Monitoring global change:

A selection of examples

CSIR

our future through science

Sincere appreciation to the following partners and sponsors:

Department of Science and Technology (DST)
www.dst.gov.za

Africa Centre for Climate and Earth System Science (ACCESS)
www.africaclimatescience.org

Benguela Current Large Marine Ecosystem Programme (BCLME)
www.bclme.org

University of Cape Town (UCT)
www.uct.ac.za

Department of Environmental Affairs and Tourism (DEAT)
www.environment.gov.za

National Aeronautics and Space Administration (NASA)
www.nasa.gov

South African National Parks, (SANParks)
www.sanparks.org

University of Venda (Univen)
www.univen.ac.za

University of the Witwatersrand (WITS)
www.wits.ac.za

Contents

Introduction

The reality of global change (including climate change) has gripped the imaginations of movie moguls, graced the agendas of international organisations such as the United Nations, and now also receives prominent attention from the international research community.

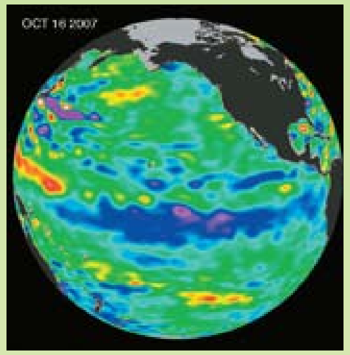
Global change extends across environmental, cultural, political and demographical spheres. As more interaction between socio-economic and environmental factors occurs, the vulnerability of nations to human-induced environmental hazards also increases.

Global climate change is, therefore, more and more perceived as a development problem as variations in the weather resulting in, for example, drought or flooding, have adverse consequences for sustained economic growth.

Although forecasts of changes in weather patterns over the next few days have reached a high level of skill, predictions of climatic fluctuations over several months and of global climate changes over several decades are difficult due to the very complex interaction of various factors that determine weather and climate.

Among other interventions, monitoring and observation programmes form an essential part in acquiring the data necessary for comprehensive situation analysis and ultimately, long-term predictable climatic behaviour.

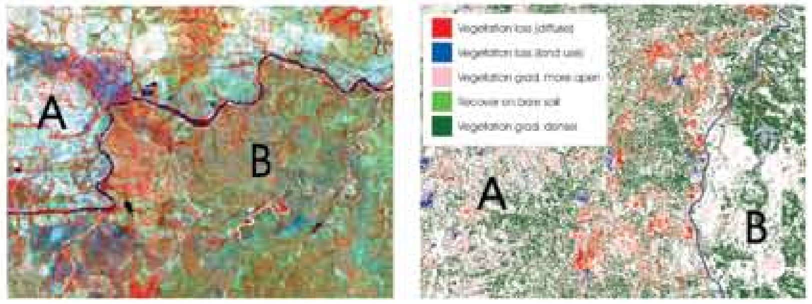
The following material gives a brief overview of some of the research activities conducted by the CSIR (and in partnership with other stakeholders) in the pursuit of understanding the processes and drivers associated with global climate change.



Degradation research in and around the Kruger National Park

The Kruger National Park (KNP) in the far north-east of South Africa provides a research environment unique in southern Africa. Founded in 1920, landscapes and wildlife are largely protected from human disturbance.

This qualifies it as a perfect site to identify processes purely driven by biotic and climate processes in contrast to unprotected areas where human influence – or human response to climate change itself – often resulting in vegetation degradation, might be difficult to distinguish from natural processes.



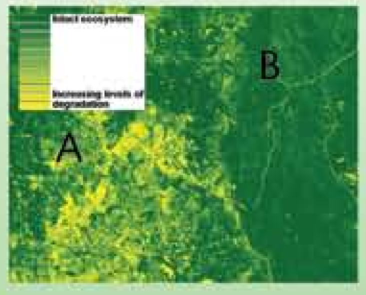
Landsat TM (left) derived land cover changes (right) in the southwestern KNP area (B) and the adjacent communal areas (A) from 1990 to 2007

High human populations and related high animal stocking rates in communal areas west of KNP are degrading natural ecosystems

Intact grass stratum and well-developed tree cover is a non-degraded savanna inside KNP

Assessment and analyses of long-term changes inside and outside the KNP are done in cooperation with ecologists from different institutions and universities.

Gradient of degradation in the southwestern KNP and adjacent communal areas



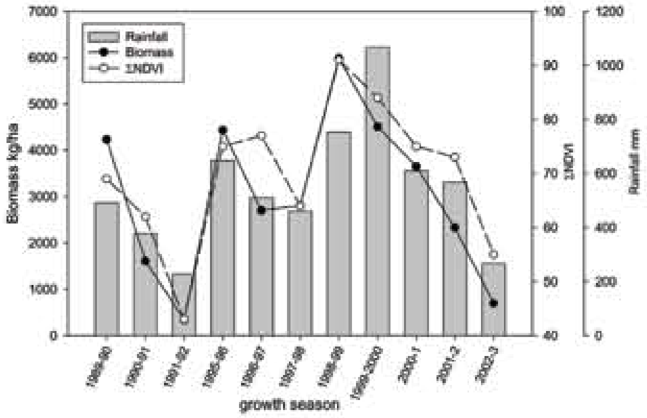
Generation of detailed information on degradation severity as input data for modelling of ecosystem benefit flows, as NLC2000 degradation information was too coarse for that purpose.

Students collecting validation data for a tree cover classification product. Tree cover serves as an indicator for vegetation degradation.

Due to the unique research environment, a wide spectrum of research activities takes place at the KNP, encouraged and enabled by the park's scientific service. The contrast between the protected park area and the neighbouring communal areas is the focus of some of the joint CSIR research activities.

Biomass measurements, disk pasture meter 1989 to 2007. Possible confrontation with wild life always requires the company of an armed ranger

1 km AVHRR growth season sum (∑NDVI), 533 fixed field sites for long-term monitoring in KNP

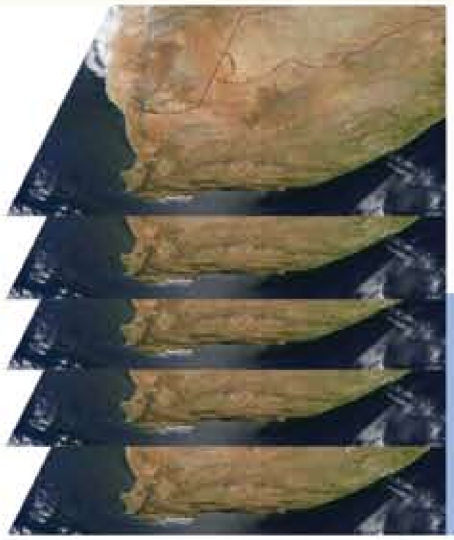


Herbaceous biomass, ∑NDVI and rainfall for Skukuza, KNP

Biomass assessment using AVHRR NDVI data, linked to field measurements with the disk pasture meter. Analysis considering rain fall data allows determination of degraded vegetation (vegetation change, which is not correlated to rain fall) in contrast to phenological vegetation variation (as response to rain fall).

Time-series analyses of vegetation phenology

Vegetation phenology examines natural life cycle events such as the start, peak and length of growing season.

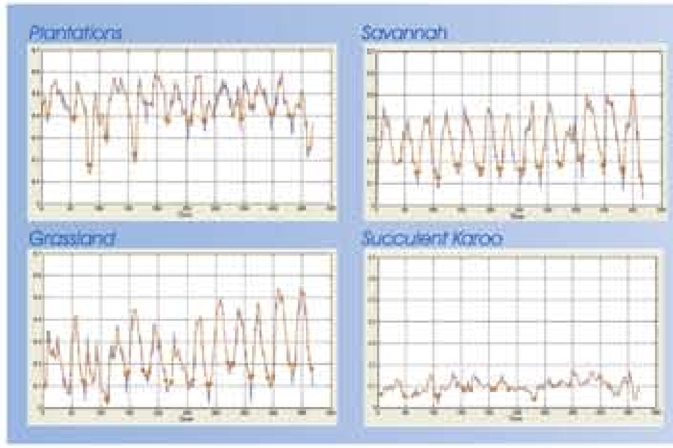


Phenology studies are important in order to:

- Generate a baseline understanding for identifying climate change impacts on terrestrial ecosystems, such as change in vegetation seasonality
- Identify and quantify the appearance and impact of land cover change (e.g. cultivation)
- Investigate the delineation of biomes and bioregions in a functional approach to vegetation classification and mapping and to monitor changes as a response to climate change

AVHRR / MODIS satellite images

The satellite sensors Advanced Very High Resolution Radiometer (AVHRR) and the Moderate Resolution Imaging Spectrometer (MODIS) provide daily data in coarse spatial resolution (1km – 250m pixels). Times series of these data provide consistent measurements of vegetation greenness and activity at high temporal frequency at regional to global scales.

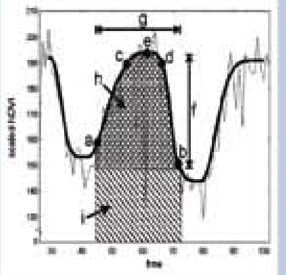


Per-pixel time-series

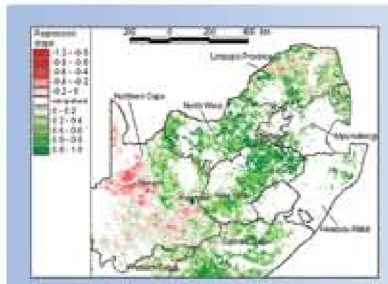
The satellite sensors Advanced Very High Resolution Radiometer (AVHRR) and the Moderate Resolution Imaging Spectrometer (MODIS) provide daily data in coarse spatial resolution (1km – 250m pixels). Times series of these data provide consistent measurements of vegetation greenness and activity at high temporal frequency at regional to global scales.

Phenological parameters

Long-term averages and standard deviations are calculated for phenometrics (i.e. characteristic vegetation state parameters (or something like that?)), such as:



- *Start date of growing season (a)*
- *Length of season (g)*
- *Total seasonal growth (i)*
- *Date of senescence*
- *Start of dormancy (b)*

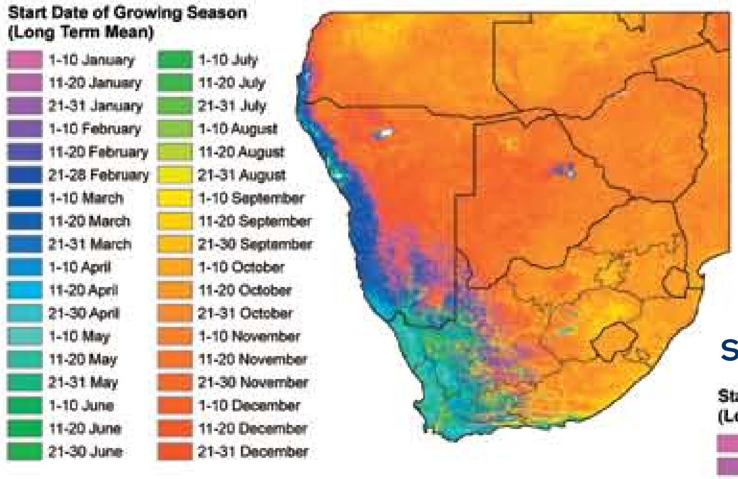


Environmental change detection

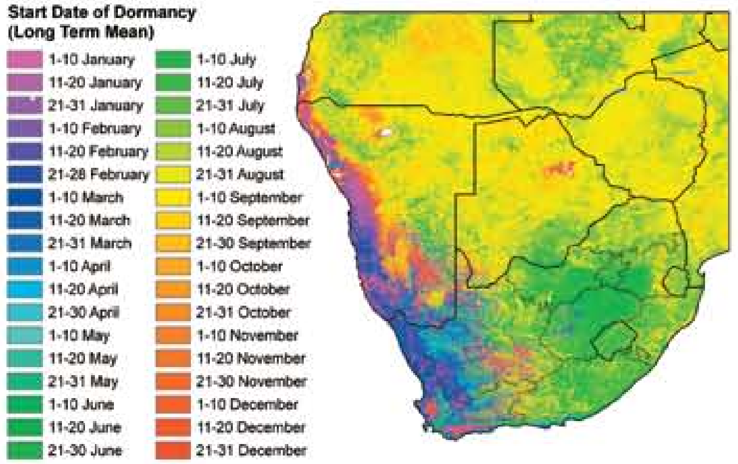
Sudden changes in the phenological behaviour indicate human (e.g. land degradation or land cover / land use change) or climate induced impacts on vegetation.

Phenology derived from 1 km AVHRR 1985-2000

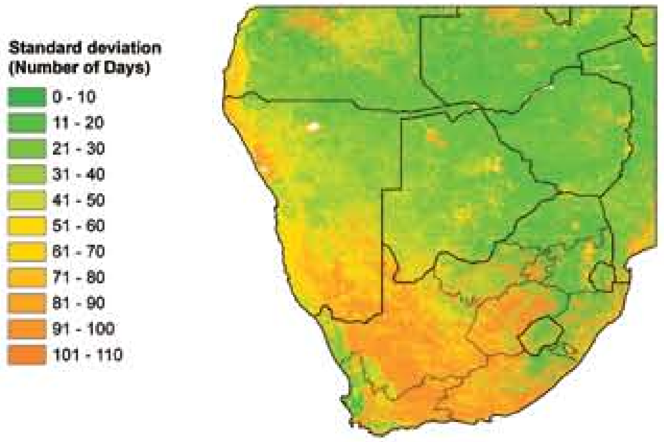
Start of growth season (long-term mean)



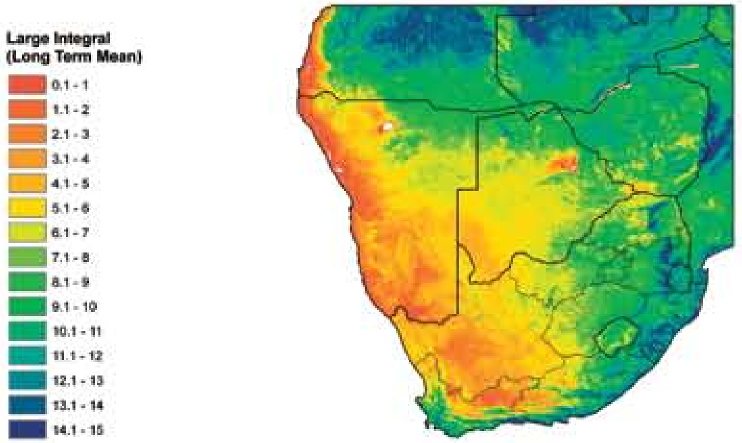
Start of dormancy (long-term mean)



Standard deviation in start of growing season



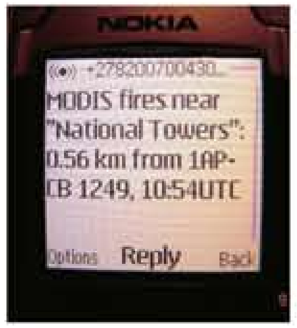
Total seasonal growth (long-term mean)



Remote sensing fire research

Veld fires, either lit by lightening or by man, are a common phenomenon especially during the dry season in South Africa. Apart from affecting human livelihoods, economy (e.g. by power cuts if power lines are affected) and natural ecosystems, veld fires contribute to global warming processes, as they set free large amounts of the glass house gas CO². Satellite based fire information systems can provide information crucial for the modelling of global carbon cycles and help to prevent impacts of fires on infrastructure and economy.

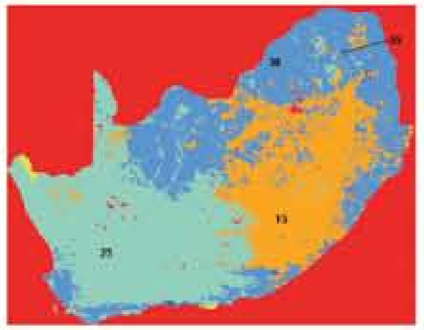
AFIS (Advanced Fire Information System)



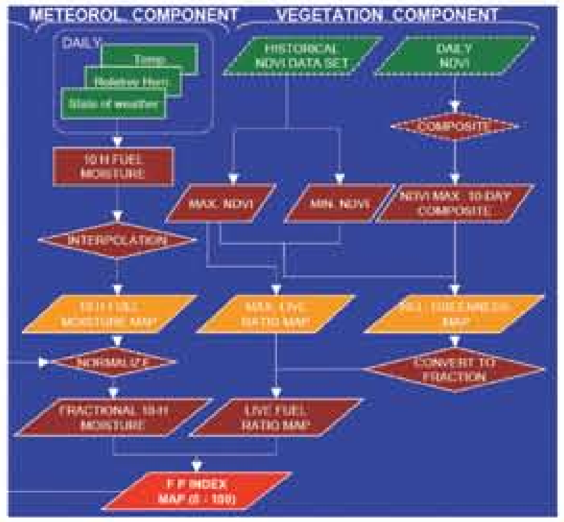
+278200700430...
MODIS fires near
"National Towers":
0.56 km from 1AP-
CB 1249, 10:54UTC

The AFIS system provides near real-time fire alerts in the form of email and SMS text messages and also allows internet users to view fire location through an online mapping tool. South Africa's power utility, Eskom as well as organisations such as Working on Fire and Western Cape Nature Conservation actively use the system on a daily bases to help mange fire events. (See www.wamis.co.za/afis/afis.htm)

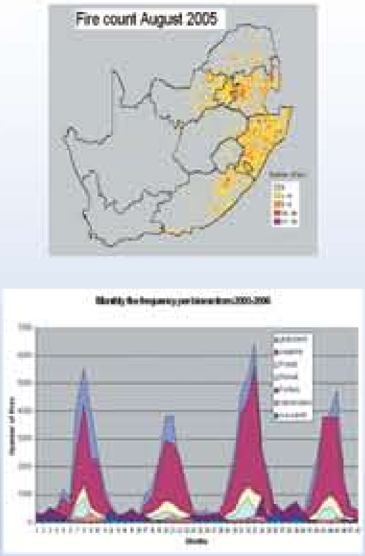
Fire hazard modelling



The process entails the development of a dynamic fire danger index, using satellite-based vegetation data and real-time weather forecast information.



Fire climatology analysis per biome

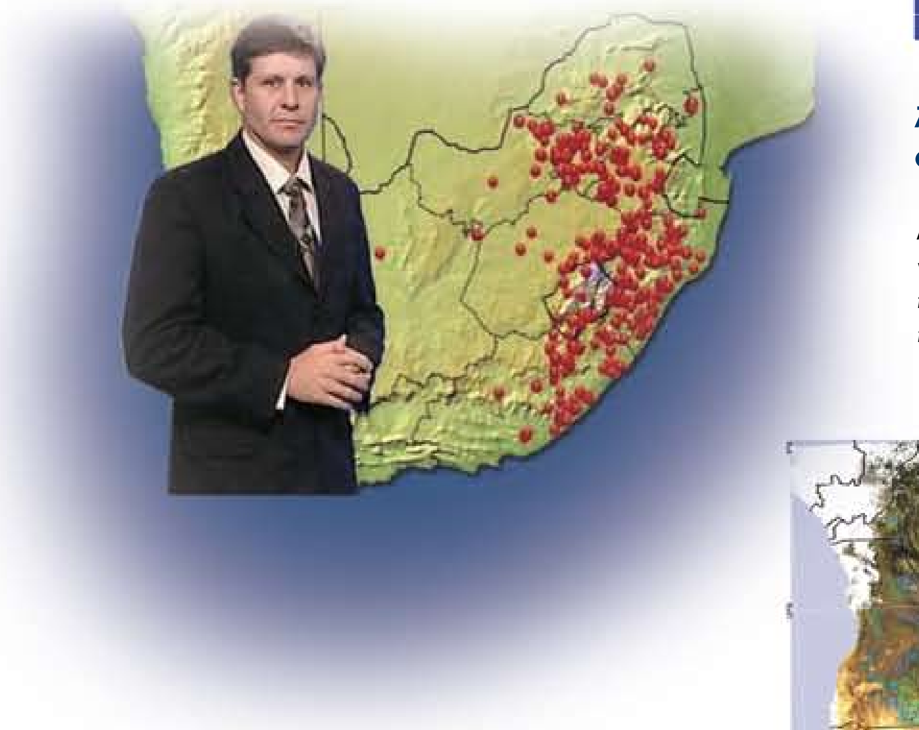


The active fire locations from MODIS are aggregated per month and used to characterise the fire seasonality. This describes the start, duration and end of the fire season, similar to vegetation phenology. By integrating seasonal fire dynamics with vegetation phenology, trends are analysed per vegetation type.

Fire and weather maps for cell phones

The animated weather visualisation system for mobile phones is a joint project by the CSIR and University of Wisconsin Madison. The system provides hourly updates of cloud movements, rainfall estimates and positions of active fires.

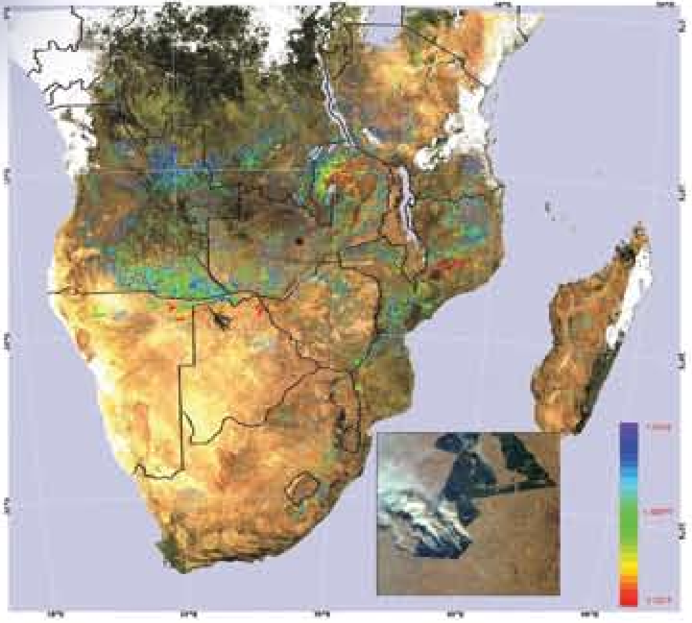
Active fire detection maps on national television



MODIS active fires of the preceding week are displayed on national television as part of the weather report following the news broadcast every Wednesday evening

MODIS burnt area product

The MODIS burnt area product provides 16 day burnt area maps at 500 m resolution. The product will be generated from the CSIR MODIS Direct Broadcast station, starting June 2008.



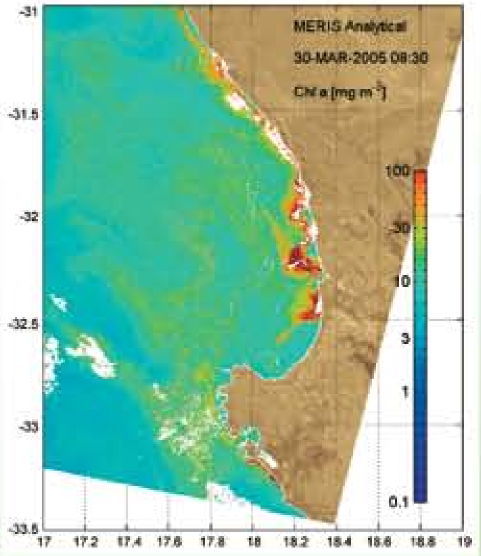
Harmful algal bloom monitoring

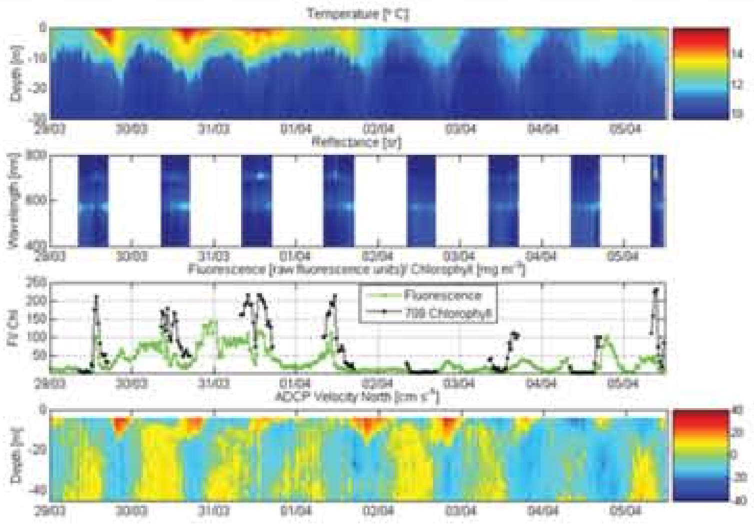
Climate change processes do not only affect land surfaces but impact on marine processes. The most well-known include effects like ENSO (El Niño Southern Oscillation) and its opposite, La Niña, which, respectively, brings warmer and cooler ocean temperatures than average. Changes in water temperature and ocean currents might affect the development of plankton organisms and might lead to the catastrophic development of poisonous algae.

West Coast 'red tides' are the most dramatic and well-known harmful algal bloom (HAB) events in South African waters, due to their toxicity and the hypoxic events associated with their decay – rock lobster stranding and hydrogen sulphide related 'black tides' causing mass faunal mortalities.

Monitoring of harmful algal bloom takes place in the southern Benguela and uses multi-platform moorings and satellites.

Blooms occur in response to extended calm periods after the upwelling-related injection of nutrients, and impacts are most severe in coastal bays where blooms are retained and subsequently collapse through nutrient exhaustion.





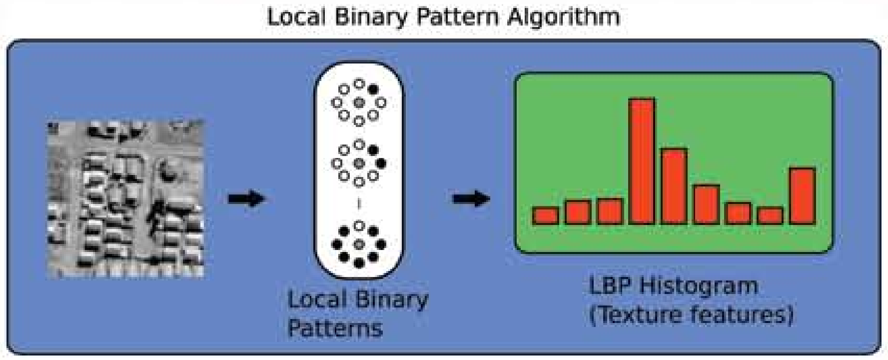
Monitoring systems have been developed for the southern Benguela, using multi-platform moorings and satellites, to allow the monitoring and early detection of potentially harmful blooms and to protect coastal populations, fisheries and aquaculture.

Ocean colour allows equivalent measurements from both buoys and satellites. New algorithms have been developed for algal biomass, mean cell size and other assemblage descriptors, allowing an indication of the potentially harmful nature of the bloom. The future will bring new autonomous platforms, further multi-satellite applications, and powerful user-focused dissemination systems.

Automated feature extraction

Automated feature extraction is the identification of geographic features and their outlines in remote-sensing imagery through postprocessing technology that enhances feature definition. This is often done by increasing feature-to-background contrast or using pattern recognition software. (GIS Dictionary, ESRI)

Automating remote sensing classification and analysis processes help to assess information derived from satellite imagery more effectively. The rapid and repeated assessment of infrastructure enables us to monitor, for example, urban sprawl and its impact on natural ecosystems. Thinking in terms of climate change, the derived data are valuable in terms of disaster management, prevention and mitigation of the impacts of flooding, draughts or storms.



Automated settlement classification

Objective

To develop a fully automated system for mapping settlement type using satellite imagery

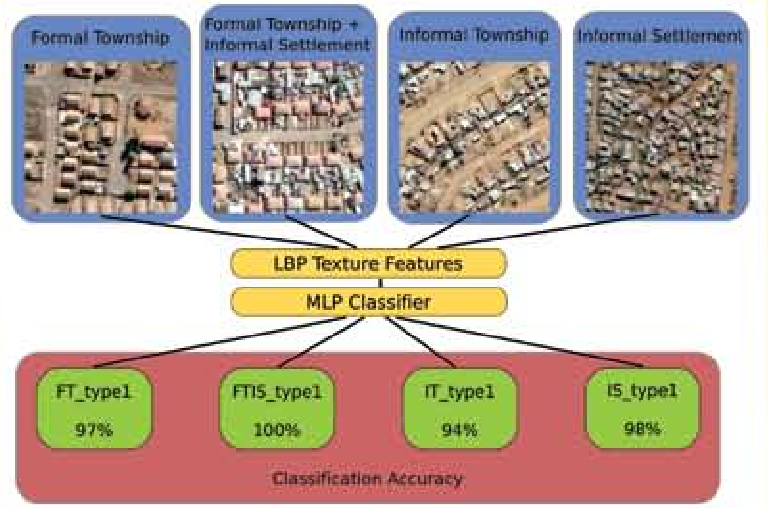
Methods

- *The local binary pattern (LBP) texture algorithm was used to extract features from QuickBird panchromatic images*
- *A multi layer perceptron (MLP) neural network is used to identify the settlement type, based on the texture features.*

Experiment

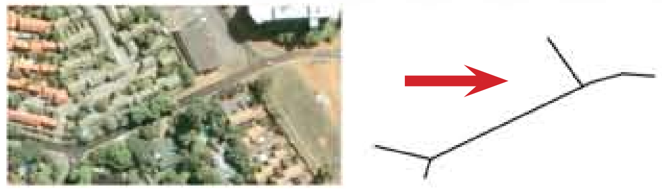
An experiment in Soweto considered the following classes:

- *Format township, characterised by planned, formal buildings (FT_type1 – 2)*
- *Format township and informal settlement, characterised by backyard shacks (FTIS_type 1 – 3)*
- *Informal township, characterised by planned layout with owner-built dwellings (IT_types1 – 2)*
- *Informal settlement, characterised by randomly-placed owner-built dwellings (IS_type 1)*
- *Formal suburb, characterised by medium to high income permanent residential structures (not shown here)*



Conclusion

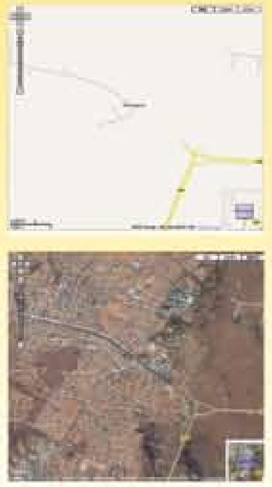
- *An overall classification accuracy of 97% was achieved in the Soweto case study*
- *This method could potentially be used to perform automated settlement mapping.*



Automated road extraction

What is automated road extraction?

- *Road extraction is the process whereby roads are detected and stored in a form that is usable by computing systems*
- *Automated road extraction is the automation of this process*
- *Automation is achieved by applying image processing and artificial intelligence techniques to satellite imagery.*



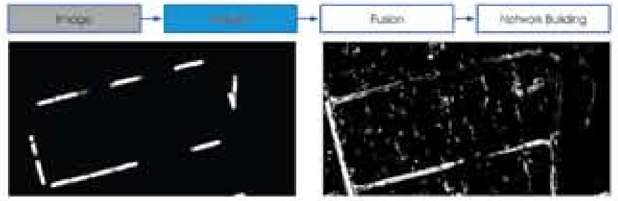
Motivation

- *A great number of geographic information system applications, such as transport planning and satellite navigation, require up-to-date road network data*
- *Large areas remain unmapped*
- *Accurate maps are not available to the general public*
- *Accurate maps are expensive due to the great number of man hours required for extraction.*

The system

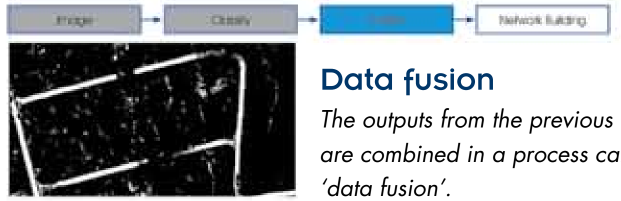
Road extractions could be created from a variety of components. No two systems are alike.

- *This system comprises of four steps*
- *An input image is given to the system.*



Classification

The image is then classified by looking at the structural (shape) and spectral (colour) properties of roads.



Data fusion

The outputs from the previous steps are combined in a process called 'data fusion'.

Final results

Finally, artificial intelligence is used to link all the pieces of road and to filter out the background noise.

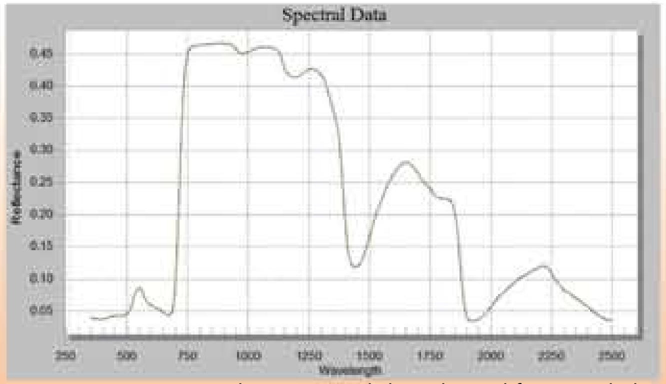
Imaging spectroscopy and hyper-structural (lidar) activities

Integration of sensing inputs from in situ and remote sensing data sources

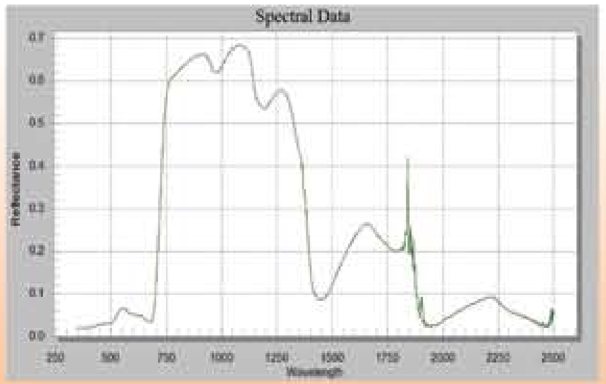
Assessment of climate change impacts on vegetation is conducted along a gradient of spatial and spectral resolutions, dependent on the size and complexity of the area of interest. Even though regional or landscape level applications are the ultimate goal of most research activities, spectral and structural vegetation responses are often assessed at the local level as a first or best case scenario stage. Remote sensing spectroscopy approaches are based on either handheld devices (spectroradiometers) or imaging spectrometers at the airborne level. Spaceborne sensors are scarce at this point in time and highly experimental.

Apart from very detailed spectral information at the leave/plant/stand level, imaging spectroscopy contributes to the assessment of inputs from diverse sensors towards an optimised modelling strategy of biophysical vegetation characteristics. Such an approach not only includes remote sensing platforms, but also in situ measurements, both of which encompass 'earth observation'. Integration of both sensing levels potentially could allow for the detection of plant response to stress, e.g. to climate change, given the enhanced ability to detect subtle spectral differences between physiological plant states along with in situ measurement of other inputs that drive system state.

Spectrum Examples - Leaf



Spectrum Examples - Canopy



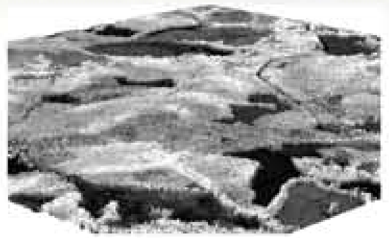
Experiments comparing hyperspectral data derived from single leaves and entire homogeneous Eucalyptus stands allow for determination of scale-dependent effects, towards robust extension to ensure multi-scale applicability.

Simulation of SumbandilaSat imagery from spectroscopy data

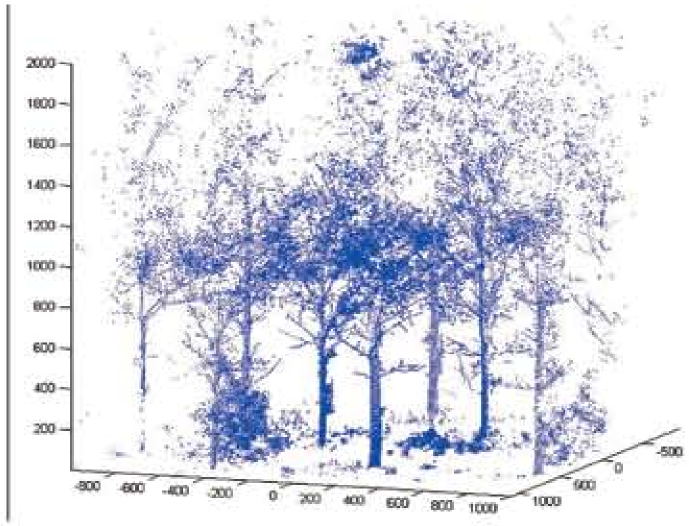
The high spectral resolution (e.g., as many as 2000 spectral bands between 400-2500 nm) of imaging spectrometers enables the simulation of existing or future satellite sensors, such as the South African SumbandilaSat (to be launched in 2009).

Test applications for the purpose of the SumbandilaSat simulations include

- *Multi-spectral forest state assessment with focus on the xanthophyll and red-edge bands*
- *Evaluation of invasive species (Acacia mearnsii) water usage*
- *Assessment of coastal forest change (fragmentation) in KwaZulu-Natal.*



A forest canopy height model (brighter tones equals taller trees) as tool for forest management and total biomass estimation.



Example of a lidar point cloud used for the extraction of forest biomass information (image source: Dimitry van der Zande, Katholieke Universiteit Leuven, Belgium)

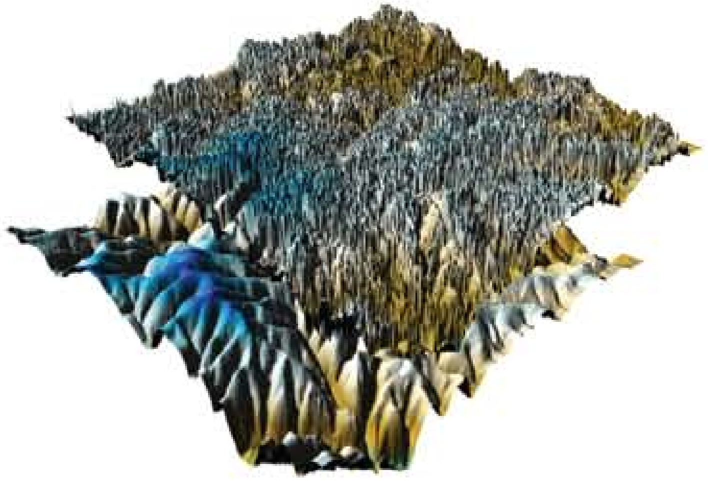
Spectral species discrimination towards determination of species abundance

Spectrally homogenous genera result in a classification challenge using conventional remote sensing methodologies. Robust multivariate approaches, e.g. discriminant analysis and classification and regression trees, allow accurate species discrimination. Research is aimed at operational, wavelength-specific multi-spectral approaches. In other words, efforts are geared towards reducing 'oversampled' spectroscopy data to only those spectral indicators that are required for a necessary application, e.g. Pinus genus classification.

Forest bio-physical parameter assessment

A cooperative project in collaboration with the CSIR's forest and forest products area aims to develop:

- Large-scale, automated, operational high precision forest inventory methods based on multi-spectral imagery, light detection and ranging (lidar), radar, and fused approaches
- Cost-benefit analysis related to the application of remote sensing technologies for forest inventory purposes
- Methods for the assessment of forest biomass in the context of global carbon sequestration.



Interpolated (kriging) top-of-canopy and DEM surfaces for the assessment of forest structures.

CSIR contact details:

Tel: +27 (12) 841 2911
Fax: +27 (12)
Email: callcentre@csir.co.za
www.csir.co.za

This booklet was made possible with the assistance
of the Department of Science and Technology

science
& technology
Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

For more information, visit:

Department of Science and Technology:
www.dst.gov.za

National Research Foundation:
www.nrf.ac.za

Africa Centre for Climate and Earth System Science (ACCESS):
www.africaclimatescience.org