the research was to evaluate the potential of the local agave plant as a raw material for inulin and the textile and paper industries with a view to adding maximum value to tequila production.

The project generated comprehensive knowledge on the structure, composition and properties of the agave plant products and also established application areas for each part of the plant. The project received additional funding in April 2008 whereby technology packages will be compiled for the production of inulin and liquid fructans from agave species, fibre-based pellets for composites, leaf-pulp processing into animal food and leaf and pina fibre-based paper making.

Value addition and beneficiation of citrus waste

Citrus farmers in the Eastern Cape are burdened with a large surplus of lemons from which they are unable to derive monetary value. This despite South Africa ranking as the third largest citrus exporter in the world, following America and Spain. Local citrus by-products are ultimately either disposed of as waste, or dried and used as low-value cattle feed.

The CSIR and project partners Chemin, Kat River Citrus Co-operative Ltd, the University of KwaZulu-Natal, LIFElab and Sasol Chemicity formed a research consortium to investigate the extraction of a valuable product from the waste lemons.

Pectin is a water-soluble, colourless, tasteless and odourless substance found in a variety of sources. The preferred source is the peel of citrus fruit. It is a valuable gelling compound in many processed foods, while it is also used

as an additive in high-quality jams, jellies and dairy products. Neither high methoxyl (HM) pectins nor low methoxyl (LM) pectins used in the manufacture of these products are produced locally.

The CSIR developed a laboratory-based HM pectin extraction process, optimised the efficiencies thereof and piloted it to 1 000 t scale. Bioscientists completed construction of a demonstration unit for the Kat River Citrus Co-operative (a body for farmers in that region) in 2007.

Production and marketing costs of additional high-value by-products from citrus waste can furthermore be made economical by integrating extraction process flow sheets with the processes developed by the CSIR. A technology package for the design of a full-scale extraction plant has also been completed. Durban-based project funder LIFElab is investigating the commercialisation of this technology.

– Asha Speckman

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Managing fires in southern Africa: a hot topic

REGULAR DRY-SEASON FIRES

are a feature of the South African landscape. They are the inevitable consequence of the co-occurrence of three necessary conditions: Fuel to burn; hot, dry weather; and a source of ignition. Vegetation fires in southern Africa consume over 200 million tons of plant material every year, and they are one of the most powerful ecological forces around. On the one hand, our ecosystems are adapted to fires, and even need them to remain healthy. On the other hand, livestock, crops, houses and human life are at risk from fires.

The CSIR is involved in several initiatives that seek to understand the factors that shape the fire environment, and to develop appropriate responses to enhance the beneficial effects as well as to reduce the negative impacts of these factors.

How fires come about

Fire science begins with the development of a sound understanding of the physical drivers of fire. Current understanding has traditionally downplayed the role of humans in determining burnt areas, but recent research by the CSIR has shown that in areas of intermediate rainfall, the density of human populations has a large effect on the area burnt.

This comes about as a result of building roads, cultivating land, and grazing cattle, all of which restrict fires. Where rainfall (and thus fuel loads) is higher, large fires seem inevitable and human activities have a negligible effect on reducing them. Conversely, in very dry areas, rainfall limits fire by determining how much grass there is to burn, and humans play less of a role.

This has implications for modelling carbon emissions from Africa. In terms of carbon trading, we need to understand how much we can manipulate fire regimes in different regions across Africa. In terms of carbon accounting, we need to be able to predict how changes in human and weather conditions will affect fires.

Lives and property are often at risk from wildfires, and climate change may increase this risk. In order to understand the aspects of fires that could be affected by climate change, a CSIR team headed by Dr Brian van Wilgen and comprising fire ecologists and statisticians, is currently conducting the most detailed analysis of past fires that has ever been done in South Africa.

Van Wilgen confirms, "The preliminary findings are very interesting. In the



Researchers engaged in various initiatives aimed at understanding factors shaping the fire environment and developing appropriate responses to fire: Sally Archibald, Philip Frost, Graeme McFerren, Dr Anwar Vahed and Dr Brian van Wilgen (not present)

fynbos areas of the Cape, for example, it appears that fires are becoming more frequent in some areas. On the Cape Peninsula mean fire return intervals declined by 18,1 years, from 31,6 to 13,5 years, between the 1970s and the first decade of the 21st century.

Despite stated policies on managing the vegetation by using prescribed burning, fynbos fire regimes are dominated by unplanned wildfires, which account for almost 90% of the area burnt. This indicates that managers of these areas have not been able to prevent large wildfires."

Long-term weather data from across the country are being analysed to identify conditions resulting in dangerous fires. Trends in the climate records are used to determine whether large, dangerous fires are becoming more or less frequent in different parts of the country.

Emerging findings show that fires occurred under a wide range of weather conditions, but large fires were restricted to periods of high fire danger. Van Wilgen explains, "It appears that weather is the main determinant of large fires, and both reducing fuel loads through prescribed burning and attempts to reduce the chances of ignition will not prevent large, uncontrolled wildfires when extreme weather conditions prevail. Being prepared for the in-

evitable wildfires will be a more effective strategy for reducing damage than trying to control fire regimes."

The CSIR's findings have important implications for fire management and will result not only in valuable risk-assessment frameworks for forestry and urban environments, but also in new insights into fire behaviour and the fire-vegetation-climate system.

Fires for healthy ecosystems

Fires are necessary for the maintenance of healthy ecosystems, but despite decades of experience, the use of fire remains contentious, and systems for managing fires are constantly being reviewed as new information comes to light. CSIR researcher Sally Archibald confirms, "Changes in ecological concepts and a new focus on biodiversity as a central objective have led to changes in fire policies."

She explains that several policy alternatives have been proposed for the fires in savanna protected areas, including natural fire regimes, patch mosaic burning and burning based on ecological criteria.

Three ecological processes in particular are affected by fire: Tree recruitment, grass production and grazer movements. The hot, intense, frequent fires used to

prevent bush encroachment are very different from ones used to control moribund grass, or to promote grazing. Farmers and park managers therefore need a flexible approach to their fire management policies. In many areas, a system of adaptive management is used, in which targets are set, outcomes are monitored and approaches changed if and when necessary. This requires frequent analysis of the outcomes and active revision of approaches. The CSIR is involved in developing this approach in the Kruger National Park, where several changes to fire management approaches have come about recently as new information surfaces.

Helping firefighters respond

Research has demonstrated that many destructive wildfires can be contained if there is a rapid response that allows these to be caught before they get too big to contain. The CSIR has developed an active fire alert system in partnership with Eskom, the University of Maryland and NASA, and with funding from the Department of Agriculture.

Known as the advanced fire information system (AFIS), it is used to pinpoint fires in near-real time over southern Africa. It is also a world-first for coupling remote sensing with cell phone technology for alert messaging, or SMSs.

Developing the next version of AFIS using free and open source software components



Active fires are detected using data from the moderate resolution image spectroradiometer (MODIS) sensor on NASA's Aqua and Terra satellites. AFIS determines the exact location of active fires on a map (each dot on the fire map shows an active fire varying in size from 200 to 1 000 m) and sends an SMS to allow Eskom to respond quickly to fires in the proximity of the transmission line to reduce damage and power supply disruptions.

The AFIS system also sends SMS alerts to registered fire protection associations (FPAs) countrywide. This puts valuable information on the location of fires into the hands of officers within these voluntary organisations. They, in turn, coordinate fire fighting efforts with those of the Working on Fire programme of the departments of Water Affairs and Forestry and of Environmental Affairs and Tourism. Members of FPAs (such as farmers and other affected parties) delineate regions and determine boundaries within which each association takes responsibility for fire fighting.

A MODIS system funded by Eskom was installed in May 2008 on the CSIR campus in Pretoria. It is a backup for the system at the CSIR's Hartebeesthoek site and will be utilised on a non-operational basis for research and capacity building as well as innovation.

Researchers at the Meraka Institute are in the process of extending AFIS as a platform for detecting, monitoring and assessing wildfires in southern Africa for both operational and research purposes. AFIS will provide functionality for accessing archives of fire data, integrating new sources of observational data and accessing current or near-real time data feeds. As a high priority, these data sources will be available in standardised formats through standardised services to increase the flexibility and reusability of AFIS. In addition, the platform is developed using free and open source software components.

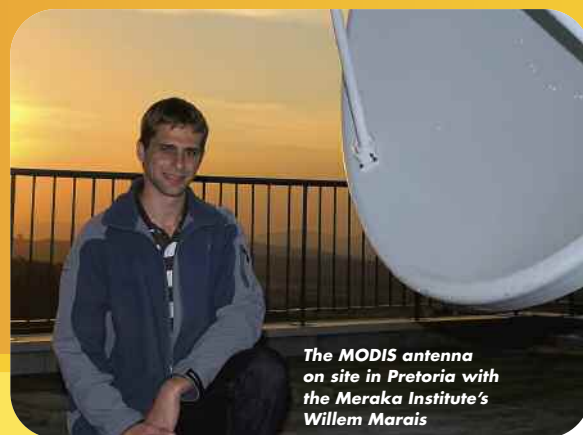
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The MODIS antenna on site in Pretoria with the Meraka Institute's Willem Marais

Bringing the sensor web to the hands of scientists

SOCIETAL BENEFITS that accrue from earth observation information pertain to disaster mitigation, health, energy, climate, water, weather, ecosystems, agriculture and biodiversity. Viewed as an advanced spatial data infrastructure, the sensor web combines data from multiple sensors and sensor networks to provide feedback to users and other sensors. In collaboration with local and international researchers, information and communications technology (ICT) specialists at the CSIR are researching technologies for integrating the sensor web with scientific workflows.

The sensor web can be seen as a coordinated infrastructure comprising a distributed collection of resources behaving collectively as a single, autonomous, taskable, dynamically adaptive and reconfigurable observing system. The sensor web concept has been well established and demonstrated through extensive recent global research and development activity.

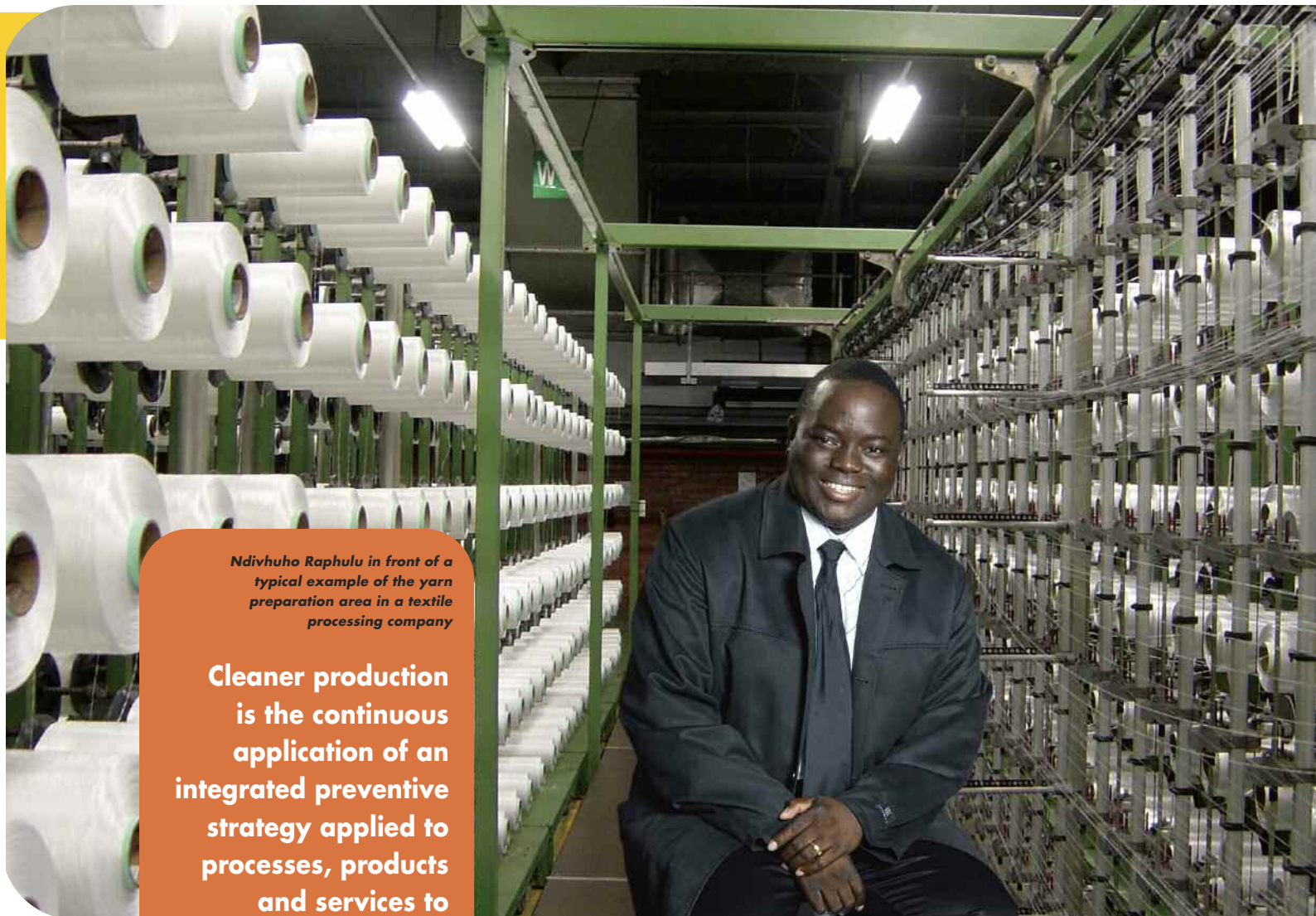
In order to realise the societal benefit of the sensor web, scientists need to leverage the resources presented by this technology for scientific exploration and knowledge generation. While current attempts at achieving this within the context of the Group on Earth Observation System of Systems (GEOSS) exist, open research questions must be addressed to make the knowledge-generating sensor web a reality.

As a technology for facilitating complex and distributed computational processes, scientific workflows can be used to advance the rate of scientific endeavour. Workflows are a key, though underdeveloped, cyberinfrastructure mechanism for scientific inquiry. This mechanism formalises the *ad hoc* steps scientists follow for deriving publishable results from raw data. In the sensor web environment, it enables experimentation, exploration of ideas and production of scientific outputs that utilise timely, adequate resolution, validated data in reproducible and shareable ways.

Research at the Meraka Institute of the CSIR will result in significant advances in turning the sensor web into an open and distributed environment for conducting research with access to timely, higher resolution, shared sensory data, processes and services; representing and autonomously composing complex processes implicit in experimentation; discovering sensor resources and integrating them with domain-specific knowledge; and optionally, recording and sharing scientific knowledge.

The outcome is an ICT environment for workflow composition and management in a sensor web context. Technology demonstrators on research for fire monitoring, and the incidence of cholera and for predicting the occurrence of floods will illustrate the benefits of such an environment and support the sensor web component of GEOSS.

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Ndivhuho Raphulu in front of a typical example of the yarn preparation area in a textile processing company

Cleaner production is the continuous application of an integrated preventive strategy applied to processes, products and services to increase resource efficiencies and promote economic, social and environmental sustainability.

Save and grow through cleaner production

CLEANER PRODUCTION (CP) technologies and services hold the key to saving billions of rand while stimulating economic growth in core South African industries. Established after the World Summit on Sustainable Development held in Johannesburg, and in its sixth year of existence, the National Cleaner Production Centre South Africa (NCPC-SA) demonstrates the value CP adds to industries in monetary terms, quality of life and balancing the scales to ensure sustainable consumption of natural resources.

Hosted by the CSIR, the NCPC-SA is mainly involved in the priority sectors of agro-processing, chemical, and clothing and textile industries. In these sectors, reductions in energy and resources have followed on the introduction of CP technologies and services.

According to Ndivhuho Raphulu, director of the NCPC-SA, CP is being advocated, established and increasingly embedded in South African industries as the public and private sectors realise the benefits of these technologies and services. "Adoption of CP invariably brings about cost savings for the organisation or company with the added benefits of responsible utilisation of non-renewable resources." It is for this reason that the NCPC-SA will now also focus on bringing about these benefits in South Africa's considerable mining industry.

In the agroprocessing sector, a major food company was assisted to bring about an annual saving of close to a million rand after an assessment by the NCPC-SA and subsequent implementation of a pre-treatment plant.

A 7% reduction in water consumption and 2% in coal consumption were also brought about, demonstrating the environmental impact CP technologies have.

This success is echoed in the chemical industry, where highlights include the NCPC-SA assisting an oil recycler to recover and harness excess energy from an evaporator off-gas stream. The energy recovered was used to preheat the incoming feedstream to the evaporator. By doing this the company was able to achieve a 7% reduction in boiler-fuel consumption, equating to 11 tons of fuel per month, or R21 000. Not only did this incur savings for the company, but it also reduced its contribution to CO₂ production and utilisation of limited fuel resources.

More recently the NCPC-SA has embarked on assessing a plastic-recycling company. In this case, the centre identified opportunities to improve maintenance, reduce energy consumption and increase the output capacity.

Most notably thus far are the optimisation of production capacity, reduction of bottlenecks and an improvement of the maintenance schedule, which could incur a projected saving of approximately R7,7 million.

CP was formally introduced to South Africa through the establishment of the NCPC-SA in September 2002 when the Department of Trade and Industry (**the dti**) concluded a three-year collaboration agreement with the State Secretariat for Economic Affairs in Switzerland and the Austrian Development Cooperation. The NCPC-SA was subsequently established within the existing framework of the United Nations Industrial Development Organisation's (UNIDO) Cleaner Production Programme. Since December 2005, when the agreement with these countries came to an end, **the dti** is funding the centre.

CP is part of the preventive approach to address global pollution and resource consumption problems. It promotes the practice of sustainable production and consumption, such as:

- Use of services and related products that respond to basic needs and bring about a better quality of life

- Minimisation of the use of natural resources and toxic materials
- Minimisation of emissions of waste and pollutants over the life cycle so as not to jeopardise the needs of future generations.

The NCPC-SA defines cleaner production as 'The continuous application of an integrated preventive strategy applied to processes, products and services to increase resource efficiencies and promote economic, social and environmental sustainability'.

The United Nations Environmental Programme describes CP and sustainable consumption (SC) as being two sides of the same coin, and therefore CP cannot be separated from SC. The NCPC-SA has adopted a holistic approach to sustainable production and consumption.

It exists as a national body to strengthen market access by South African industry and business sectors through the fostering of networks to transfer CP technologies and services that can contribute to the sustainability of value chains by delivering measurable socio-economic and environmental impacts that support the national priorities of growth, equity and employment.

Apart from advocating CP, the NCPC-SA facilitates technology relevant to industrial processes or products in a way that will produce the required CP results. The centre develops new approaches to the relationship between industry, other role players and the environment and applies expertise and know-how for the improvement of efficiency and better production management techniques in the industry sectors.

Raphulu concludes that the centre believes CP has an increasingly important role to play in the country's socio-economic future and that it can contribute greatly in facing global challenges.

– Patsy Scholtz

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Ecologist, Graham von Maltitz



CONSERVATION:

challenges posed by climate change

GLOBAL CLIMATE CHANGE is predicted to have substantial impacts on southern Africa's biodiversity. Thousands of species could be committed to premature extinction over the next 50 years.

Studies predict that South Africa will experience a substantial change in the location of current ecological regions (biomes), at a rate with no evolutionary precedent. The succulent karoo biome is projected to be the most severely impacted, since its 'climate envelope' shrinks dramatically or even disappears. The grassland and fynbos are also vulnerable.

Fynbos and succulent karoo are biodiversity hotspots of international importance, containing many thousands of species that occur nowhere else on earth.

This daunting outlook has been the focus of several in-depth studies by South African experts. CSIR scientists have been active participants in the research for more than a decade. "Temperature and water balance are the two climate parameters critical for animal and plant species' distributions," says CSIR ecologist, Graham von Maltitz.

"In southern Africa, global circulation models project the greatest increases in temperature (2–4 °C this century) for the inland areas, while the coastal areas are predicted to experience somewhat lesser increases (1–3 °C). A combination of increased temperature with decreased rainfall will increase the aridity of affected environments. A combined increase in rainfall and temperature will increase primary plant production, but will still be detrimental to some species."

Persisting or hopeless

Von Maltitz explains that species can be classified into four groups based on the ability of these to adapt to climate change, namely:

- **Persisters** have the tolerance for the new climate of their current location
- **Obligatory dispersers** will have to physically move with the changing climate to track areas with suitable land or will have to be moved artificially
- **Range expanders** may expand into new climatic envelopes not currently available, but to which the species are already well adapted.
- **No hoppers** cannot do any of these and will become prematurely extinct in the wild although they may persist under unsuitable climates for some time.

"With this in mind, one study – a detailed modelling of the impacts of climatic change on the *Proteaceae* (a key component of the fynbos vegetation) – was analysed to understand individual species' responses to changing climate over the next 50 years," he notes.

Natural vegetation in the Paulshoek region of the Karoo





"The purpose was to evaluate future conservation strategies. The model predicted that 57% were persisters, 26% partial dispersers, 6% obligatory dispersers, and 11% were no hoppers."

Fauna

A similar study in the Karoo found that the endangered riverine rabbit is likely to become extinct because its specialised food and habitat requirements will no longer be satisfied. In contrast, the padloper tortoise, which is less selective, is likely to survive in the 50-year study timeframe, despite its apparently slow migration rate. The tortoise beats the hare again.

"In terms of animals, the carrying capacity for large herbivores is projected to decrease by about 10%," Von Maltitz says. "Although this study did not consider individual species, it suggested that the functional integrity of the savanna habitat can be maintained near to current conditions through appropriate management."

Conservation strategies

Effective conservation strategies and management are thus imperative to ensure the survival of South Africa's amazing biodiversity heritage. "The

conservation network in southern Africa, though extensive, is poorly configured to conserve biodiversity adequately, even less so under a climatically-changing environment," he warns.

"The largest proportion of biodiversity is still found outside of the reserve areas, despite the impacts of land transformation and degradation. With the anticipated impacts of climate change over the next 50 to 200 years, many species will have to move from their current locations to remain within areas of suitable climate."

The most recent trend is toward international assistance for conservation in Africa, and for the first time in decades, new areas are being proposed for conservation, while existing conservation is being strengthened. Von Maltitz says it is encouraging that strategic conservation planning tools are making it possible to plan the location of reserves in a scientific and defensible manner to achieve agreed conservation targets.

Adaptation options

"Conservation becomes a moving target in a climatically-changing environment," Von Maltitz says. "Our current understanding of ecosystem response to climate change, based both on historical data and modelled predictions, suggests that individual species will respond at different rates. As a consequence entire

ecosystems will not move in unison, but species will move independently, leading to altered community composition. It is therefore important that, in attempting to minimise losses, conservation strategies must consider individual species in addition to the need to maintain habitats (ecosystems)."

Reconfiguring the reserve network

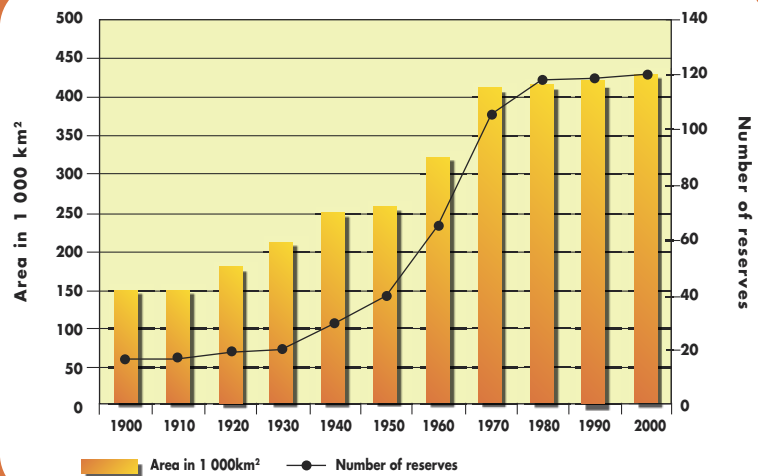
Although South Africa has only 5.4% of its land area under state conservation, it is estimated that an additional 13% is currently managed as private conservation areas. Not all game-ranching practices result in improved biodiversity conservation automatically, but it is argued that on balance, greater biodiversity benefits are achieved through this land use versus alternative agricultural practices.

Von Maltitz believes the benefits of existing formal conservation areas can be enhanced by ensuring that these are well configured to best conserve biodiversity, given the impacts of climate change. However, conservation cannot be achieved through the formal reserve network alone. It is also critical that important migratory pathways outside of reserves are managed in a biodiversity-friendly manner.

— Renatè Janse van Vuuren

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The increase in conservation areas and the number of reserves in seven southern African countries (based on Cumming, 2004). Note: Only national parks and large reserves in South Africa are included

The link between water and human health

ALTHOUGH WATER is not a cure for HIV/Aids, access to a clean and wholesome resource can enhance the quality of life of people with compromised immune systems.

"Appropriate access to supplies of clean water is not only a fundamental human need," says CSIR anthropologist Dr Jeanette Rascher, "it is also protected in our Constitution." Rascher heads up the CSIR's water resource governance systems team that is investigating the imperative role that water plays in human health.

Statistics show that some 1,1 billion people in developing countries have inadequate access to wholesome supplies of water and 2,6 billion people lack basic sanitation. In the face of these figures, one cannot ignore the life-sustaining role that water has to play in communities where poverty and HIV/Aids are prevalent.

The CSIR team's current research forms part of a Department of Water Affairs and Forestry (DWAF) water sector initiative, Masibambane, roughly translated from the Nguni language as 'let's work together'.

Led by DWAF and funded by international donors, Masibambane focuses on strengthening the local water sector and building inter-governmental

"We shall not finally defeat Aids, tuberculosis, malaria, or any of the other infectious diseases that plague the developing world until we have also won the battle for safe drinking water, sanitation and basic health care."

– Secretary-General of the United Nations,
Kofi Annan, Geneva (2005)

relations towards the provision and management of water for socio-economic development. The CSIR's research forms part of the third phase of this comprehensive initiative and aims to answer questions such as the impact of HIV/Aids on the skills base within the water sector; the water quality and quantity needs of households affected by HIV/Aids; the number of pregnant women who do not have access to clean water; and how HIV-affected households, living in poverty, deal with their water and sanitation needs.

"Through our research we will be able to develop strategic interventions and technological innovations to address these problems," says Rascher, who is passionate about the subject. "By understanding the problem and the environ-



Dr Jeanette Rascher

ment where the problem exists, we are better equipped to inform policies and make a real and tangible difference on a large scale."

– Cat van Rooyen

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*Environmental scientist,
Elizabeth Masekoameng*

The problem with mercury pollution arises when it is converted to methylmercury in the aquatic environment, as this form of mercury not only bioaccumulates in aquatic food chains, but it is many times more toxic than other forms of mercury.

Assessing mercury in waste and water

THE PRESENCE OF MERCURY in the environment (air, water and sediments) is a global concern. This metal, which occurs as organic and inorganic forms in the environment, is highly toxic and has led to fatal and chronic toxicity incidents in various parts of the world, including South Africa. In the 1950s, many people in Minamata, Japan, died following exposure to toxic mercury; while in South Africa, a mercury-contaminated spill into a local river in KwaZulu-Natal resulted in mercury poisoning during the 1990s.

Aquatic food chains

Although mercury occurs naturally in the earth's crust, human activities are important contributors to the global mercury cycle. "The problem with mercury pollution arises when it is converted to methylmercury in the aquatic environment, as this form of mercury not only bioaccumulates in aquatic food chains, but it is many times more toxic than other forms of mercury," explains CSIR mercury research expert, Dr Joy Leaner. "Bottom-feeding fish obtain mercury from their diet when they take in sediment and debris containing mercury; while pelagic fish, fish-eating mammals and other shellfish products accumulate methylmercury to levels that are much greater than the surrounding waters."

Large predatory fish such as shark and swordfish often have extremely high methylmercury concentrations. The consumption of methylmercury-contaminated fish or shellfish products poses a significant health risk to humans, with women of child-bearing age, pregnant women and developing children considered at high risk. Symptoms of methylmercury poisoning include motor-neuron and developmental problems, reproductive and nervous system disorders, speech and vision impairment, hearing and walking difficulties, and death.

Mercury-related research

In an attempt to understand the dynamics of mercury in the South African environment, a large team of researchers from various disciplines at the CSIR has embarked on a series of mercury-related research projects under the supervision of Leaner. The overall focus of the research is to assess the extent of mercury pollution in South Africa, and the degree to which mercury may be a problem in the country. All major mercury emission sources, long-range atmospheric transport, and partitioning among environmental media (air, soils, water, biota), as well as the various chemical forms in which mercury can occur, are being investigated.

In addition, the CSIR and stakeholders in the South African Mercury Assessment (SAMA) Programme (the Department of Environment Affairs and Tourism, Sasol and Eskom) have estimated mercury emissions for South Africa based on different mercury source categories, as defined by the United Nations Environmental Programme's Global Mercury Programme. "Overall, our findings suggest that South Africa's mercury emissions may be lower than previously thought. However, it may be likely that South Africa still ranks among the top 10 countries in the world in terms of global mercury emissions to the atmosphere. Atmospheric mercury measurements, which are very limited in South Africa at present, are the only means of verifying this," Leaner adds.

Mercury in waste

It is believed that among many sources of mercury to the environment, waste plays a significant role. CSIR environmental scientist, Elizabeth Masekoameng, says imported ready-made products are likely to represent a large source of mercury to South Africa. Solid waste such as batteries, fluorescent lamps (including energy-saving bulbs) and electronic waste (computer components) are the main products that contain mercury.



Mercury research expert, Dr Joy Leaner (foreground) and James Beukes

"An unnerving reality is the electronic donations that developing countries receive from well-meaning developed countries. Delivery of aged computers, with an obvious shorter lifespan, is often accepted. As a result, the equipment enters the waste stream very quickly, along with the pollutants these carry," she says. The determination of mercury in solid waste, landfill leachate and landfill air emissions requires special protocols – leachate collects when rainwater passes through waste in the landfill.

"Analytical techniques to measure mercury in leachates are being set up within the CSIR in collaboration with the University of Connecticut, USA; however, gaining access to private landfills to collect leachates remains a challenge," says Masekoameng, who completed her MSc in ecotoxicology at Ryerson University in Canada.

Masekoameng is currently focusing her research on determining how much mercury enters the country, via both products and in its pure form, and what happens to this mercury. "I ultimately want to uncover the net release of mercury into the waste stream. I plan to investigate the level of contamination in the country, and develop a strategy for managing contaminated sites," she explains.

"Elizabeth's project links very well with furthering the aims of the SAMA Programme. The interactions between mercury in runoff from landfills, leachates and groundwater pollution will be explored," adds Leaner.

Mercury in ecosystems

"One of the larger projects that we are working on focuses on the development of a mercury-in-ecosystems (MERIECO)

model," she says. The model aims to integrate the mercury data collected in the national water survey with the results of atmospheric monitoring and modelling and the waste management project, so that an integrated view of mercury impacts on ecosystems can be achieved. CSIR researcher Alta De Waal has been instrumental in developing this model, where a single, predictive framework, in the form of a Bayesian network model, is being developed to model the transport of mercury through the ecosystem. "The project's progress towards achieving the overall goal has been excellent, especially considering the multi-scale and complex nature of the work that has to be undertaken to develop the integrated MERIECO model," Leaner concludes.
– Renatè Janse van Vuuren

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The obstacles and lack of waste management in South Africa pose huge challenges for authorities at all three levels of government

Economics of waste management: the way forward



Linda Godfrey

"We are finding increasingly that economics underlies the successful management of waste, and in particular in the promotion and implementation of the waste hierarchy (minimisation, reuse, recycling) in South Africa," says the CSIR's pollution and waste research manager, Linda Godfrey.

AN ECONOMICS PERSPECTIVE is also needed on other aspects of waste management, such as providing incentives for diverting waste from landfills to reuse and recycling initiatives, for example community-run composting sites that has the potential to generate income for communities; and providing incentives for the reuse or recycling of 'problem wastes' such as electronic waste, tyres or mining waste.

Waste economics

Godfrey believes the timing is right to take pollution and waste economics forward. "We believe that an assessment of the feasibility of specific economic instruments for waste management within the South African context is a good starting point," she says. A need exists to evaluate possible incentive-based instruments (such as taxes and subsidies), which could be applied in South Africa, based on what is being done internationally, and then to evaluate the opportunities and constraints of each of these instruments within the South African context. In so doing, economic instruments implemented are more likely to succeed in the developing country context of South Africa, given our current obstacles and challenges to integrated waste management.

In this regard, Anton Nahman, environmental economist at the CSIR's Stellenbosch offices, has commenced on a project to research the viability of economic instruments for waste management in South Africa.

"The use of economic instruments for this purpose in South Africa is currently limited," he says, "but it is imperative that we come to understand the South African context, especially with respect to economic instruments (EIs) that aim to achieve waste management objectives. Currently, waste management policy in developing countries is dominated by 'command and control' regulation, which involves setting and enforcing waste management legislation and standards."

CSIR initiatives

In recent months, the CSIR has conducted interviews with experts from municipal waste-management departments and private companies across South Africa, and produced three reports

examining potential instruments for solid-waste management. The first report reviewed the underlying economic theory as well as the instruments available; the second was a summary of the first that was sent to the interviewees as a background document prior to the interviews; and the third was an assessment of the opportunities and constraints associated with the implementation of these instruments, based on the findings of the interviews.

"These three reports focused on instruments aimed at reducing the amount of waste generated and/or diverting waste from landfill to recycling; namely product and input taxes, quantity-based user fees, recycling subsidies, and deposit-refund schemes," Nahman explains.

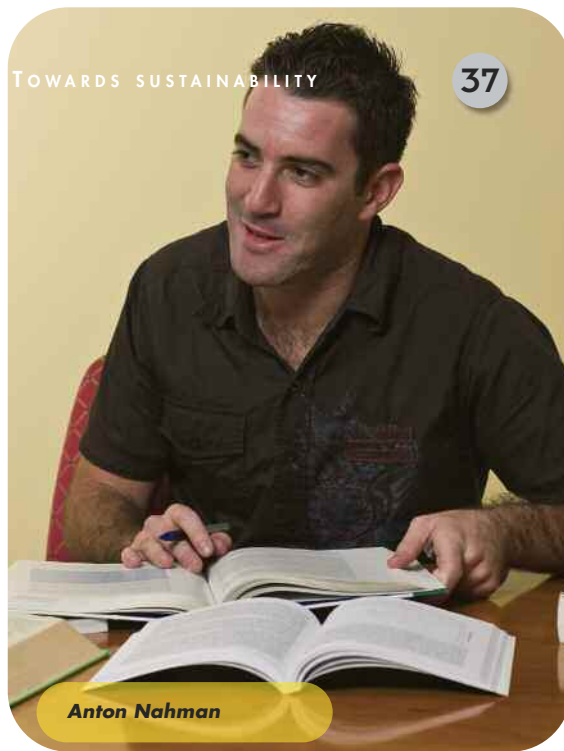
"The objective of our ongoing research is to assess the potential for and constraints to the implementation of EIs for waste management in South Africa, and to identify possible solutions to ensure the implementation of such EIs instruments in a way appropriate to the South African context," says Nahman.

Practical guidelines

"The aim of the research is thus to generate practical guidelines for waste management authorities at all three levels of government, and to provide an introduction to the range of instruments available. In reality, EIs can be administratively demanding on government and waste authorities, and require the fulfilment of a number of pre-conditions, such as:

- Well-functioning markets and related institutions (e.g. the legal system)
- Institutional capacity to fulfil the necessary requirements in terms of support structures, information, monitoring and enforcement
- Political will to implement potentially unpopular instruments, such as taxes.

Indeed, one of the main findings of the research to date has been that a number of fundamentals must be in place before sophisticated, first world policy instruments can be introduced. For example, the majority of municipalities in South Africa do not fully understand the true costs of waste



Anton Nahman

management (including socio-environmental costs). Thus, charges for waste management services (including collection and disposal) are either lacking or too low to cover these costs. No incentive is therefore present for producers or consumers to reduce the amount of waste they generate, or to switch to recycling rather than landfill disposal. Further, any revenues obtained are not ring fenced to be returned to the waste management department for re-investment in improved waste management.

Key to the implementation of EIs is the collection of comprehensive and reliable waste data. "Research conducted during 2006/07 shows that the collection of waste data has the potential to change the way waste is managed in South Africa, through knowledge generation and informed decision-making and planning," says Godfrey. "However, organisational culture and available capacity (both human and financial) within the three spheres of government play a fundamental role in facilitating this process."

Future research in this area will therefore focus on understanding how these fundamentals can be put in place and on the selection and design of instruments that are tailored to the developing country context; where markets, institutional capacity and political will may be lacking. — Renatè Janse van Vuuren

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Heidi van Deventer and Dr Moses Cho explore the state of our ecosystem through the use of spatial technologies

Snapshot from the sky

They say a picture is worth a thousand words... even more so in the case of a hyperspectral image; an airborne image that is helping CSIR scientists study the impact that nature and our own actions have on the world.

A HYPERSPECTRAL IMAGE is produced by a spectral imaging sensor that is mounted on a distant platform, such as a satellite or aircraft. It uses hundreds of very narrow wavelength bands to detect reflected energy that appears in the form of 'spectral fingerprints' across the light spectrum. Once these fingerprints are detected, special algorithms assess them to differentiate various natural and man-made substances from one another.

The technology is used for a variety of purposes: To identify plant species, map vegetation, characterise soil properties, identify contamination, classify habitat characteristics and differentiate causes of vegetation stress. The ecosystems earth observation group of the CSIR uses this and other spatial technologies to monitor the changes that occur in our ecosystem.

These are generally attributable to natural variations, climate and global influences, or the result of human impact. One of the human impacts studied by the team is the effect that wastewater from mines has on vegetation growing on the banks of streams and rivers.

Abandoned metal and coal mines flooded by water are sources of acid mine drainage (AMD). The acid mobilises heavy metals – including arsenic, uranium, copper and nickel trapped in the rock – and becomes something like battery acid. This cocktail of heavy metals finds its way back into the ecosystem and it is through spatial technology that scientists get a better understanding of the extent and effects it may have on the environment.

Through hyperspectral data we are able to detect changes in vegetation that even the naked eye can't see.



An exercise in hyperspectral analysis

(Image credit: Brigette Martini, UCSC)

Heidi van Deventer is a geo-information researcher at the CSIR who is working towards obtaining her PhD in geography. By studying hyperspectral image data she investigates the effects these heavy metals have on riparian vegetation.

Plant conditions are assessed by their spectral signature – a measure of electromagnetic energy reflected from the vegetation. Plant health is a major factor that dictates the amount of energy reflected. “Through hyperspectral data we are able to detect changes in vegetation that even the naked eye can't see.

You can detect plant stress, heavy-metal uptake, nutrient deficiencies, insect damage and red tide, for example. It is incredible to think that we can capture such intricate detail over such a large geographical area,” says Van Deventer.

Once the data have been collected and analysed, the CSIR can help authorities grasp the nature and causes of changes

to the ecosystem and advise them on strategic solutions that can reduce destructive impacts on our living environment.

Using spatial technologies in research has definite benefits over existing approaches; field-bound techniques are time consuming and most often result in ecosystem state information that is significantly constrained. “Hyperspectral image data help us form a holistic and integrated picture of the ecosystem,” says Van Deventer, “It gives us a bird's eye view of the influence that external factors, such as mine effluent, have on our living environment and enables us to act timeously and appropriately.”

– Cat van Rooyen

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A hyperspectral image with a near-infrared (NIR) treatment. The wavelength shown as red is reflected energy from the NIR section of the electromagnetic spectrum. Since vegetation is highly reflective in the NIR, the forests appear red. The relative overall reflectance-level observed in forest canopies often says much about the general condition of vegetation. For instance, a bluish cast to vegetation may indicate physiological stress of some kind

CHANGING THE WAY WE LIVE

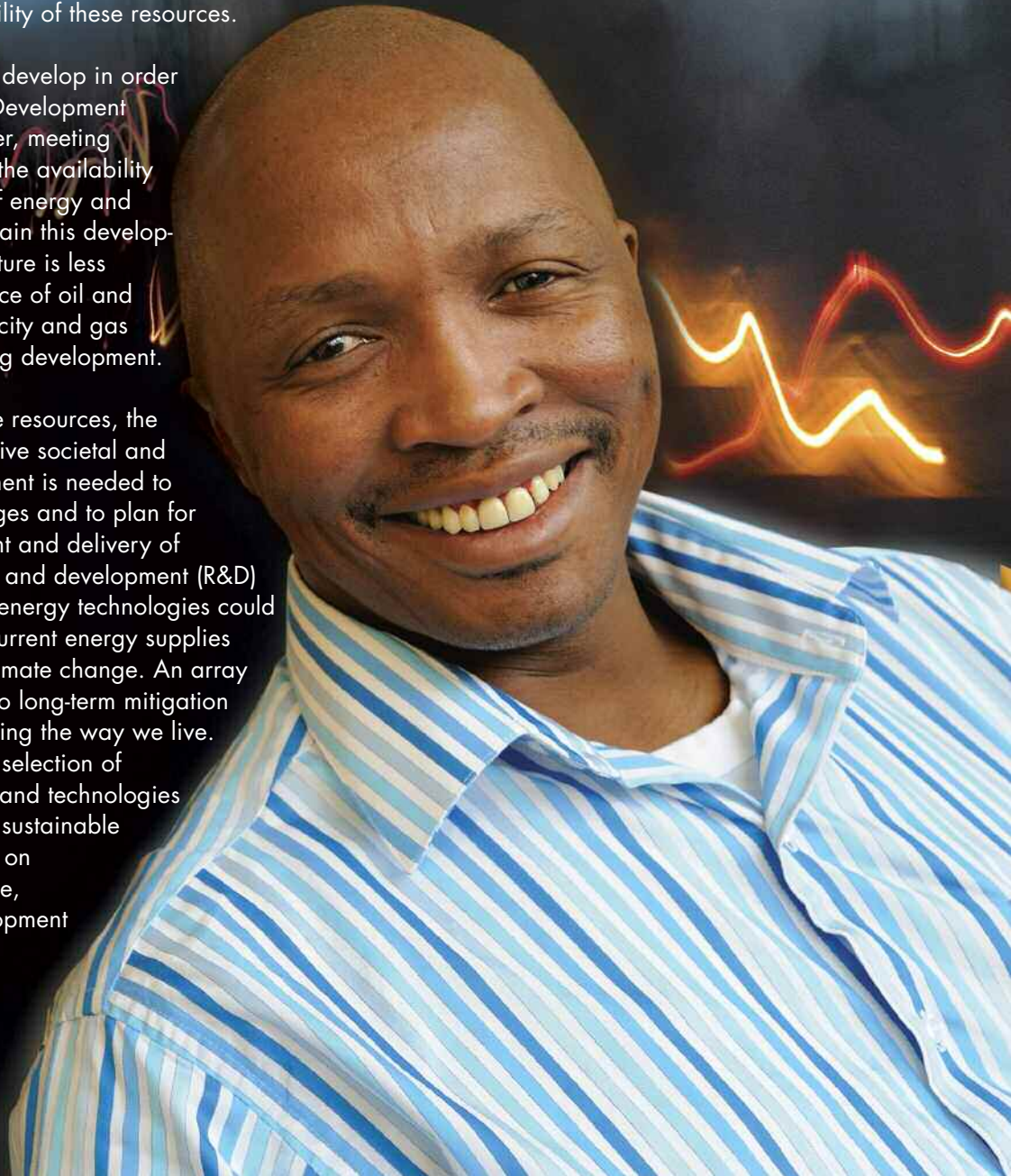
IS THE EARTH BECOMING TOO SMALL for its inhabitants? The answer to this question is definitely in the negative. Despite predictions that the world's population will reach the nine billion mark by 2030, it will still be able to accommodate all its inhabitants. The problem is that we are running out of habitable spaces mainly because of unsustainable utilisation of the earth's resources. Development in these habitable spaces is often characterised by rapid infrastructure delivery that increases the environmental burden. As the population increases, the pressure on the natural resources (i.e. mineral resources, soil quality, water and energy) and on human environments becomes more pronounced. At present, climate change is also threatening the availability of these resources.

Africa must and should develop in order to meet its Millennium Development Goals (MDGs). However, meeting the MDGs depends on the availability of adequate amounts of energy and the infrastructure to sustain this development. Currently, the picture is less promising. The high price of oil and the undeveloped electricity and gas infrastructure is derailing development.

As we run out of infinite resources, the use of new and innovative societal and technological development is needed to alleviate energy shortages and to plan for sustainable development and delivery of infrastructure. Research and development (R&D) in new and renewable energy technologies could somehow supplement current energy supplies and mitigate against climate change. An array of R&D can contribute to long-term mitigation scenarios and to changing the way we live. This chapter presents a selection of innovative approaches and technologies that could contribute to sustainable living, particularly R&D on sustainable infrastructure, housing and city development and renewable energy.

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Alfred Nkuna monitoring the testing of a material sample

Investigating enzyme-based liquid stabilisers in road construction

By Dr Martin Mgangira

A TOTAL ROAD NETWORK of 760 000 km criss-crosses South Africa. According to the Department of Transport, 17 000 km of this is surfaced national roads, 56 000 surfaced provincial roads, 170 000 km surfaced and unsurfaced urban roads, while 300 000 km is gravel provincial roads and 220 000 km unclassified roads. Unclassified roads include access roads in rural communities and roads in settlements on the urban periphery. This shows that the country's road network comprises mostly unpaved roads.

Roads give economic life but also stifle environmental life through disturbed habitats; concentrated water flow that causes accelerated erosion; air pollution from vehicles and dust, particularly along unpaved roads, resulting in reduced quality of life; and increased sediment in streams. These realities are taken into consideration in the geotechnical research agenda of the CSIR where a research project focuses on

liquid chemical stabilisers in road construction, which can be used to alleviate the negative impact on the environment and to provide economic benefits.

Significant research has been done to improve the engineering properties of materials used in road construction, notably through chemical stabilisation products. A number of proprietary new and alternative liquid chemical stabilisation additives have been developed for this purpose. In terms of unpaved roads – which proportionally far outstrip surfaced roads – improved properties lead to less materials being lost during both dry and wet periods and less dust during dry periods; increased capability of supporting higher levels of loading; and improved compactability during construction. The effective use of these products could have an ecological impact as the need to import other materials is reduced after material is treated on site. Liquid chemical stabilisation additives are generally classified as being either

ionic, polymer or enzyme in type. While the use of these is generally increasing for low-volume roads in developing countries, most of the research (particularly on the use of enzyme types) has been conducted in countries with environmental conditions different to South Africa's. Examples have been reported – mostly by product manufacturers – where enzyme-based products have apparently been used successfully as geotechnical stabilisers in road construction in different parts of the world. There is, however, a need to conduct local independent studies on these products.

The CSIR is trying to gain new knowledge of physicochemical properties of local geotechnical materials treated with enzyme products. In addition, researchers want to quantify the microstructural bonding mechanism of the treated materials.

To determine the true performance of materials treated with liquid chemical

stabilisers, changes that will occur when treated soil is subjected to traffic loading have to be considered. This can be simulated through cyclic/repeated loading in the laboratory.

The research involves extensive laboratory testing that includes variation in soil type (mostly considered to be marginal material in conventional pavement design), two locally-available enzyme-type additives, additive quantity, curing period and variation in loading cycles. The testing enables researchers to evaluate the cumulative effect of loading cycles at various stress levels and to relate the response of the stabilised material to its performance under traffic loading.

Initial work has been done on basic requirements and limitations of repeated load testing on materials stabilised with enzymes-based products. In addition, advanced material characterisation has been conducted using a scanning electron microscope image analysis technique on both treated and untreated samples to determine the characteristic changes that may have occurred in the treated materials.

Ultimately, the analysis of the test results will enable CSIR researchers to formulate simple and practical methodologies for assessing the long-term performance of enzyme-based stabilised marginal materials for low-volume roads. Such methodologies can then be implemented through Agrément South Africa, under the fit-for-purpose certification process. This study is a component of an ongoing project on non-traditional chemical stabilisers.

Enquiries

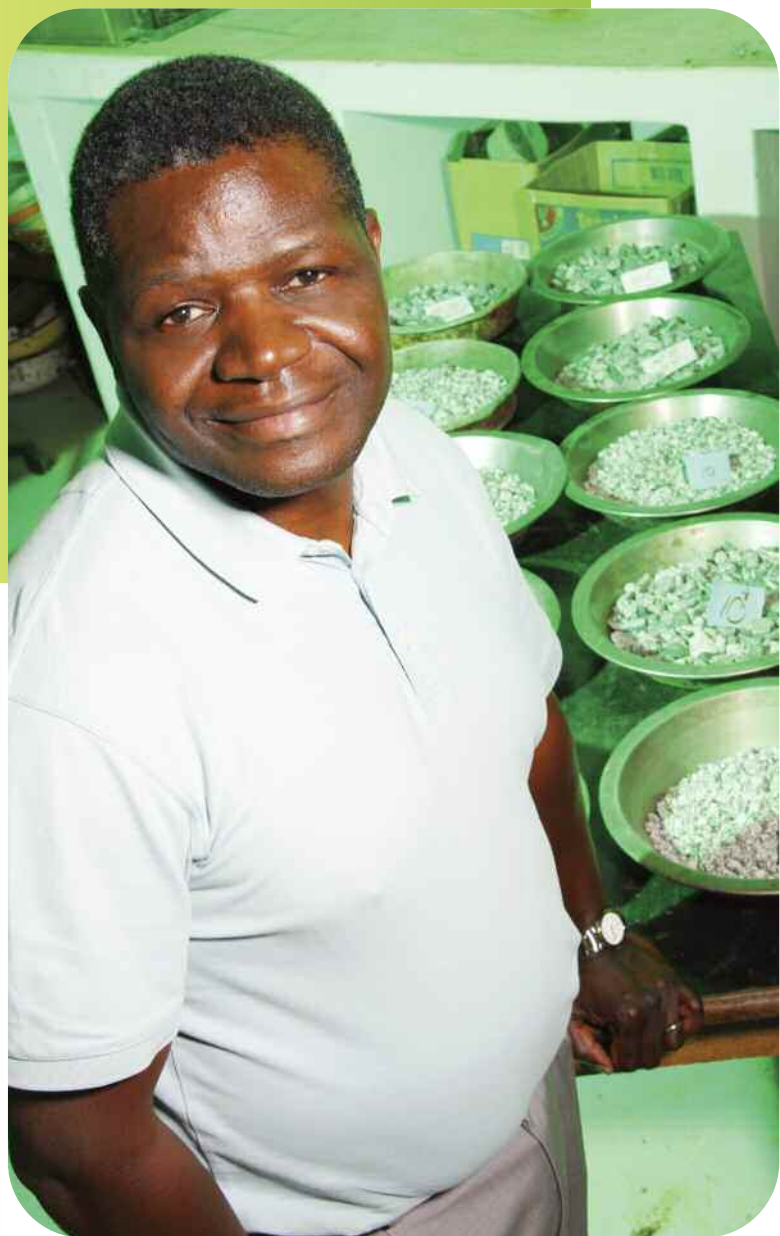
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The CSIR has undertaken research on liquid chemical stabilisers since the late 1980s. Dr Phil Paige-Green carried out a systematic study into the effects of sulfonated petroleum products (SPPs) on different soils; his work formed the basis for the development of the SPPs toolkits produced by TRL of the United Kingdom. Dr Dave Jones and Dave Ventura have developed a procedure for fit-for-purpose certification of non-traditional road additives.

Dr Martin Mgangira of the CSIR in one of the laboratory rooms where materials used in road construction are tested

Four small samples of two different soils treated with two different enzyme-based products at the same concentration, ready for analysis, using scanning electron microscopy



CSIR researchers have undertaken field tests using non-traditional stabilisers for unsurfaced roads in the Kruger National Park, an important South African conservation area. The results were monitored over a period of a year. In this context, soil stabilisers play an important role in reducing the loss of gravel from the roads over time, thereby reducing the amount of replacement gravel that needs to be extracted from the areas within the conservation area. It also contributes to a reduction in dust generated and thus damage to vegetation and animals.



Sample manufactured with 3.5% agribinder, which has properties between conventional asphalt and cement concrete

Researchers continue to pursue road binders from renewable sources

By Dr Phil Paige-Green

Bitumen is an essential component of flexible sealed roads, with unique properties providing a strong adhesion to most rock aggregates, yet allowing adequate flexibility and ductility to permit limited flexibility of the road pavement under a range of temperature conditions.

A foresight study done at the CSIR in 1999 identified the possibility of a future shortage of bitumen for road construction. This led to a brief investigation into the potential of developing an alternative binder from renewable resources. Following this, a prototype alternative binder was developed, although the properties indicated that the material was too stiff and brittle for use as a binder in the form prepared. It was, however, considered possible to modify the product chemically to enhance its visco-elastic properties and make it more suitable for use in roads.

At that stage, increasing international literature was being generated on the pending shortages of oil, environmental effects of fossil fuel usage and its impact on climate change. Various alternative binders were being investigated and developed, but many of these were based on products that were basic foodstuff, as was the prototype binder developed by the CSIR.

In 2007 resources were allocated for the development of an improved binder. The objective was to use raw products that would not normally be utilised in food production. A prototype binder based primarily on materials currently considered as industrial waste products has subsequently been developed. This material is being evaluated and improved to develop the necessary properties for use as a road binder.

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New materials and technologies investigated for sustainable housing

By Llewellyn van Wyk



Llewellyn van Wyk

After decades of demands for rapid infrastructure and improved construction management, calls are being heard to lessen the environmental burden of construction.

The construction sector has been under unprecedented pressure from clients since 1945: The huge demand for rapid infrastructure delivery in the aftermath of World War II brought into question the efficacy of management techniques and construction technologies employed almost uninterrupted in the construction sector for over 5 000 years. A legacy of poor quality, overspending and failure to complete on time resulted in sector efforts to improve construction management processes during the latter part of the 20th century.

However, the final two decades of the 20th century saw an additional focus emerge around unsustainable consumption and production patterns within the construction sector as a whole. The construction sector has an abysmal record with regard to consumption and production patterns: through its dependence on raw materials derived largely from the extractive industries, it is responsible for consuming almost half of all resources used globally.

Extractive industries already use most of the electricity consumed in South Africa (in itself generated by the burning of fossil fuels derived from the extractive industries).

In addition, the conversion of raw materials derived from the extractive industries into construction materials requires a further significant amount of electricity (steel, aluminium, cement, and bricks).

According to Brian Edwards¹, buildings are significant users of raw materials:

- Materials:** 50% of all resources globally go into construction
- Energy:** 45% of energy generated is used to light, heat and ventilate buildings and 5% to construct them
- Water:** 40% of water used globally is for sanitation and other uses in buildings
- Land:** 60% of prime agricultural land lost to farming is used for building purposes
- Timber:** 70% of global timber products end up in building construction



An increasing global net population growth of 73 million people – enough to fill the Johannesburg/Pretoria metropolis every three weeks – and ongoing urbanisation require construction to significantly increase the pace of delivery while reducing resource consumption. The beginning of the 21st century therefore sees a sector under pressure to improve the pace and quality of infrastructure delivery while transforming its consumption and production processes. It is thus not surprising that large inter-governmental organisations – such as the United Nations and the World Bank – and multinational organisations – such as the World Business Council for Sustainable Development (WBCSD) – have turned their attention to ‘transforming’ the sector.

The construction sector is also re-examining its performance, with some contracting companies, material manufacturers and research institutions revisiting the prefabrication movement of the late 19th and early 20th centuries. Construction is one of the few industries that still assembles all raw and finished materials required for the finished product on the actual site where the product is required in what is referred to as a ‘bespoke’ process. Prefabrication, on the other hand, aims to replicate the manufacturing processes of the automotive and aeronautical industries within the construction process.

Quite why prefabrication has never delivered on its promise is not clear. However, its inability to deliver the variation of the bespoke approach,

and the absence of the ability to debug construction problems through the application of ‘virtual construction’ facilitated by the use of information and communications technology (ICT), have undoubtedly impeded its success.

A manufacturing approach to construction will require at least three technologies, those in the areas of materials, production and assembly.

Materials technology concerns the production of new materials that are lighter, stronger, recyclable, use less energy, ecologically sustainable and maintenance free over its entire life cycle. Production technology in the contemporary production process involves the electronic transfer of the product design to a production machine able to adjust the settings to suit the design. This adjustment is both shape and thickness oriented.

Assembly technology encompasses the proper assembly of the manufactured components in a manner that ensures the whole benefits from the integrity of the high performance qualities of individual components. In addition, assembly technology must ensure flexibility, interoperability and disassembly of individual components in line with the emerging open building approach. Responding to these, the CSIR has created an advanced construction technology platform to develop, test and roll-out these technologies in the construction process to improve building performance and delivery while reducing environmental burden, and con-

tributing to sustainable human settlements.

CSIR researchers will identify, develop and test next generation materials, production and assembly technologies. The identification of next generation materials will be predicated on mechanical properties of high strength (tensile and compressive), lightness, enabling a manufactured production process, derived from renewable resources, and a capability to be reused and/or recycled.

Researchers will also identify, develop and test the exploitation of the surface opportunities of identified materials in terms of hardness, embedded colour and texture, self-cleaning, self-healing, pollutant removal, colour changing, and sensor embedding potentials.

The CSIR focuses on developing a new production process based on computer-aided manufacturing (CAM) that can read computer-aided design directly from the designer’s computer software.

Significant research efforts will also be directed at developing new assembly technologies and fixing technologies generated in and through the CAM process.

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¹ Edwards, B. (2002), *Rough guide to sustainability*, RIBA Publications, London

Planning for city growth in Gauteng

By Helga Goss



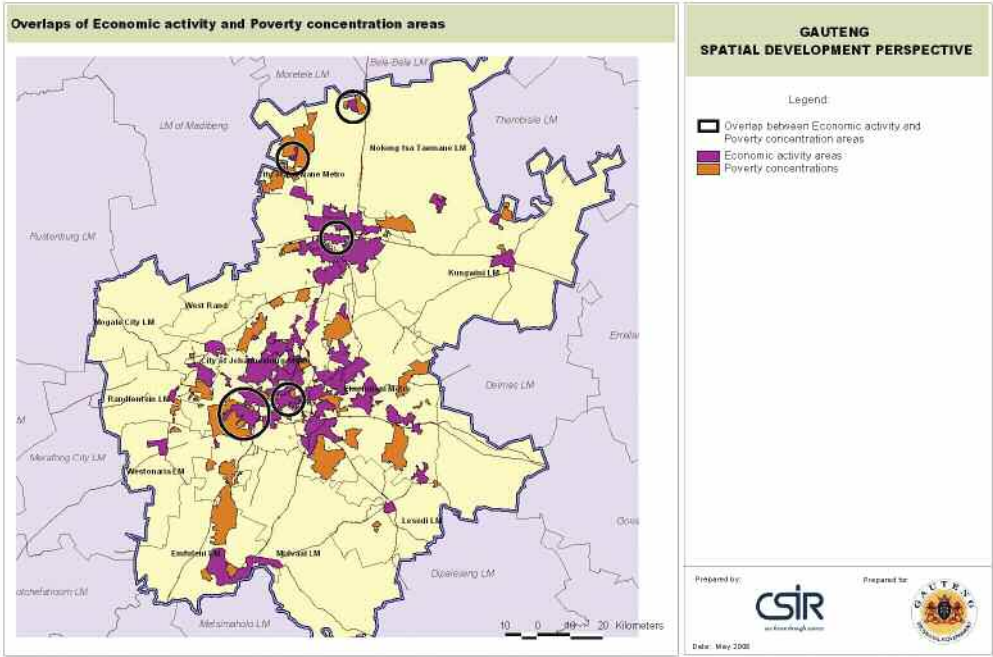
Helga Goss, senior townplanner at the CSIR

GAUTENG is regarded as the economic powerhouse of South and southern Africa, with economic activity contributing around 40% of the national gross value added in 2004¹. Simultaneously, it houses a substantial proportion of the country's poor (11,3% of people living below the minimum living-level nationally²). In striving to fulfil this role, the province faces a complex set of challenges.

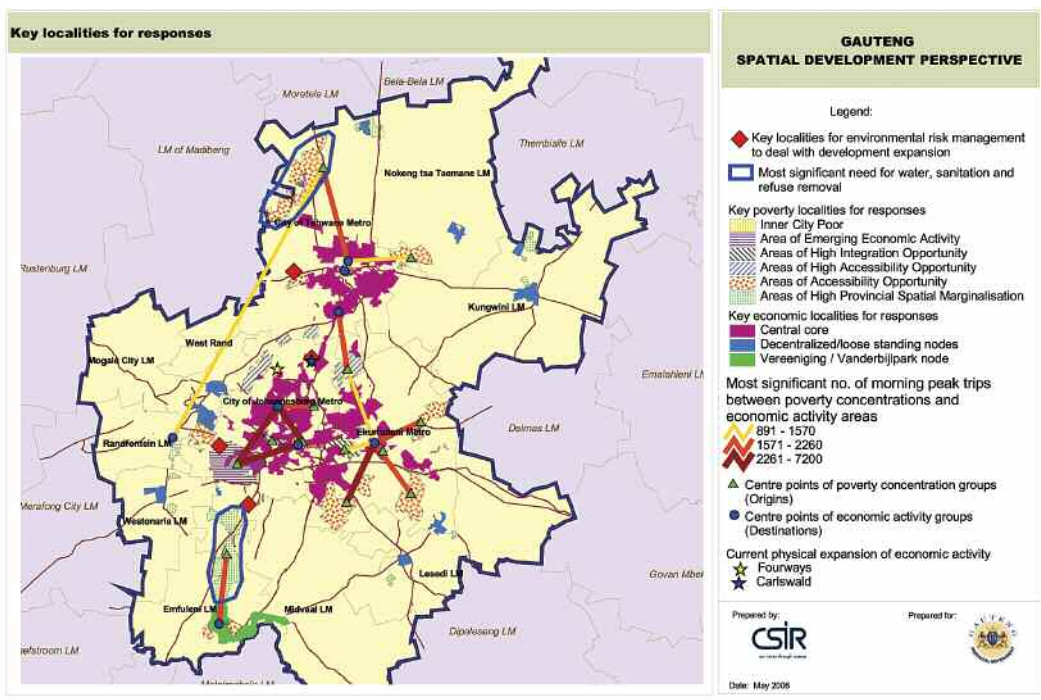
These include high but unequal growth, environmental degradation, socio-economic and spatial fragmentation manifesting in huge differences in quality of living, as well as the institutional challenge of prioritising, focusing and coordinating the actions of the three spheres of government and the business community. Recent initiatives in Gauteng all raised the importance of and need for a common spatial perspective of the province. These

initiatives include the development of a provincial growth and development strategy, the vision of making Gauteng a globally-competitive city region, the development and review of long-term metro and district development strategies, and the study of various land use, environmental and housing issues conducted by the Land Use Task Team.

To address this need, the Gauteng Spatial Development Perspective (GSDP) was prepared by the CSIR's planning support systems group as part of a memorandum of understanding between the CSIR, the Gauteng Department of Transport and the Gauteng Department of Economic Development. The primary function of the GSDP is to serve as a common platform for planning and investment. It is a tool to help all stakeholders in the province agree on a common understanding of the nature and functioning of the provin-



Sharing growth – current spatial distortion and exclusion



Targeted areas for fixed investment and development spending



cial space economy and as such guide and align infrastructure investment and development spending.

The reading of the space economy provided by the GSDP enables the province and municipalities to focus on and prioritise the areas and sectors generating growth, thus optimising the opportunity presented by these. This would assist in achieving the provincial objectives of generating and sustaining economic growth rates of 8% and more, sharing this growth and addressing poverty.

The ultimate goal would be not only to support economic growth, but also improved livelihoods, mobility, accessibility and compact land use agendas in the next decade or longer.

The GSDP was also the provincial-scale application of the principles and methodologies introduced by the National Spatial Development Perspective (NSDP). The NSDP, prepared by The Presidency in 2003 and updated in 2006, provides an analysis and identification of a number of challenges regarding the national space economy, as well as a set of principles to be adhered to by the three spheres of government when making fixed investments and undertaking development spending.

This initiative was further abetted by a framework to ensure greater harmonisation and alignment in the developmental actions of the three spheres of government in 2004. The GSDP was prepared in accordance with the proposals contained in the framework and provides an analysis of the challenges facing the province in terms of the NSDP principles and a set of province-specific, contextualised investment principles derived from the NSDP principles, as well as principle-led responses prioritising specific areas for fixed investment and development spending.

The GSDP³ confirmed the necessity for focused investment and development spending in the province and the value of understanding the spatial manifestation of economic activity and poverty.

It provided insight into the degree of concentration of economic activity in the province – the most significant areas of economic activity, mostly located in the central areas cover only 8,4% of the provincial land area, but generate 86,5% of the total provincial gross value added in 2004. It also confirmed the intensity of socio-economic exclusion and spatial disparities, with 60% of all households in the province, and 81% of all households living under the minimum living-level, residing in 30 dispersed

poverty concentrations mostly located in peripheral areas, far from the central core of economic activity.

An analysis of the dimensions and trends related to these areas of economic activity and need, as well as current commuter flows between these areas, enabled the identification of priority areas for investment and development spending to aid the achievement of provincial economic development and poverty eradication. A set of principle-led responses has been formulated for each of these areas.

The GSDP has been adopted officially by the Gauteng provincial government in 2006 and has since been used to inform planning processes in the provincial sphere (e.g. the Provincial Spatial Development Framework currently being completed). The reading of the provincial space economy that was provided has also been used in the formulation of a spatial strategy for Tshwane Metro, been referred to in spatial planning presentations by Johannesburg Metro and is being incorporated in the development of a spatial framework for Mogale City.

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¹ The Presidency (2006) National Spatial Development Perspective, p71: based on Ricon (Pty) Ltd, REX version 2.0c (190) Economic Focus: 2004

² The Presidency (2006) National Spatial Development Perspective, p36: Mesoframework Version 1.1, based on population estimates for 2004, Ricon (Pty) Ltd, Regional Economic Explorer (version 190)

³ Gauteng Department of Economic Development. 2007. Gauteng Spatial Development Perspective

Natural fibres set to fly high



CSIR staff members active in textiles research: (front) Roger Metelerkamp, Dr Maya John, Dr Lizette Erasmus, Dr Rajesh Anandjiwala, Lydia Boguslavsky, Dr Asis Patnaik; (back) Dr Paul Wambua, Abisha Tembo and Steve Chapple

Today, fibre researchers can combine, modify and tailor fibres in ways far beyond the imagination and performance of fibres from the silkworm cocoon, harvested and spun, or grown in fields.

ALTHOUGH MANUFACTURED FIBRES, composite fibres and modified fibres are used widely in modern clothing, home furnishings, medicine, aeronautics, energy, industry, and many more applications, researchers are still working on investigating the morphology and fine structures of natural fibres which itself is a composite.

For years, engineers and scientists have been in search of alternatives to traditional materials to combat the high costs of repair and maintenance of structures damaged by corrosion and heavy use. Since the 1940s, composite materials – formed by the combination of two or more distinct materials on a microscopic scale – have gained increasing popularity.

Today, fibre researchers can combine, modify and tailor fibres in ways far beyond the imagination and performance of fibres from the silkworm cocoon, harvested and spun, or grown in fields.

Ideal for widespread applications in construction worldwide, natural fibre composites promise to be a substitute for traditional materials and may contribute to successfully addressing major challenges of the automotive and aerospace industries.

Investigating the unique properties and characteristics of plant fibres is a primary focus area of the CSIR.

Emerging technologies such as nanotechnology, biotechnology, and polymer and natural fibre composites are used to research, enhance and develop improved fibres and products.

During the past decade, natural fibre-reinforced composites have witnessed increased awareness and considerable growth. This is attributed to their unique properties, as well as the technologically-demanding aerospace and automotive industry sectors.

In the context of end-of-life of vehicle laws and an eco-efficient aviation industry, these materials have the advantages of weight saving (light material), lower raw-material price from natural origin, 'thermal recycling' and the ecological advantages of using renewable resources.

Due to their properties, the most important of the natural fibres used in composite materials are flax, hemp, jute, kenaf and sisal and are widely grown in the country. Except for sisal, these are bast fibres and have more or less similar morphologies, which mean they have similar functions in the composite.

The fibres are composed mainly of cellulose and some lignin, and are sometimes called ligno-cellulosic fibres. As a result, many non-structural components for the automotive and other sectors are now made from natural fibre-composite materials. These materials are largely based on polypropylene, polyester and polyamide matrices incorporating the aforementioned natural fibres. However, the current applications of natural fibre-reinforced composites are somewhat limited to non-structural automotive components, partly because of low impact properties, poor moisture resistance and difficulties to reach good surface quality.

South Africa's renewed global involvement in the automotive and aerospace sectors and the interest of leading players in aerospace for sourcing natural fibre-reinforced composite products and technology from the country, set the scene for a project on natural fibre-reinforced composites. This project, under the Advanced Manufacturing Technology (AMTS) programme of the Department of Science and Technology (DST), researches technical applications in structural and exterior components of

aircraft. The AMTS is hosted by the CSIR.

Recently, the DST appointed the CSIR to lead a consortium to develop natural fibre-reinforced composites for potential use in the interiors of aircraft. It has been awarded by the DST's AMTS to CSIR Materials Science and Manufacturing.

The CSIR's fibres and textiles research area in Port Elizabeth has invested in a state-of-the-art nonwoven pilot plant, which is one of the top four such facilities in the world. CSIR researchers are involved in developing a natural fibre-composite material in conjunction with several academic institutions and industry partners.



**Temafa
natural fibre
preparation
line**

Research currently centres on the development of natural fibre composites for use in the non-structural components of aircraft cabins as well as the use of these in the automotive industry. It investigates the impact-energy absorption and failure mechanisms of woven natural fibre-reinforced polypropylene composites and the hybrids of these.

Chemical modification of natural fibres like flax, hemp and sisal are researched by the use of suitable compatibilisers and biological coupling agents. Other areas include the influence of processing conditions on the physical and chemical characteristics of natural fibres, fabrication of composites from needle-punched nonwovens (flax and kenaf) and thermoplastics by compression moulding, along with the characterisation of green composites.

Mathematical modelling and computer-aided simulations are used to maximise efficiency. This aims to develop computer-based models for different physical phenomena involved in the actual applications of textile materials. The fundamental work proposed for flexible fibrous assemblies will benefit the cross-fertilisation of scientific disciplines, such as mechanics of reinforced composite structures and of biomedical devices.

Computer-driven theoretical models to predict mechanical properties of natural fibre-reinforced composites by utilising finite element analysis are being developed and are required to incorporate in the analysis of real-life problems through component modelling to predict the failure mechanism of computer-aided designs for the aerospace industry.

On yet another level, research is conducted on the different surface treatments and compatibilisation along fibre retardancy in composite material, the characterisation of composite materials and suitable substrates from different natural fibres as reinforcing media for composites.

The CSIR invested in composite characterisation and fire-retardancy testing laboratories recently besides developing 2 700 kN compression-moulding equipment and acquiring vacuum-assisted resin transfer moulding to meet the infrastructure needs of the projects.

- Patsy Scholtz

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Instron tensile and flexure testing being conducted



Locality of subsidised housing in Gauteng to change

By Dr Sharon Biermann

Subsidised housing in Gauteng at a cross-road

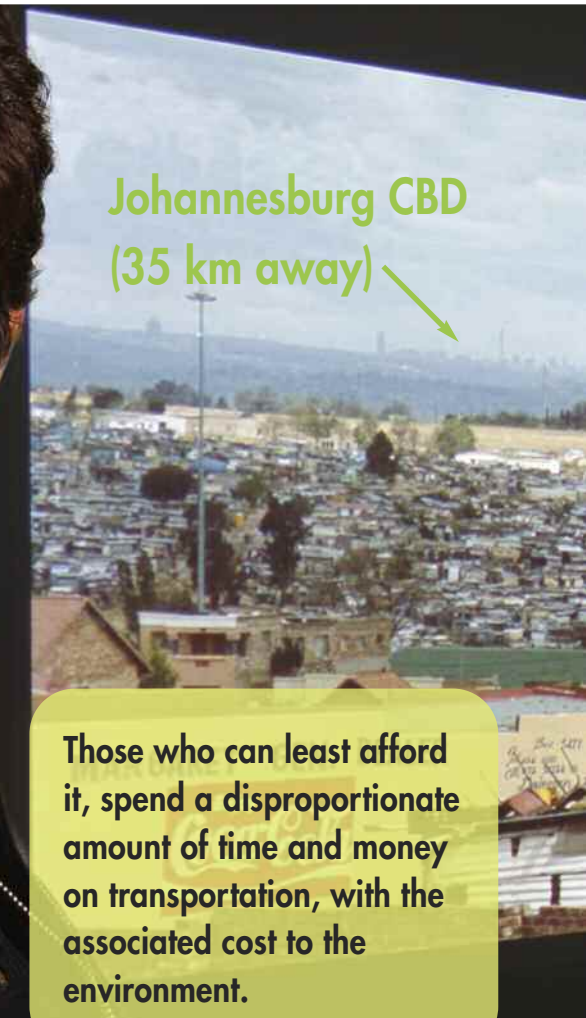
Gauteng is experiencing a population growth rate of twice the national average, while unemployment rates have doubled, resulting in a significant increase in the number of urban poor. To keep pace with the growing demand, but within funding and legal constraints, the provincial government built just over 300 000 serviced housing units during the period 1994 to 2004. These houses are located mainly on the urban periphery, adjacent to existing low-income settlements, where land is relatively cheap and easy to acquire.

While this approach has delivered a significant number of housing units, it has been at the expense of quality, in terms of the location of these settlements in relation to the wider urban region, necessary for sustained livelihood development. Continued peripheral subsidised housing delivery at scale, on poorly-located land, perpetually marginalises poor people from urban opportunities, including employment,

amenities and social networks. Those who can least afford it thus need to spend a disproportionate amount of time and money on transportation, with associated costs to the environment in terms of resource use and greenhouse gas emissions.

CSIR models implications of directional change

The provincial leadership called for an investigation into the feasibility of a 'directional change' in housing delivery – a turn-around from delivering housing at low densities on the urban periphery to more sustainable delivery on better-located land, closer to urban opportunities, at higher densities. To inform this investigation, a cost-benefit-affordability assessment model was developed by the CSIR to guide decision-makers in Gauteng. The aim was to direct low-income housing delivery to localities



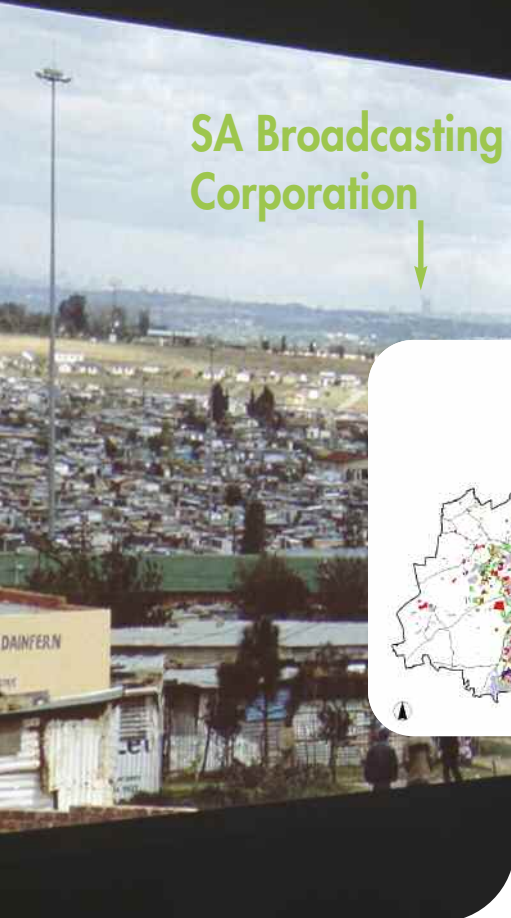
Johannesburg CBD
(35 km away)

Those who can least afford it, spend a disproportionate amount of time and money on transportation, with the associated cost to the environment.

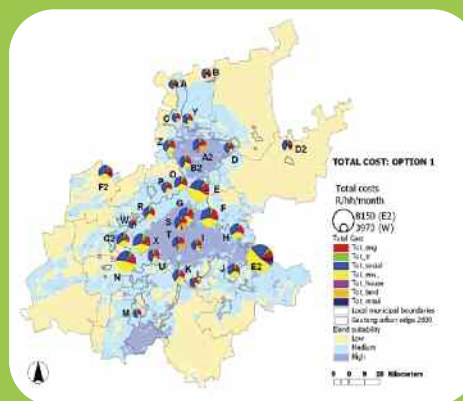
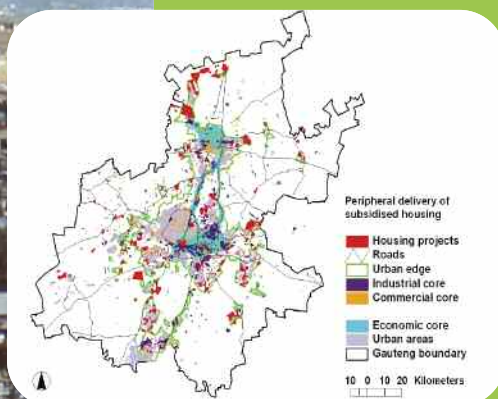
least costly to develop, maintain and operate over the longer term. Simultaneously, this housing had to yield the greatest benefit in terms of sustainable livelihood capitals or assets, allowing individuals to improve their livelihood condition, leading to economic growth and increased household income levels.

The model is multidisciplinary and incorporates engineering services, transportation, social amenities, retail goods and services, environmental resources, land and house top structure costs and benefits, including once-off or capital and recurrent costs to both government and households. A high-level affordability assessment model was incorporated to determine the gap between funds required for meeting the housing backlog in the form of a directional change and funds available. The model allows the testing of various measures to reduce the gap and increase afford-

SA Broadcasting Corporation



Continued peripheral subsidised housing delivery at scale, on poorly-located land, perpetually marginalises poor people from urban opportunities, including employment, amenities and social networks.



ability through either cost reduction or fund augmentation. The model structures the significant contributors to costs and funds according to those accruing to the household and those accruing to each sphere of government. For both cost-benefits and funds available, costs are further disaggregated into recurrent and capital costs.

Lower land and environmental costs

The most significant cost implication of a directional change to housing delivery on better-located land for government, is that capital land costs decrease, with an associated significant decrease in environmental costs. Capital housing costs of higher density housing, however, increase more than the land cost saving. The overwhelming cost increase for higher density housing on better located land accrues to the household in the form of an increase in both capital and recurrent costs.

Considering costs in relation to funds available, the assessment model clearly indicates that the directional change to better-located housing delivery is affordable to provincial government over the longer term. Although there is an increase of capital and recurrent costs to local government, the directional change is affordable under conditions of reasonably attainable increases in funding. The directional change, however, has major cost implications for households.

The very low income levels of some households mean that after expenditure on basic private goods and consumables, insufficient funds remain for capital and recurrent costs associated with housing, even with free basic services and low levels of rates and tax repayments. Even if all capital costs of housing are subsidised by provincial government in the form of a location subsidy, the recurrent housing expenditure requirements are not affordable by households under current conditions of low income levels and unemployment.

This study did not directly quantify and include the increased economic activity that may occur as a result of better location, other than including measures of certain precursors of growth, in the form of cost savings, e.g. lower transport costs. It is assumed that if disposable income is increased through cost savings due to better location, and if access and exposure to urban activities improves and affords better opportunities for income generation and improved livelihoods, a directional change in housing delivery will ultimately contribute to economic growth. Improved location is, however, a necessary, but (in itself) insufficient condition for growth. For growth to take place, improved location must be complemented by increased private investment and improved skills/entrepreneurial levels to ensure that at least household income improves enough to afford the recurrent costs of housing.

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Alternative energy for Africa: enhancement of the UN Millennium Development Goals

The alleviation of poverty is the major challenge facing Africa and most development efforts are focused on ultimately addressing this challenge. South Africa, though a relatively developed country, has one of the world's highest levels of inequality, and poverty therefore remains a major problem.

The United Nations (UN) General Assembly adopted the Millennium Development Goals (MDGs) in September 2000. The eight goals (see text box) range from alleviating poverty and hunger and halting the spread of HIV/Aids to providing universal primary education; all to be achieved by 2015.

The MDGs do not address energy as one of the goals. Energy is, however, inherently linked to poverty alleviation, education, gender equity, health and the protection of the environment.

With this in mind, African leaders, in 2005, led an alternative energy initiative. The New Partnership for Africa's Development (NEPAD) declared: **"...Given the uneven distribution of energy resources on the African continent, it is recommended that the search for abundant and cheap energy should focus on rationalising the territorial distribution of existing but unevenly allocated energy resources..."**

MDGs and energy

"Energy cuts across all the MDGs simply because it is required for the successful realisation of each goal," says CSIR alternative energy specialist, Maxwell Mapako. "To eradicate extreme poverty and hunger, nations have to have access to energy (modern fuels and electricity) to increase household incomes. It improves productivity, increase output, and value-addition. Moreover, energy for irrigation increases food production and access to nutrition. This is why the United Nations Development Programme has subsequently produced a guide to energising the MDGs."

The MDGs also aim to achieve universal primary education and promote gender equality. Access to modern fuels and electricity allows more time for education, facilitating teaching and learning, and empowers women to become informed about health and nutritional issues.

SA energy strategy

"In 2006 South Africa's Department of Science and Technology and the Department of Minerals and Energy (DME) tabled the South African Energy Research and Development Strategy, which states that the challenge is to develop fully the available resources. In addition, it aims to promote innovative, competitive, equitable and sustainable energy systems for various socio-economic sectors across South Africa and the continent," Mapako notes.

Practical government support is exemplified by the DME's subsidy through the Renewable Energy Finance and Subsidy Office (REFSO), an instrument that pro-

vides capital subsidies for entrepreneurs intending to provide renewable energy services.

Rural electrification in SADC

The governments of many developing countries have dedicated rural electrification programmes. In a recent South African National Energy Research Institute-funded study by Mapako, the energy policies and strategies were investigated for rural electrification in four Southern African Development Community (SADC) countries – Botswana, Namibia, South Africa and Zimbabwe.

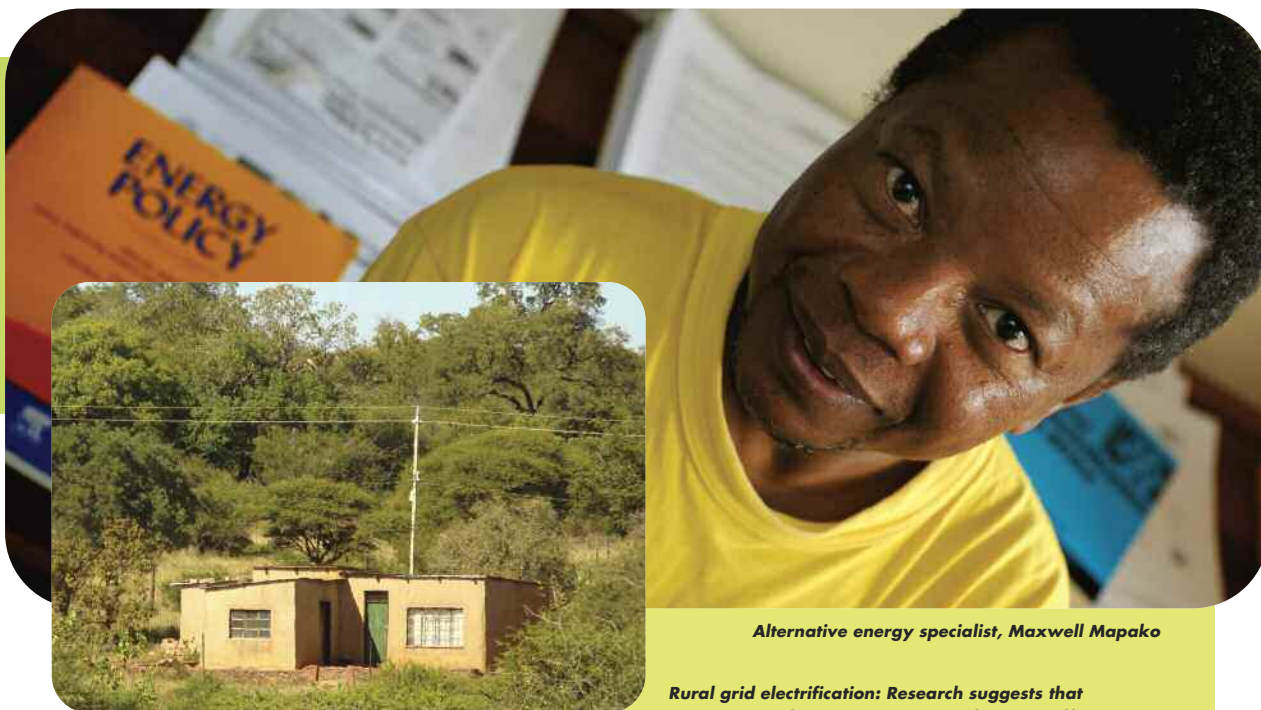
"The aim was to contribute to a larger regional comparison of the implementation approaches to rural electrification and the lessons that may be learnt from each country," Mapako explains.

The study showed that it was important to focus on the economic activities of the poor in rural electrification programmes, and that significant policy shortcomings existed partly due to lack of capacity in the SADC region to develop and maintain relevant and up-to-date policies.

Dr Alan Brent, engineering and energy management specialist notes, however, that external (market) forces have resulted in multiple purposes and goals associated with alternative energy, especially bioenergy.

Examples include:

- Utilising existing natural (renewable) resources, whilst maintaining social and cultural beneficiation of the resources



Alternative energy specialist, Maxwell Mapako

Rural grid electrification: Research suggests that targeting productive activities may be more effective in transforming rural livelihoods

- Stimulating socio-economic growth and development across different communities or parts of society
- Addressing local basic energy needs directly or indirectly through economic empowerment
- Reacting to market needs, national and international.

The question has subsequently been raised whether multiple conflicts exist with alternative energy interventions at a global scale. Brent mentions that, as an example at an international level "...a recent survey has shown there is much concern with the alternative energy market reaching a plateau; indeed, in the order of 50% of multinational players in the alternative energy field believe a possibility is present of a 'bubble burst', or a collapse of the alternative energy market." This, he says, "...is in light of the fact that, in general, the industry's current form relies in many ways on the public sector, and where supply, demand and potential growth depend as much on government policy as technological innovation or traditional market structures." Brent continues that many believe in a world focused on climate change, public and private behaviours might explain current valuations better than irrational exuberance.

Brent and Mapako state that it is vital to reach a common understanding and purpose on alternative energy interven-

tions, across all stakeholders, and to develop policy models and frameworks that address these (multiple) challenges.

Priorities include increasing the viability of the existing South African Biofuels Industrial Strategy (see page 56), and learning from other SADC country policies such as those implemented successfully in the reform of the sugar industry in Mauritius. Mapako mentions regional research suggests that the crafting of dynamic and responsive

policies depends on a sound relationship that facilitates active networking between researchers, policymakers and other stakeholders.

Mapako and Brent conclude that research needs to be able to respond more rapidly to pressing policy issues.

– Renatè Janse van Vuuren

What are the United Nations Millennium Development Goals?

The eight Millennium Development Goals (MDGs) – which range from halving extreme poverty to halting the spread of HIV/Aids and providing universal primary education, all by the target date of 2015 – form a blueprint agreed to by the world's countries and leading development institutions. They have galvanised unprecedented efforts to meet the needs of the world's poorest. The eight goals are:

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/Aids, malaria and other diseases
7. Ensure environmental sustainability
8. Ensure a global partnership for development.

(Source: www.un.org)

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The viability of the South African biofuels industrial strategy



Engineering and energy management specialist, Dr Alan Brent

TO EXPLOIT THE BIOMASS (see page 57) energy potential of the country, the South African Department of Minerals and Energy (DME) introduced and ratified a new Biofuels Industrial Strategy at the end of 2007.

"The strategy aims to achieve a biofuels (see page 58) average market penetration of 2% of liquid road transport fuels, i.e. petrol and diesel, in the country by 2013," explains CSIR engineering and energy management specialist, Dr Alan Brent.

Thereby, the biofuels target aims to contribute up to 50% of the national renewable energy target of 10 000 GWh (one Giga watt hour is one million kWh).

Political and economical analyses

It is stated in the strategy that the biofuels target is achievable without excessive government support. This can be achieved by using surplus agricultural capacity and assuming the oil price remains above US\$65.

According to CSIR environmental and resource economist, Dr Russell Wise, the target is based on local production capacity, both agricultural and manufacturing.

This target can contribute to reducing poverty and unemployment, and increasing economic growth and black

economic empowerment (BEE) through the value chain (see page 58).

In terms of its potential success, the South African Biofuels Industrial Strategy is primarily based on a feasibility study of the National Biofuels Task Team (NBTT). Since its inception in 2005, the NBTT has had a major influence on the business and political landscape pertaining to a possible South African biofuels production sector.

"For biofuels to be a viable alternative, these types of liquid fuels should provide a net energy gain, have environmental benefits, be economically competitive, and be producible in large quantities without reducing food supplies," Wise states.



**Environmental
and resource
economist,
Dr Russell Wise**

“One should keep in mind that a large-scale biofuel industrial sector in South Africa will substantially increase the demand for inputs to production (labour, fertilisers, water and land), with unknown environmental and socio-economic implications.”

To assess the environmental, social and economic aspects of biofuels in developing countries, a number of criteria have been proposed (see page 59).

CSIR study and recommendations

Based on such a framework of criteria, and the conclusions of the NBTT feasibility study, the CSIR reviewed the viability of the Biofuels Industrial Strategy in the short term with respect to the environmental, social and economic conditions of sustainability. “We specifically identified the main uncertainties and associated risks relating to these three

sustainability conditions,” according to Dr Alan Brent, who led the study.

The analysis was undertaken within:

- The global context of climate change and the uncertainty over its impacts
- A rapidly expanding global biofuels market
- Extreme inequalities between the rich and poor of the world
- Peaking world oil production.

What is biomass?

The International Energy Agency (IEA) defines biomass as material of recent biological origin that can be used either as a source of energy or for its chemical components. As such, it includes trees, crops, algae and other plants, as well as agricultural and forest residues. It also includes many materials considered as wastes by our society, including food and drink manufacturing effluents, sludges, manures, industrial (organic) by-products, and the organic portion of household waste.

We use the term ‘bioenergy’ for biomass energy systems that produce heat and/or electricity and ‘biofuels’ for liquid fuels for transportation. In many ways biomass can be considered a form of stored solar energy. The energy of the sun is ‘captured’ through the process of photosynthesis in growing plants.

Biomass is the oldest fuel known to man. It is also one of the most versatile and, in modern-day systems, a clean and efficient way of producing heat and electricity. Biomass arises in many forms and can be converted readily into solid, liquid or gaseous fuels.

According to the US Department of Energy, biomass is the only clean, renewable energy source that can help to diversify transportation fuels significantly. The department aims to transform that country’s renewable and abundant biomass resources into cost-competitive, high-performance biofuels, bioproducts and biopower.

BIOFUELS SUPPLY CHAIN



Feedstock production



Feedstock logistics



Biofuels production



Biofuels distribution



Biofuels end use

"Our overall objective was to identify research opportunities to help understand, quantify and reduce these uncertainties," Brent explains. "Our aim is to improve the viability and sustainability of meeting the renewable energy target of the strategy through improved policy and decision-making in the implementation of the strategy and subsequent management of the biofuels sector."

The detailed review and analysis are to be published toward the end of 2008 in a special edition of the *International Journal of Environment and Pollution*. Brent, Wise and colleague Henri Fortuin (coastal zone and environmental specialist) outline the CSIR's recommendations, summarised in six focus areas:

- Life cycle analyses: Impact assessment and costing methodologies need to be developed to better evaluate the environmental, social and economic implications of the biofuels value chain
- Strategic assessments: Methodologies need to be refined to improve the understanding of the ecological and socio-economic consequences of biofuels scenarios at a regional level
- Farming practices: Biofuels feedstock production must be enhanced to suit

What is biofuel?

According to internationally-acclaimed *National Geographic*, biofuels have been around as long as cars. At the start of the 20th century, Henry Ford planned to fuel his Model Ts with ethanol, and early diesel engines were shown to run on peanut oil.

But discoveries of huge petroleum deposits kept gasoline and diesel cheap for decades, and biofuels were largely forgotten. Petrol and diesel are actually ancient biofuels. They are known as fossil fuels because they are made from decomposed plants and animals that have been buried for millions of years. Biofuels are similar, except that they're made from plants grown today.

Biofuels may look like a great solution. It is a renewable resource since we can always grow more crops to turn into fuel. Using straight vegetable oil for fuel can lower greenhouse gas emissions by nearly 100%, greatly reducing air pollution.

Unfortunately, it's not that simple. Crop production consumes excessive energy hence countering its financial viability. Moreover, non-renewable resources such as coal are used in the production process. Other environmental aspects, such as water usage and land conversion, together with complex socio-economic aspects, have further complicated the issue.

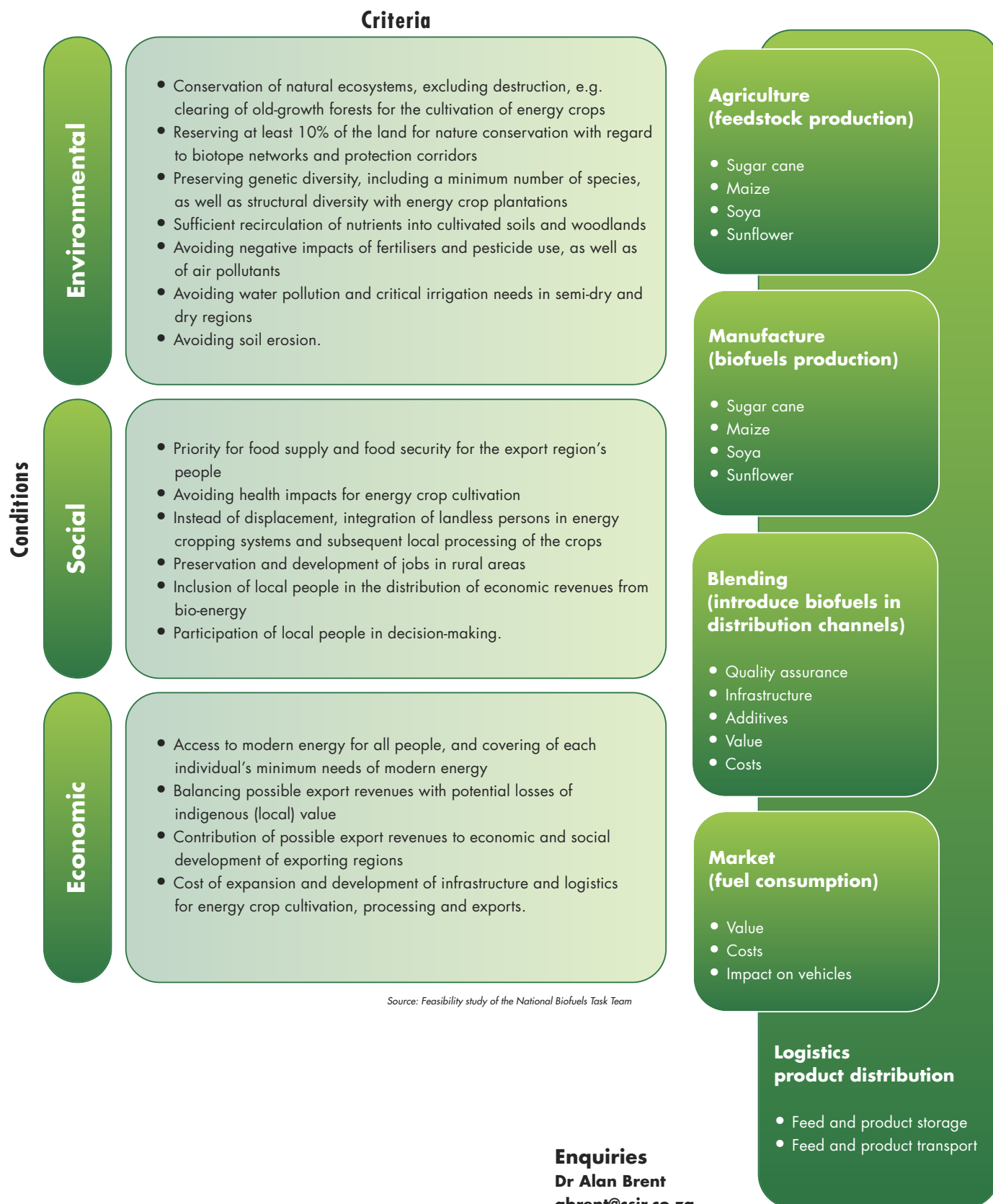
the environmental, socio-economic and cultural contexts in different regions of South Africa, and specifically in rural areas

- Economic incentives: The potential of methods such as taxes and subsidies must be investigated in the South African context in a comprehensive manner
- Adaptive management: A framework must be developed to instil adaptive learning and capacity building in communities that undertake co-production of biofuels feedstock

- Technology management: Models, normally applicable to the traditional organisational context, must be refined for the assessment, development, transfer and adoption of biofuels-related technologies in rural communities in the context of co-production strategies.

"By addressing these six research focus areas it is envisaged that the Biofuels Industrial Strategy can be a viable and sustainable one," Brent, Wise and Fortuin conclude. – *Renatè Janse van Vuuren*

Criteria for sustainable biofuels value chains in developing countries



Carbon capture and storage: towards sustainable energy management

Greenhouse gases and the resulting climate change hazard in our atmosphere are internationally-recognised threats. Without swift and drastic measures, the consequence could be disastrous for both our vulnerable planet and ourselves.



Dr Alan Brent

In December 1997, the Kyoto Treaty – an international protocol signed by 37 industrialised countries and the European Union – compelled the signatories to meet certain greenhouse gas (GHG) emission reduction targets within a specified period. To support the effort, the protocol offered countries additional means of meeting their targets by way of mechanisms and reduction incentives.

Clean development mechanism

“Various GHG reduction incentives exist,” explains CSIR engineering and energy management specialist Dr Alan Brent. “The United Nations Framework Convention on Climate Change (UNFCCC), through the Kyoto Protocol, drives one such incentive, the clean development mechanism (CDM). The CDM is a financial incentive intended to make economically-marginal GHG prevention projects more feasible. Industrialised countries, through the companies located there, could thereby earn GHG emission reduction credits. The incentives for developing countries such as South Africa to participate in the CDM are acquiring of technology and foreign capital, and accelerated growth.”

“The CDM aims to mitigate GHG emissions by offering a trading platform for proven emission reductions in develop-

ing countries through technological interventions by developed countries. Emission reductions are quantified in so-called certified emission reduction (CER) units that are tradable,” Brent says. A CER is simply the prevention of one tonne of carbon dioxide (CO₂) gas equivalent emitted in a developing country.

Trade-off between methane and CO₂

The other targeted GHGs are all related via a GHG potential rating back to equivalent CO₂. For example, methane (CH₄) has a 21-fold GHG higher potential than CO₂ over a period of 100 years. “This implies that one tonne of CH₄ emissions prevented is equivalent to 21 tonnes of CO₂ emissions prevented. CER units are traded on the open market at a price driven by supply and demand pertaining to specific projects; the trends in the carbon market are reported by the World Bank. The CDM is governed by the Executive Board of the UNFCCC, while the trading of CER units are facilitated by the Carbon Finance Unit of the World Bank (2007),” Brent explains.

Carbon capture and sequestration

CO₂ capture and sequestration (CCS) is a possible GHG mitigating strategy.

The Intergovernmental Panel on Climate Change (IPCC) defines a CCS project as a process consisting of three phases:

- The separation of CO₂ from industrial and energy-related sources
- Transportation of CO₂ to a storage location
- Long-term isolation of CO₂ from the atmosphere.

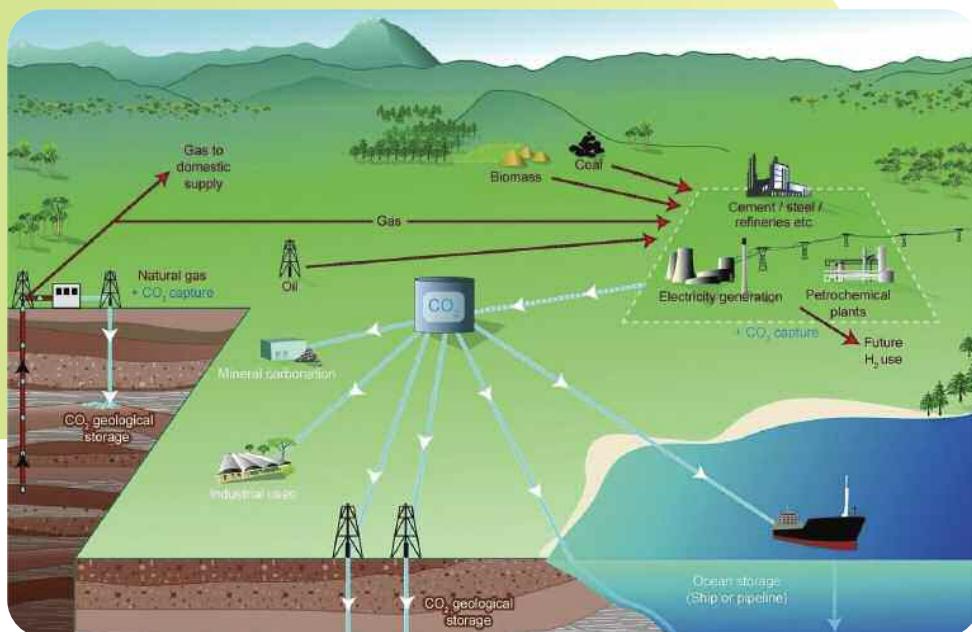
According to Brent, the conventional understanding of the CCS process is that CO₂ would be compressed and transported for storage in geological formations, for pumping into the ocean, for land storage in biomass or as mineral carbonates, or for use in industrial processes. “It is currently believed that the industrial use of CO₂ will be limited and that the other storage approaches are most promising. For CCS to be viable, large point sources must be identified,” he explains.

Energy – a culprit?

The energy sector has the largest amount of point sources and contributes an order of magnitude more to CO₂ emissions than any other industry; this sector is thus deemed to hold the most potential for CCS projects. It is then an obvious assumption that many CCS projects in the energy sector would claim CER units. This is not the case – currently not a single CCS project is registered as a CDM project.

Schematic diagram of possible carbon capture systems

Credit: IPCC Special Report: Carbon Dioxide Capture and Storage



CCS comes at the expense of additional CO₂ production due to the capturing technology, proposed compressing and the transport energy required. This must be accounted for to ascertain the net reduction in atmospheric CO₂ reduction. Accounting for emissions associated with a CDM project activity is a standard process. However, certain challenges with the non-permanence of CCS have been noted. A paper by Brent and his colleagues in the February 2008 edition of the *Journal of Energy in Southern Africa* subsequently reviewed, among other things, the maturity of CCS technologies and current CCS projects; the applicability of CCS as a GHG-reducing technology; and the potential of CCS in southern Africa.

“More research is required to quantify the trade-offs presented between mitigating CO₂ from the atmosphere at the possible detriment of the areas of storage in the southern African context. Only then may CCS projects be deemed more viable from a CDM perspective. Finally, although the potential for CCS in South Africa has been noted due to major point sources, the cost of capture and storage is a major obstacle; matching point sources and geological storage options is problematic for South Africa and neighbouring countries due to large transport distances. The regulatory risks associated with CCS are further deterrents for the implementation of CCS clean mechanism projects in southern Africa.”

“I believe that the CDM is unlikely to benefit the implementation of CCS projects in southern Africa in the near future, although research is ongoing as to the potential benefit of similar carbon reduction schemes in the mid to long term,” Brent concludes. – *Renatè Janse van Vuuren*

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THE KYOTO PROTOCOL was adopted in Kyoto, Japan, on 11 December 1997 and came into force on 16 February 2005. Almost 200 nations have ratified the treaty to date. The detailed rules for the implementation of the protocol were adopted at COP 7 in Marrakesh in 2001, and are called the ‘Marrakesh Accords’.

The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change. The major feature of the Kyoto Protocol is that it sets binding targets for 37 industrialised countries and the European community for reducing greenhouse gas (GHG) emissions. These amount to an average of 5% against 1990 levels over the five-year period 2008-2012.

The major distinction between the protocol and the convention is that while the convention encouraged industrialised countries to stabilise GHG emissions, the protocol commits them to do so. Recognising that developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere as a result of more than 150 years of industrial activity, the protocol places a heavier burden on developed nations under the principle of ‘common but differentiated responsibilities’.

The Kyoto mechanisms: Under the treaty, countries must meet their targets primarily through national measures. However, the Kyoto Protocol offers them an additional means of meeting their targets by way of three market-based mechanisms. The Kyoto mechanisms are: emissions trading (known as ‘the carbon market’), the clean development mechanism and joint implementation.

The mechanisms help stimulate green investment and help parties meet their emission targets in a cost-effective way.



Ecologist and renowned invasive alien species expert, Dr Brian van Wilgen

Alien plants and ecosystem services: estimating the costs

Pines trees invading fynbos in the Western Cape. If allowed to spread unchecked, these alien trees will severely impact on the ecosystem services derived from fynbos

MODERN HUMANS are responsible for relocating the planet's species on an unprecedented scale. We introduce foreign species both deliberately (for agriculture, forestry, mariculture, horticulture and recreation) as well as accidentally (in cargo containers, on aircraft, in the ballast tanks of ships, and in our luggage when we travel).

While very few introduced species manage to become invasive, those that do can severely compromise ecosystem stability, and threaten economic productivity. The sheer volume of trade and travel that takes place today ensures that the number of invasive species keeps growing exponentially.

CSIR scientists focus on scenarios regarding the impacts and costs of alien species, with a view to formulating appropriate policies to deal with this significant environmental problem.

Alien plants and ecosystem services

"Ecosystem services provide significant benefits to South African society and we have an obligation to preserve these," says CSIR ecologist Dr Brian van Wilgen. The benefits – including provisioning services (such as food, water and fibre), regulating services (such as waste recycling) and aesthetic or spiritual services – are important aspects of environmental security.

"The estimated impacts of invasive alien plants on water runoff from catchments are perhaps the best-known aspect of the problem in South Africa, but many other impacts are present," Van Wilgen explains. "We need to both quantify the current extent of these impacts, as well as estimate how big they will be-

come if nothing is done to manage the problem."

The estimated reductions in surface water runoff as a result of current invasions are about 3 000 million m³ (about 7% of the national total), most of which is from the fynbos (shrubland) and grassland biomes. However, the CSIR's recent work suggests that the potential reductions would be more than eight times greater if invasive alien plants were to occupy the full extent of their potential range.

Reductions in grazing capacity as a result of invasion are currently small (just over 1% of the potential number of livestock that could be supported). CSIR work indicates that future impacts could potentially increase to 71%.

The effects of alien plants on biodiversity can be measured with a 'biodiver-

While biological control will never be able to solve or lessen all of the problems, it should be used far more extensively than currently.

sity intactness index' (the remaining proportion of pre-modern populations of plants and animals). With the exception of the fynbos biome, current levels of invasion have almost no impact on biodiversity intactness.

Under future levels of invasion, however, these intactness values may decrease to around 30% for the savanna, fynbos and grassland biomes, but to even lower values (13% and 4%) for the two karoo biomes – we stand to lose a significant amount of our biodiversity unless we can manage this problem effectively.

Thus, while the current impacts of invasive alien plants are relatively low (with the exception of those on surface water runoff), the future impacts could be very high. Van Wilgen acknowledges that these kinds of estimates cannot be made with high levels of confidence, so the potential errors may be high. However, given that the estimates are large, they will remain large even if substantial errors are made. For example, if biodiversity were reduced to only 40% instead of 4%, in the Karoo, the impact would still be very big.

Biological control

"The effective management of plant invasions will integrate various control options, including mechanical, chemical and biological control, and ecosystem rehabilitation," Van Wilgen explains. While mechanical and chemical control can be effective weapons against alien

plant infestations, they are at best holding actions, as the invasive species are never eradicated and will resume invading as soon as the control effort stops. Biological control is the deliberate introduction of specific insects, mites or pathogens to attack the target plant. It involves exhaustive safety testing before a biological control agent is released, but it remains controversial despite an impeccable safety record.

Biological control (if it works) is a safe, cheap and sustainable option. The CSIR has for some years been involved in estimating the costs and benefits of biological control as part of its contribution to finding sustainable solutions to the problem of invasive species.

"While biological control will never be able to solve or lessen all of the problems, it should be used far more extensively than currently," says Van Wilgen. "Our economic studies indicate that the returns on investment in research can be phenomenal, and many examples exist where invasive weed species have been brought under complete control."

Economic impacts

"Environmental-economic evaluation techniques and economic instruments have an essential contribution to make towards understanding the problem of invasive species and providing regulatory and management advice on cost-effectively mitigating or adapting to invasions," according to CSIR environmental economist, Dr Russell Wise.

"We have used economic studies to investigate how different management approaches across Africa can deliver different economic outcomes. While our studies demonstrate that some approaches to alien species management can deliver significant benefits, we still face problems in communicating these benefits effectively."

The benefits of alien species control, especially those in natural (rather than agricultural) environments, are often 'public good' benefits. In such cases, the individual marginal benefit (the amount of benefit gained by any one person) is small. Where individual marginal benefits are small, people tend not to take them seriously, despite the total benefit being huge (as there are many people). In addition, many of the projected benefits of alien plant control come about by avoiding future impacts rather than removing current impacts (for example, by preventing further spread of a weed that has not yet reached its full potential).

"People find it difficult to appreciate (or gain political benefit or advantage from) the avoidance of future impacts that are not yet manifesting. The degree to which we can overcome these obstacles will eventually determine how effective our work really is – and this is something we take very seriously," he concludes. – *Renatè Janse van Vuuren*

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Integrating lidar and
imaging spectroscopy
remote sensing for

improved characterisation of land degradation

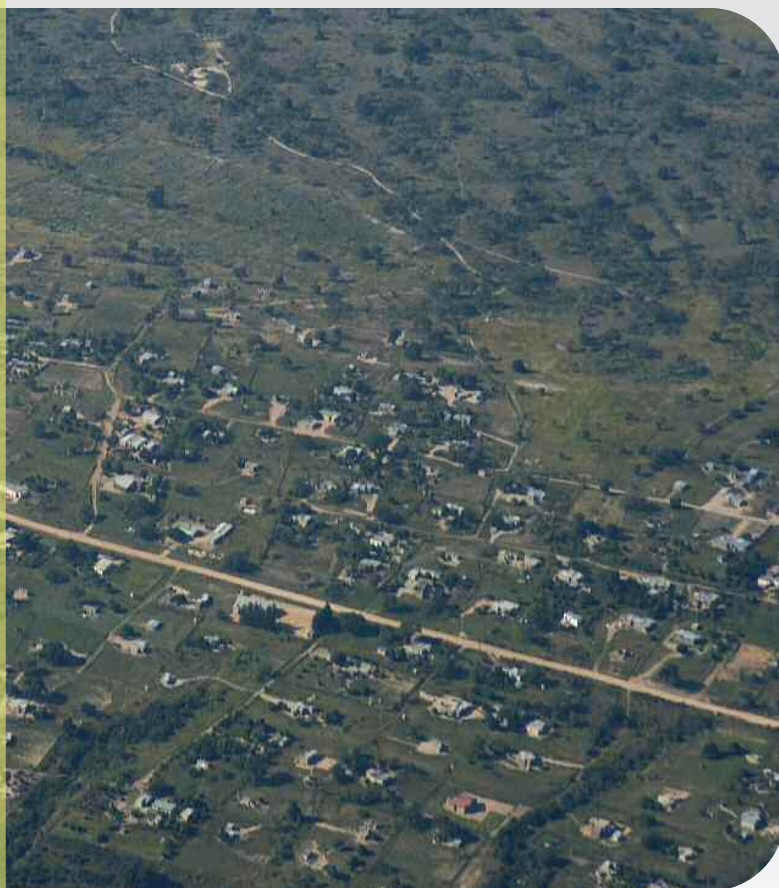


The Carnegie Airborne Observatory in action aboard the aircraft



What lidar sees: Lidar's usefulness in assessing 3D structures illustrated through this graphic

Credit: Dr Greg Asner, Carnegie Airborne Observatory



A unique collaborative research effort between local and international researchers in the Kruger National Park (KNP), utilising the integration of two relatively novel remote sensing approaches, has been set in motion by the CSIR for the purpose of land degradation assessment. The Carnegie Airborne Observatory (CAO), a state-of-the-art integrated airborne spectrometer-lidar (light detection and ranging) platform operated by the Carnegie Institute at Stanford University, has been used for the first time outside the United States for 80 hours of flight to collect remote sensing data as part of an April-May 2008 pilot study.



LAND DEGRADATION is one of the most important environmental issues facing sub-Saharan Africa and is especially relevant in the former communal 'homeland' areas of South Africa. Past regional modelling and monitoring have been constrained by traditional remote sensing technology. CSIR research team leader, Dr Jan van Aardt, explains, "Efforts at explaining detailed differences among degradation patterns are hampered by current sensor technology, as the scale and sensitivity of the remote sensing measurements are too coarse to capture the phenomenon on the ground."

Two research methods have the potential to alleviate this constraint and deliver improved understanding of ecosystem degradation. Imaging spectroscopy – also called hyperspectral remote sensing – has a broader wavelength range, defined in narrower wavelength bins. This allows very fine resolution, spectrally-contiguous measurement of radiant energy, similar to what the human eye can resolve in terms of colour hues across the visible spectral range, but extending far beyond the human range into the infrared. Lidar, on the other hand, is capable of describing the 3D vegetation structure through detailed vertical and structural characterisation of vegetation, such as the height of trees, at the resolution (a few tens of cm) that is relevant to ecologists.

Van Aardt confirms, "Although both methods have been used in the past in South Africa, the unique integration of these two remote sensing technologies by the CAO can potentially address a range of research questions." The main

research questions are how to determine the differences in terms of woody vegetation vertical structure, density, and species composition across gradients of land use intensity; whether improved quantification of degradation across such gradients can be achieved; identification of prime spectral/structural indicators necessary to address these research issues; and whether this package of information can be used to predict annual production of 'sustainable' grazing and fuelwood ecosystem services for improved management decisions.

Additional research questions are to quantify the influence of different fire and grazing regimes on species composition, vegetation structure and leaf chemistry, and to evaluate how vegetation composition, 3D structure and eco-physiology change in relation to location and soil properties.

The full research team comprises CSIR researchers Van Aardt, Dr Moses Cho, Dr Konrad Wessels, Dr Bob Scholes, Bongani Majeke, Russel Main, Abel Ramoelo, Karen Steenkamp and Sally Archibald, with Dr Barend Erasmus and Professor Kevin Rogers from the University of the Witwatersrand and Dr Onesimo Mutanga from the University of KwaZulu-Natal, Dr Izak Smit from the KNP, and Dr Greg Asner from the CAO. While the CSIR will research a land use gradient comprising the KNP, a private game reserve and a communal settlement, the other subgroups will study fire regime impacts and natural topographic variations (chemical and physical characteristics of the soil in relation to surface features) in the ecosystem.

Dr Konrad Wessels (Meraka Institute), Matt Slater (Optech lidar company engineer), Dr Barend Erasmus (University of the Witwatersrand), Ty Kennedy-Bowdoin (CAO engineer), Dr Greg Asner (Stanford-Carnegie; CAO principal investigator) and Haiden Harrington (CAO campaign pilot); the CSIR's Dr Jan van Aardt, who is the team leader on the degradation project, is in front

The Carnegie Airborne Observatory (CAO) delivers a unique visualisation product that combines both the hyperspectral (spectral domain) and wave-form lidar (structural domain) technologies to study regional ecosystems anywhere in the world. It uses aircraft-mounted cameras and is flown over the landscape to produce 3D images of the earth surface. The instruments are precise enough for the measurement of individual tree heights (and biomass) and the distribution of specific species (e.g. invasive species mapping). The system can be used for regional assessment of carbon, water and biodiversity services provided by ecosystems to society. The CAO can be operated in two modes, depending on research/user needs. The CAO 'Alpha' mode (used by this project) is intended for larger scales and can map nearly 20 000 ha per hour at a 1-2 m spatial resolution.

The outcomes of the research efforts, in the form of advanced structural algorithms and application of results to operational modelling, will contribute to conservation of protected savannah systems and the mitigation of degradation processes in intensively-used systems, in order to maintain the ecosystem functionality as a base for rural livelihoods. Other benefits are high-level capacity building in the form of higher degrees (some eight postgraduate students at various higher education institutions participating in the project will receive Department of Science and Technology-funded bursaries), international knowledge transfer and improvement of South African scientific expertise, and alignment with and impact on various international priorities (such as the South Africa Earth Societal Benefit Areas: Ecosystems and biodiversity).

– Biffy van Rooyen

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CSIR encourages future science buffs

THE CSIR HAS EMBARKED ON AN INITIATIVE to build environmental awareness in the receptive minds of school-children. The organisation hosted an inquisitive group of 20 learners from the acclaimed LEAP school* in Cape Town at the Jonkershoek nature reserve outside Stellenbosch where they were introduced to the diversity of the fauna and flora around them.

Senior researchers from the biodiversity research group in Stellenbosch and the ecophysiology group in Pietermaritzburg spent time to sharpen the learners' awareness of the often hidden world of plants and microscopic animals.

The children participated in hands-on experiments and excursions in the area. Under the guidance of experienced CSIR scientists, the learners clad themselves in water-resistant gear to collect microscopic specimen in the nearby stream and analysed the 'catch' afterwards.

In the subsequent biological diversity study tour the learners were introduced to, among others, the fynbos species in the region, invasive alien plants and fire management. In addition, one of the researchers revealed the fascinating world of frogs, especially the important differences between native and alien amphibians.

The aim of the experiments and tours was to introduce the learners to river health, river conservation, biodiversity and ecosystem services. This memorable occasion was one of the many events – facilitated by the CSIR – aimed at creating science awareness among the youth.

**The LEAP school is the only privately-funded MST (maths, science and technology) school in South Africa. The school represents a workable solution to one of South Africa's key problems, namely the acute shortage of science, engineering and technology skills, particularly among the previously disadvantaged. The school achieved a 100% matric pass rate in 2007. Most of the learners graduate from the school with a university exemption; with science, maths and English on the higher grade.*







This memorable occasion was one of the many events – facilitated by the CSIR – aimed at creating science awareness among the youth.

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■ CSIR National Laser Centre

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