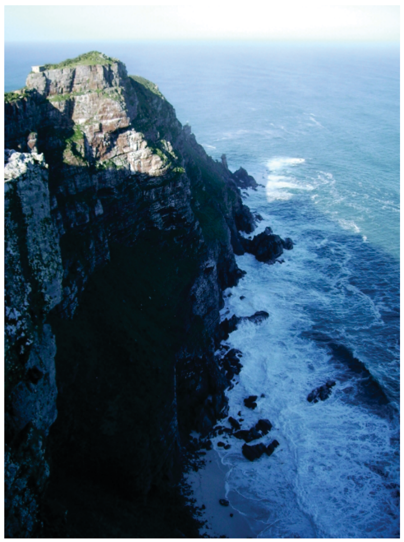
10-Year Global Change Research Plan for South Africa

science & technology

Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA



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Boxes

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Mrs GNM Pandor, MP
Minister of Science and Technology
Republic of South Africa

Foreword

by the the honarable Minister Nalede Pandor

It gives me great pleasure to write this foreword for the Department of Science and Technology's *10-Year Global Change Research Plan for South Africa.*

South Africa's location at the tip of the African continent, and its proximity to the Indian, South Atlantic and Southern Oceans — as well as the Agulhas and Benguela currents — which influence global weather patterns and atmospheric greenhouse gas concentrations in significant ways, is one of many features that place it advantageously for the study of global change.

South Africa has three internationally recognised biodiversity hotspots: the Cape Floral Kingdom (contained within the country's borders); the Succulent Karoo (the only arid land hot-spot in the world, shared with Namibia); and Maputaland-Pondoland (shared with Mozambique and Swaziland).

South Africa's wide variety of ecosystems include savannas, grasslands, shrublands, deserts and forests; perennial, seasonal and ephemeral rivers; estuaries, and coastal and marine environments. Whilst South Africa has only 2% of the world's land area, it is home to nearly 10% of its plants and 7% of its reptiles, birds and mammals; hence its status as one of the world's "megadiversity countries".

The country's seas include an exceptional range of habitats, from cool-water kelp forests to tropical coral reefs. The southern African coast is home to almost 15% of known coastal marine species, providing a rich source of nutrition and supporting the livelihoods of coastal communities.

This wealth of biodiversity underpins a large part of the country's economy. Many urban and rural people are directly dependent on it for employment, food,

Foreword *continued..*

shelter, medicine and spiritual well-being. These dependencies span the continuum from commercial and semi-commercial to subsistence, through both formal and informal markets.

Add to this South Africa's outstanding record of scientific research, and it is evident that the country not only a unique living laboratory for the study of global change, but is also capable of leading global change research on the African continent. Solutions found for South Africa are generally applicable to many other countries, on the African continent and further afield.

This bountiful natural heritage also provides a living classroom for the youth of our nation. South Africa through its Department of Science and Technology is funding a range of environmental science education outreach programmes aimed primarily at previously disadvantaged communities. The goal is to help learners gain a better understanding of the environment and factors that influence it, such as global change. They will be challenged to come up with practical adaptation and mitigation solutions in their own environments. In the process, they will be introduced to the wonderful world of science and the solutions it can offer. We are sure that many budding young scientists will find their initial inspiration and motivation in these projects. This is a matter of urgency as we are keen to ensure that we develop increased numbers of persons that have scientific and technical skills.

In our education outreach programmes we need the assistance of South Africa's scientists, and call on them to give generously of their time, expertise and teaching skills to inspire, motivate and nurture these budding young scientists and act as long-term mentors to them. We need their commitment, and also that of Science and Mathematics teachers who bring science education outreach programmes into the curriculum and into the classroom. To South Africans, climate change is not merely a looming threat, but is also an opportunity to facilitate the development of science throughout the continent.

I would like to take this opportunity to thank South Africa's cadre of enthusiastic, dedicated and innovative global change scientists and researchers, our research institutions, many of which are internationally recognized for the quality of their research, the authors of this research plan and everyone who contributed to it, as well as South Africa's leaders and policy makers, for their commitment to making a difference. They have accomplished much and we are counting on them to do even more.

Dr Phil Mjwara
Director-General:
Science and Technology
Republic of South Africa

Preface

by the Director General Dr Phil Mjwara

Governments, decision-makers, innovators and researchers around the world agree that climate change is an imminent threat that calls for mitigation and adaptation policies and strategies. South Africa shares these concerns - Africa has been identified as one of the most vulnerable continents to climate variability and change. However, to us climate change is not just a threat, but also an opportunity to address our most urgent problem, the alleviation of poverty.

It would be irresponsible of us to tell our children and grand-children that their inheritance will be environmental disaster. We owe these children, most of whom live in abject poverty, some hope and confidence, some promise of a better future.

The key to this hope is education, and the environment is an excellent vehicle for the promotion of education at all levels. One of southern Africa's major assets is the glorious diversity of its flora and fauna, which depends on a wide range of climatic zones created by the three remarkably different surrounding oceans, and which provides limitless opportunities for learning.

A very interesting fact about the global importance of the regional ocean-basin around Southern Africa is the role it plays in driving the global climate system, biogeochemically and physically. An important service offered by the southern ocean is its ability to provide a "sink" for some 50% of all the natural and anthropogenic carbon dioxide taken up by the world's oceans.

Two years ago, in 2008, South Africa's Department of Science and Technology (DST) released its Ten-Year Innovation Plan for South Africa, *Innovation Towards a Knowledge-based Economy 2008-2018*. This landmark publication identifies five broad areas on which efforts within the National System of Innovation are to be concentrated. The scale of the proposed key knowledge and innovation priorities is very ambitious, and we have thus described them as grand challenges. If we are to succeed in meeting any of these grand challenges, we will need an informed and educated nation.

One of the grand challenges is the science and technology for global change, with a focus on climate change, commonly known as the Global Change Grand

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Challenge. The Global Change Grand Challenge supports knowledge generation and technological innovation to enable South Africa, Africa and the world to respond to global environmental change, including climate change, in an informed and innovative way.

The DST followed an inclusive process, involving a wide cross-section of the science and policy communities in South Africa, to develop a detailed implementation plan for enhancing the scientific understanding of global change. The process has culminated in this *10-Year Global Change Research Plan for South Africa*.

The research plan identifies four major cross-cutting knowledge challenges — understanding a changing planet; reducing the human footprint; adapting the way we live; and innovation for sustainability. These challenges will be addressed through a set of complementary initiatives, research programmes, and science-into-policy and practice processes and institutions, which will work together to enhance understanding of global change science, and open the door for action on the new knowledge that is generated.

The DST is drawing on the proven ability of South Africa's science community to meet challenges, and to lead and collaborate in scientific efforts on the continent, which could contribute significantly to international knowledge on global change, as well as influencing the international policy-making process.

The *10-Year Global Change Research Plan* is South Africa's signal to the world that we are harnessing our country's significant science talent to address the challenge of global change. This document bears testimony to the fact that we are placing our trust in our country's internationally renowned global change scientists, and in the next generation of young African scientists, to put forward innovative adaptation and mitigation solutions.

An April 2010 Thomson Reuters report on the African contribution to global research observed that Africa has a higher than average share of global research publications in areas related to natural resources. South Africa contributed 1,29% in the environment and ecology research field, confirming South Africa's pre-eminence in an area of research that is becoming ever more important. This 10-year plan provides a powerful platform to grow and strengthen our position in this area.

We are also calling on world leaders to recognise that global warming poses not just a threat, particularly to the world's most vulnerable communities, but also an opportunity for a better future.

It is therefore with great pleasure, and with great expectations, that I introduce the *10-Year Global Change Research Plan*, our scientific blueprint for addressing the impacts of global change -for the conservation of our planet and the benefit of all humankind.

1. EXECUTIVE SUMMARY

The Department of Science and Technology's Ten-year Innovation Plan for South Africa, *Innovation towards a Knowledge-based Economy 2008-2018,*[1] identifies five key Grand Challenges for the National System of Innovation over the next decade. One of these Grand Challenges relates to global change, and has three main aspects: enhancing scientific understanding of global change, developing innovations and technologies to respond to global change, and understanding the social context within which solutions will have to be implemented.

An inclusive process involving a wide cross-section of the science and policy communities in South Africa was followed to develop a detailed implementation plan for the first of these aspects, i.e. enhancing scientific understanding. This process has culminated in the development of the ten-year national research plan (the *10-Year Global Change Research Plan for South Africa*) for the Global Change Grand Challenge.

The research plan identifies four major cross-cutting knowledge challenges and 18 key research themes, summarised in the table on page 11.

The *10-Year Global Change Research Plan for South Africa* is notable for the following reasons:

- It adopts a systems approach.
- It is strongly interdisciplinary.
- It is based on the unique geographic location and developmental challenges of South Africa.
- It is grounded in a social-ecological paradigm.
- It supports making a contribution to the international knowledge base as well as to locally relevant and required research.
- It aims to advance a better understanding of the functioning of the earth system and to support efforts to respond effectively to changes.
- It is intended to be policy-relevant.
- It has a strong focus on climate change, and takes into consideration contemporary debate and discussion in this regard.

[1] *Available on the DST website (www.dst.gov.za).*

2. BACKGROUND AND CONTEXT

2.1 Introduction

In 2008, South Africa's Department of Science and Technology launched its Ten-year Innovation Plan for South Africa*, Innovation towards a Knowledge-based Economy 2008-2018.* This plan identifies five Grand Challenges on which efforts will be focused to bring about social, economic, political, scientific and technological benefits, namely –

- the "Farmer to Pharma" value chain to strengthen the bioeconomy;
- space science and technology;
- energy security;
- science and technology for global change with a focus on climate change; and
- human and social dynamics.

Each of these Grand Challenges is designed to stimulate multidisciplinary thinking and to challenge the country's researchers to answer existing questions, increase interdisciplinary collaboration and develop new technologies.

The Challenges will contribute to transforming South Africa into a knowledge-based economy by –

- developing human capital;
- generating new and relevant knowledge;
- facilitating the establishment of research infrastructure; and
- bridging the divide between research results and socio-economic outcomes.

The Global Change Grand Challenge initiative supports science and technology, as well as key socio-economic development and environmental management objectives.[2]

2.2 Scope and opportunities

This *10-Year Global Change Research Plan for South Africa* embraces the wider sphere of global change (see Box 1), although its main focus is on climate change.

It includes changes in economics, politics, land use and atmospheric conditions, as well as loss of biodiversity. It also includes palaeo-analysis and the geosciences in so far as they illuminate global change issues. The research plan follows a three-pronged approach aimed at (i) studying and understanding the changes, (ii) understanding the implications of these changes for decision making, and (iii) stimulating innovation in responding to the challenges posed by global change.

Topics range widely within the linked human-ecological system in which global change is believed to play a crucial part and include technological innovation and the social sciences and humanities where relevant.

This Grand Challenge specifically engages with global change, bearing in mind that two other Grand Challenges focus on the related areas of human and social dynamics, and energy security.

The research plan prioritises addressing local needs and working in areas of global comparative advantage.

- **Local needs** – researchers will investigate aspects of global change that affect the well-being of the country and the region and that are unlikely to be examined by scientists elsewhere (for example, the

[2] *The key formal documents that underpin the design of this Grand Challenge are: the White Paper on Science and Technology (1996); South Africa's National Research and Development Strategy (2002); the Climate Change Response Strategy (2004); the National Industrial Policy Framework (2007); the National Sustainable Development Framework (2008); and the relevant sectoral policies (water, agriculture and others).*

areas of urbanisation, agriculture, forestry, fisheries and water); they will investigate the implications of global change for national strategic priorities; and they will investigate local technological, development and institutional responses to mitigation and adaptation pressures.

- **South Africa's areas of comparative advantage** – researchers will build on existing scientific and disciplinary strengths; investigate what is specific to the country's geographical location and of global as well as local interest (such as the Southern Ocean and South Africa's rich biodiversity); consider the human dimensions of vulnerability and impacts of abrupt, extreme events (such as floods and cyclones) and required mitigation and adaptation strategies, as well as longer-term, slower trends; and explore global change from the social and economic perspective of a top-end developing country, emerging from a troubled past, operating as a participatory democracy, with innovative laws.

Box 1

Global change refers to an interconnected set of phenomena, resulting largely from human actions that have altered the environment over virtually the entire planet at an accelerating rate during modern times. It includes changes to the composition of the atmosphere; the nutrient loading of the biosphere; the global, regional and local climate; the distribution and abundance of species; the cover and use of the land surface and the use of marine resources; the size, location and resource demands of the world's human population, as well as its patterns of governance and economic activity.

2.3 Facts about global change

After much debate, contemporary climate change has become accepted as a scientific reality, and the facts relating to global change have become central issues to be addressed by researchers, innovators, decision makers and governments around the world.

The ways in which human societies engage with their environment to satisfy basic needs, stabilise and grow their economies and improve their quality of life, affect and are affected by the natural cycles that regulate the land, water and air. Changes are occurring so rapidly, however, that greater understanding of the Earth's natural processes, the human influence on these processes and the interactions between the two has become a global priority – as has the need to find ways to mitigate these changes where possible, and to adapt to them.

Climate change is not new and during its existence the Earth has experienced significant variations, manifested in its ice ages, for instance, and periods of warming. Of particular concern today, however, is the unprecedented speed at which the planet is warming and the clear human-induced component.

Human activity in the form of industrialisation and altered land use over the past 150 or so years has had by-products that are altering the composition of the atmosphere. Carbon dioxide from the burning of fossil fuels such as coal, oil and gas have increased the amount of greenhouse gases to create what is known as an "enhanced greenhouse effect", trapping additional heat energy within the atmosphere, which is predicted to have a range of effects on the planet's climate.

Of the US$827 billion spent by the US government in its 2009 economic stimulus plan, US$100 billion was allocated to green investments. South Korea's "Green New Deal" investment package worth US$56 billion in the same year was the most ambitious of any developing country. Such responses recognise the complexity of the early 21st-century polycrisis. They also drive innovation as governments and private-sector players strive to convert these investments into competitive advantages in the global economy.

Box 2: Global change effects

Global change has already had many effects across the globe. The changes listed below have come about in the past 100 years.

- **The Earth's average surface temperature has increased by about 0,6 °C;**
- **sea levels rose by an average of 0,1 - 0,2 m;**
- **mountain glaciers in non-polar regions are in widespread retreat;**
- **the extent of snow cover has decreased by about 10 % since the 1960s;**
- **the extent of spring and summer sea-ice in the northern hemisphere has decreased by 10 to 15 % since the 1950s;**
- **over 400 of South Africa's plant and animal species are threatened with extinction;**
- **18 % of South Africa's land has been transformed or degraded, while much of the remainder consists of sparsely inhabited arid areas;**
- **almost half of South Africa's river systems are critically endangered; and**
- **over 7 million ha of land in South Africa have been invaded by alien plants.**

2.4 South Africa as a priority research destination

South Africa has many features that make it both an attractive and a priority area for research on global change. Some of these are listed below.

- Its position at the tip of the African continent, adjacent to the Indian, South Atlantic and Southern Oceans, which influence global weather patterns and atmospheric greenhouse gas concentrations in unique ways (Figure 1).
- Its size and diversity – South Africa is a relatively large (1,2 million km^2), topographically and climatically varied country, with a wide variety of ecosystems. These include savannas, grasslands, arid shrublands, Mediterranean shrublands, deserts and forests, perennial, seasonal and ephemeral rivers, estuaries, and coastal and marine

Box 3: The world's "polycrisis"

The term polycrisis refers to a multiple, mutually-reinforcing set of nested crises. They cannot easily be reduced to specific major determining crises, such as the world economy or natural resource limits or population growth, because cause-effect relationships are unstable and uncertain and mutate from context to context. For this reason it is difficult to predict the exact outcomes of particular interventions.

Nevertheless, key dimensions of the polycrisis are being recognised in global discussions of a Green New Deal. Increasing attention is being paid to the intersections between global warming, ecosystem breakdown, resource depletion, the global economic crisis, poverty and urbanisation. Global warming by a minimum of 2°C, exacerbated by the 70 % increase in greenhouse gas emissions between 1970 and 2004, is both an outcome of an unsustainable economic system and the most significant catalyst for change. According to the Stern Report, poorer countries will suffer "first and most" from the consequences of global warming even though they have "contributed least" to it. The global economic crisis will aggravate this suffering as the global economy shrinks and up to 90 % of the value of listed companies is lost.

environments, including those of offshore islands. Territorial waters, as defined by the Exclusive Economic Zone, cover twice the country's land area.

- Its wealth of biodiversity – South Africa is one of the world's "megadiversity countries". It occupies 2 % of the world's land area, but is home to nearly 10 % of its plants and 7 % of its reptiles, birds and mammals. It has eight biomes, each with distinctive fauna and flora. It also has three internationally recognised biodiversity hotspots: the Cape Floral Kingdom (contained within the country's borders); the Succulent Karoo (the only arid land hotspot in the world, shared with Namibia); and Maputaland-Pondoland (shared with Mozambique and Swaziland). The country's seas, straddling three oceans (the Atlantic, the Indian and the Southern Ocean) include an exceptional range of habitats, from cool-water kelp forests to tropical coral reefs. The southern African coast is home to almost 15% of known coastal marine species, providing a rich source of nutrition and supporting the livelihoods of coastal communities.

- The wealth of biodiversity underpins a large proportion of the economy and many urban and rural people are directly dependent on it for their livelihoods, jobs, food, shelter, medicines and spiritual well-being. These dependencies span the continuum from commercial and semi-commercial to subsistence, through both formal and informal markets.
- Its social composition, which make it a microcosm of the world – The ratio of rich and poor people approximates the global average (which is rare in a single country), and accentuates the problem of finding equitable solutions to address the needs of developed and developing sectors of society.
- Its outstanding record of scientific research, the solid basis of knowledge on which it is able to build and its sophisticated scientific infrastructure – many South African scientists are recognised world leaders in their fields.
- Its pressing problems, deserving urgent attention, that offer the prospect of finding innovative solutions – as a dry country, South Africa's water supplies are stretched to the limit. Resources are also being depleted, resulting in, for example, shortages of electricity supply. Solutions found for South Africa would be applicable to many other countries.

All of the above make South Africa an exciting and fruitful research destination for both local and foreign researchers.

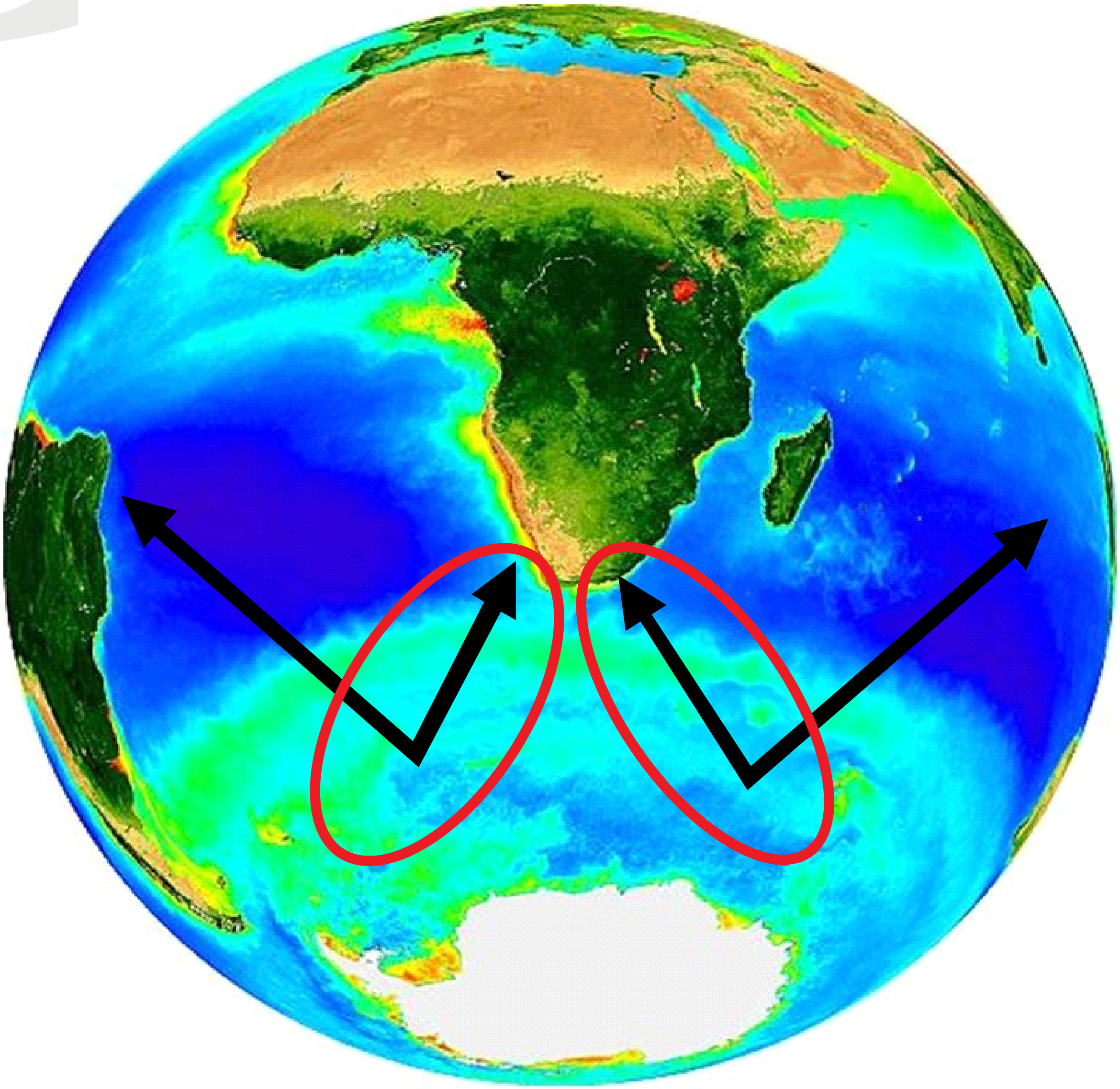


Figure 1: South Africa is located at the tip of the African continent, adjacent to important oceans that influence global weather patterns and atmospheric greenhouse gas concentrations in unique ways that are applicable globally (outward arrows) and regionally and locally (inward arrows).

2.5 Possible scenarios

This section outlines the key uncertainties and externalities that will affect South Africa as it attempts to navigate a changing future. Two main axes of uncertainty have been identified – the rate of global environmental change and the rate of innovation by South African society, including its science and technology system. Four scenarios are shown in Figure 2.

The "**Meltdown**" scenario is self-explanatory – the world changes more rapidly than humans are able to adapt, with clearly undesirable outcomes. To avoid this scenario, work is required through international negotiations to domestic mitigation actions to keep the rate of environmental change as low as possible and, simultaneously, to increase the rate of adaptive innovation.

If these political processes are successful (informed by good science derived in part from this Grand Challenge), and the world changes more slowly than is currently expected, the "**Concerned observer**" scenario will allow South Africa to survive with only a fairly modest rate of innovation. However, innovation will still be required, as the need to adapt is already unavoidable.

The best possible scenario is the "**Safe landing**", with a slow rate of environmental change and a high rate of adaptation through innovation. Under this scenario a strengthening of South Africa's global economic position can be anticipated, with an improved standard of living for South Africans.

Finally, if the rate of environmental change is at the upper anticipated limit, then it is imperative for the innovation to be equally rapid. This "**Nimble dancer**" scenario is a risk-filled one, and significant hardships may have to be endured, but survival and even moderate prosperity will be possible.

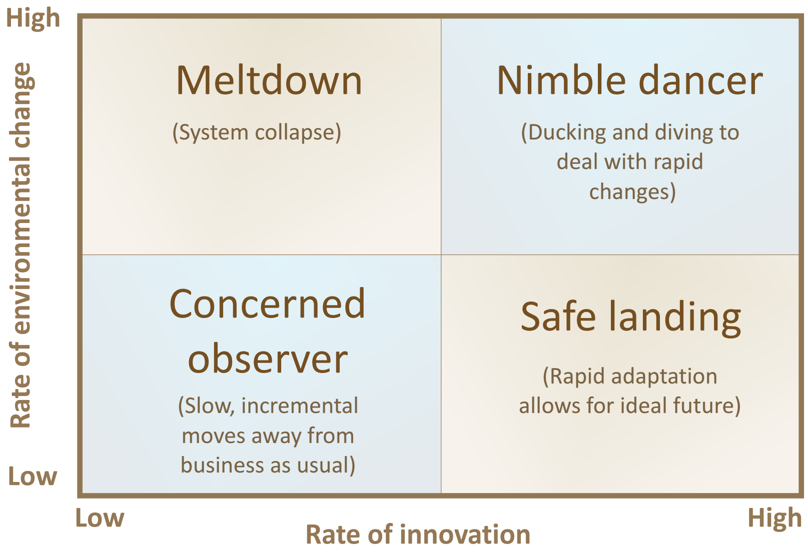


Figure 2: Four possible scenarios.

3. RISING TO THE CHALLENGE

A RESEARCH PLAN FOR GLOBAL CHANGE

A
Understanding a changing planet

1. Observation and monitoring
2. Dynamics of the oceans around southern Africa
3. Dynamics of the complex internal earth system
4. Linking the land, air and sea
5. Improving model predictions at different scales

B
Reducing the human footprint

1. Waste-minimisation methods and technologies
2. Conserving biodiversity and ecosystem services
3. Institutional integration to manage ecosystems and ecosystem services
4. Doing more with less

C
Adapting the way we live

1. Preparing for rapid change and extreme events
2. Planning for sustainable urban development in a South African context
3. Water security for South Africa
4. Food and fibre security for South Africa

D
Innovation for sustainability

1. Dynamics of transition at different scales – mechanisms of innovation and learning
2. Resilience and capability
3. Options for greening the developmental state
4. Technological innovation for sustainable social-ecological systems
5. Social Learning for sustainability, adaptation, innovation and resilience

The Global Change Research Plan identifies four major cross-cutting knowledge challenges and 18 key research themes.

The *10-Year Global Change Research Plan for South Africa* has four key focus areas or "knowledge challenges" that address our understanding of ecosystems and propose ways to reduce our footprint, change the way we live and promote innovation. Each of these focus areas has several themes. This section introduces these themes and lists key research focus areas for each.

While the knowledge challenges give thematic focus, the research themes within each focus area are designed to cover a wide range of options, enabling researchers in all disciplines to contribute to this Grand Challenge.

The aim is to encourage investigation and improved understanding of global change and its diverse effects and to encourage the development of practical ways forward. The research conducted will provide the scientific basis for improving national, regional and broader international efforts to address global change. The benefits of the research generated by the Plan will include improved mitigation and adaptation strategies, opportunities for human capacity development in key areas, information to assist government in formulating and implementing policy, and innovations and technologies towards a sustainable future for all.

The research plan builds on work that has been and is being conducted and encourages further work that needs to be done.

Goals of the Research Plan

The goals of the research plan are to –

- coordinate South Africa's agenda on global change and guide the South African research community towards probing and addressing key issues that affect people's future;
- market South Africa and southern Africa as a priority area for globally relevant research, so as to add value to, as well as benefit from, international research collaborations; and
- attract South African and other young researchers to the region and retain them by exciting their interest in aspects of global change, developing their capacity and professional skills in the relevant fields of investigation, and offering career opportunities.

The knowledge challenges

As depicted in the table on Page 11, this Plan has four knowledge challenges:

- Understanding a changing planet.
- Reducing the human footprint.
- Adapting the way we live.
- Innovation for sustainability.

In the sections that follow, the themes associated with each knowledge challenge are described. Each theme is introduced briefly, the areas of focus are identified, and a small number of high-level key research focus areas are listed.

3.1 KNOWLEDGE CHALLENGE A: Understanding a changing planet

This key focus area seeks to build an understanding of how our ecosystems are changing, where that change is taking place and how rapidly the change is happening. It also seeks to understand complex interactions that take place within ecosystems and how changing certain aspects of any of them will affect other aspects. This is basic research that does not necessarily result in technologies or applications. The understanding gained will be necessary to improve predictive capability and to plan appropriate adaptive responses.

In order to develop knowledge in these areas, several approaches should be followed, including –

- developing and running a network of observing stations, analysing the data collected by them and determining what trends are emerging;
- furthering our understanding of the world by developing and testing computer simulation models that mimic it and can be used to arrive at robust predictions of change;
- fostering international collaboration so that we can contribute to building global understanding of problems and contribute to, as well as benefit from, the considerable international efforts in this field; and
- ensuring that we build on our strengths by focusing the research on areas where we have already made progress and where we have a comparative advantage by virtue of our regional features.

Theme A1: Observation and monitoring

Global change is already having an effect on southern Africa's environment. South Africa's commitment to global efforts to mitigate further change needs to be informed by a greater understanding of the limits beyond which change becomes excessively costly or adaptation becomes impossible.

Of particular concern is the likely existence of thresholds, which, when crossed, make change effectively irreversible within realistic human timescales. Crossing of such thresholds may occur with little or no warning if the dynamics of the system are not understood well enough. Well-planned and improved monitoring, linked to analytical and modelling tools, makes it possible to recognise critical thresholds of change with increasing accuracy, and to act to avert negative consequences.

Addressing global change means developing innovative ways to live sustainably in a changing world, responding timeously to environmental disasters and health hazards and reducing the ecological footprint of humans. To assist in achieving these goals and fostering equitable and improved access to vital resources, data are needed from diverse sources. Systems that coordinate the collection, archiving, analysis and distribution of data are needed in order to provide government, the private sector, civil society, and on-the-ground managers with relevant and timely decision-support tools. Earth observation networks are

used to monitor the environment and collate data that reveal trends and provide information for use in decision-support tools (e.g. forecasting changes in the environment).

National long-term environmental monitoring is already supported by government initiatives such as the South African National Antarctic Programme, the South African Environmental Observation Network and the South African Weather Service. Other organisations also contribute to environmental monitoring but, because such activities are long-term, monitoring and data management may be threatened by the vagaries of funding cycles and changes in research priorities. The Space Science and Technology Grand Challenge will provide a dedicated earth observation platform to address South African concerns best monitored from space.

The South African government has proposed the development of the South African Earth Observation System, which aims to make data in different observation systems accessible and interoperable. As such it mirrors international observation networks with which South Africa is partnered.

The development of functional earth observation networks require several interrelated activities, which include –

- building South Africa's existing monitoring networks and developing new networks to collect appropriate data at the right scales to identify the drivers of change, their effects and thresholds of concern. This will require observations of the land, oceans and atmosphere, using both in situ and remote-sensing technologies;
- acquiring the ability to coordinate and integrate the activities of different observation systems;
- developing information systems infrastructure which can ensure secure archiving, interoperability and accessibility of data collected through earth observation;
- securing existing data which may provide valuable baselines for detecting change;
- developing advanced systems analysis and modelling capability;
- developing systems for monitoring the effect of adaptation and mitigation measures on global change.

Research focus areas

Fundamental research focus areas underlie the development and design of earth observation networks. These include the following:

- **Understanding the nature of change.** What are critical thresholds that, if exceeded, will precipitate significant and possibly irreversible changes; what would the consequences of such change be; and what indicators can be used to detect them?
- **Ensuring ongoing benefits.** What earth observation network models are best suited for detecting critical thresholds and promting appropriate knowledge dissemination and action?

A

Theme A2: Dynamics of the oceans around southern Africa

The regional ocean-basin scale processes around southern Africa regulate its climate variability and change. They also affect the global climate and long-term change.

The main gaps in regional understanding centre on the natural variability of the climate in this part of the world. Strengthening the modelling capabilities of this "coupled" ocean-atmosphere-biosphere will improve weather and seasonal climate predictions, with benefits to ecosystem services affecting food and water security, affecting protection from extreme events and, more broadly, affecting human well-being.

There is also uncertainty about the regional effects of large-scale global climate change. While it is understood, for example, that the Earth will become warmer if concentrations of carbon dioxide and other greenhouse gases continue to rise at their present rates of 1 to 3 % per annum, regional responses to such a rise remain unclear. The strong links between local climate and the three oceans surrounding the southern African landmass make any seasonal and decade-scale forecasts dependent on the changing nature of these links. This is a key knowledge gap.

Of global importance is the role of the region's oceans in driving the global climate system, biogeochemically and physically. One of the most important services offered by the Southern Ocean is its ability to provide a "sink" for some 50 % of all the natural and anthropogenic carbon dioxide taken up by the world's oceans.[3] It is unclear how this ability will be affected by global warming. Also insufficiently understood is the role of the Southern Ocean in modulating albedo (that is, the ability of the Earth to reflect solar radiation). The ocean produces (emits) trace gases, which help to seed low clouds that increase reflectivity, but some of these gases also reduce stratospheric ozone, allowing more radiation to reach the Earth's surface.

Other areas of global interest that can be studied fruitfully in this region are the reconstruction of past ocean climate, which, through the climate change that coincided with the ascent of humans in the region in the Pliocene epoch (5.3 - 2.5 million years before present), could provide important clues about the types of responses to global warming for long-term adaptation of human systems and ecosystem services.

Research focus areas

Key research focus areas include the following:

- How will the large-scale Southern Ocean ocean-climate system including the Antarctic Oscillation, frontal zones, overturning circulation and surface mixed layers, respond to global warming?
- How will the Southern Ocean's capacity to take up anthropogenic and natural carbon dioxide and provide the required energy supply to its ecosystems change in response to climate change?
- How will the Southern Ocean respond to climate change through changes in ecosystem function and structure which modify food webs and climate feedbacks such as atmospheric albedo?

[3] *The world's oceans take up some 2,2 billion tonnes of carbon dioxide a year, valued at $US20 to $US60 per tonne.*

A

Theme A3: Dynamics of complex internal earth systems

From the geological record it can be deduced that the rates of change witnessed today are not unprecedented.

The activities under this theme will focus on the role of the Earth's subsurface processes typically studied in geology, geochemistry and geophysics.

Research focus areas

- What can be learned about the past rates of change in the Earth's subsurface processes and the feedback to past climates?
- How can the knowledge of the rates of past climate changes improve the model predictions?

Theme A4: Linking the land, air and sea

Although many researchers tend to work within a single domain (for example, oceanographers focus on marine ecosystems), it remains a fact that ecosystems are connected. In order to further understanding of the ways in which ecosystems are linked and how changes in one system will affect others, studies that cross traditional boundaries are needed.

The management of our land surface affects water drainage into rivers, which in turn affects the health of estuaries and of the sea fishes that rely on estuaries as nursery areas. Changes in ocean currents can influence weather patterns, changing rainfall regimes on the land and affecting agriculture. Studies that combine understanding from a range of domains and that focus on the interface between connected domains, are needed if meaningful understanding is to be developed.

Studies in this theme will focus on the following:

- Changes in linked terrestrial-marine processes, with a focus on the ways in which land-based processes (such as vegetation fires, fossil-fuel burning or methane production by livestock) affect the dynamics of the ocean. The theme seeks to clarify the links between land and ocean ecosystems, how

these will change and how feedbacks from changes in the ocean can affect the land.
- Changes in hydrological cycles, with a focus on freshwater resources. This area includes the effects of land-based activities (such as impoundments, abstraction, interbasin transfers and pollution) on estuaries and the sea.
- Changes in the dynamics of the atmosphere, with a focus on ways in which it is affected by processes on land and in the sea, and how these in turn drive the regional climates of southern Africa. The atmspheric transport of aerosols and pollution in the air, and their influence on climate processes also need to be considered.

A

Research focus areas

Key research focus areas include the following:

- What are the priority forms of change on the land that will directly or indirectly affect atmospherics, estuarine and marine dynamics?
- Can any thresholds be identified beyond which changes in one system will cause irreversible or sudden change in another system? If so, how can reaching such thresholds best be avoided?

Theme A5: Improving model predictions at different scales

Current predictions of climate change rely on a number of models that simulate possible future changes in the real world. When they were first developed, these models were relatively rough, but they have improved steadily as new knowledge became available, and better understanding has resulted. In addition, several different models were initially developed in isolation of each other. With improved global collaboration, these models are starting to converge as global understanding develops. However, global models focus on broad-scale changes to the Earth's climate, and their predictions are often too coarse to be useful at a regional or local level. It is also true that, by adding understanding generated at a local level, it is possible to improve global models, their predictions, and therefore their usefulness.

Simulation of past climate provides stringent tests for climate models and can contribute to reduced uncertainties in climate predictions. Southern Africa is an ideal location to carry out palaeo-climate research because it currently has a wide range of climatic zones that support significant biodiversity, and in addition has splendid records of very different conditions in the past. These are found at places such as the Fossil Park at Langebaanweg, located about 100 km north of Cape Town, and the Sterkfontein caves at the Cradle of Humankind near Johannesburg. This research is of interest to many, especially anthropologists, biologists and those who attempt to predict the climate changes that will accompany global warming.

This theme focuses on –

- improving the accuracy of models by correctly representing important southern African biomes (such as fynbos, Succulent Karoo, Miombo woodlands and Mopane shrublands) that form the basis for model predictions;
- improving the simulations of bushfires that burn southern African vegetation and drive atmospheric dynamics;
- correctly characterising the release of carbon from the land and its uptake in the sea; and
- including the simulation of convective rainfall processes in general circulation models.

Research focus areas

The overarching research focus areas to be addressed in this theme are the following:

- What is the relative importance of southern Africa's biomes in terms of their influence on climate and on carbon storage?
- Which were the global climate changes that favoured the evolution of the impressive diversity of flora and fauna of southern Africa? More specifically, what were the climate changes over the past 5 million years that saw the rise of African hominids, fynbos and many other life-forms?
- What are the relationships between bushfires and greenhouse gases and carbon storage? Are fire regimes likely to change and, if so, how will the relationships change?
- To what degree do the land and the oceans around southern Africa act as sources and sinks for carbon and other important elements?
- How will changes in sea surface temperature and ocean currents affect rainfall patterns?

3.2 KNOWLEDGE CHALLENGE B: Reducing the human footprint

Humans have been an integral component of South Africa's terrestrial ecosystems for over 150 000 years, first as hunter-gatherers and later as nomadic pastoralists. The ecosystems have co-evolved with their human inhabitants to today's landscape of increasingly urban and increasingly monoculture agricultural systems. These changes have brought with them significant improvements in many elements of human well-being.

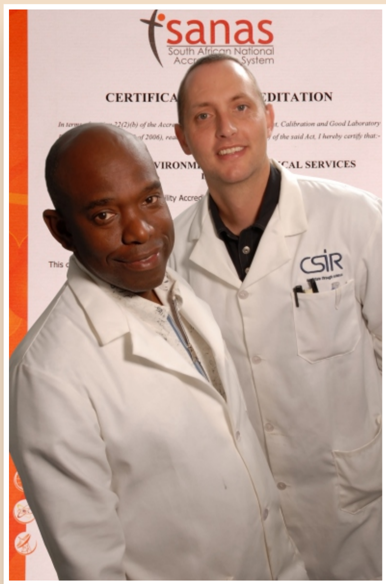
However, these improvements have not been experienced by all, especially in rural and impoverished communities, and they have come at a cost to biodiversity, available freshwater and the quality of our land, soil and vegetation. It is now clear that these ecosystems are our life support systems, providing ecosystem services like drinking water, food, fuel, fertile soil, waste assimilation and recreational and spiritual opportunities, among many other benefits. The changes humans have wrought on ecosystems (our footprint) have compromised the ability of these life support systems to improve the quality of life of all South Africans. This ability will be further compromised by global change, especially in vulnerable communities.

We urgently need to discover new ways to support and improve human well-being; ways that do not have adverse consequences for our ecosystems and for those that rely on them. We need to reduce the human footprint, at the same time ensuring that current and future generations across the country have an equal chance to experience a decent quality of life. We need to balance socio-economic development and environmental protection and sustainability.

Theme B1: Waste-minimisation methods and technologies

The production of waste, along with the ability of the Earth's ecosystems to absorb waste products, form a significant aspect of global change. Burgeoning human populations and increases in energy generation, manufacturing and trade all result in substantial amounts of materials being used (stocks degraded through overexploitation) and waste being produced and disposed of, at times indiscriminately.

The South African government is faced with a number of challenges with respect to delivering an effective and sustainable waste-minimisation service. At municipal level, authorities have to deal with insufficient budgets, lack of skill, lack of appropriate equipment and poor access to service areas. These problems are exacerbated by the growing urban population, which requires access to municipal services, and poverty-driven migration from rural to urban areas. South Africa's economy has been growing fast and the trend upward is generally expected to continue in the medium to long term. A Long-term Mitigation



Can Africa rise to an acceptable level of human development without overloading its environment?

WWF 2008 Africa: Ecological Footprint and Human Wellbeing WWF -Gland, Switzerland and Global Footprint Network (GFN), Oakland, California USA.
ISBN 978-2-88085-290-0

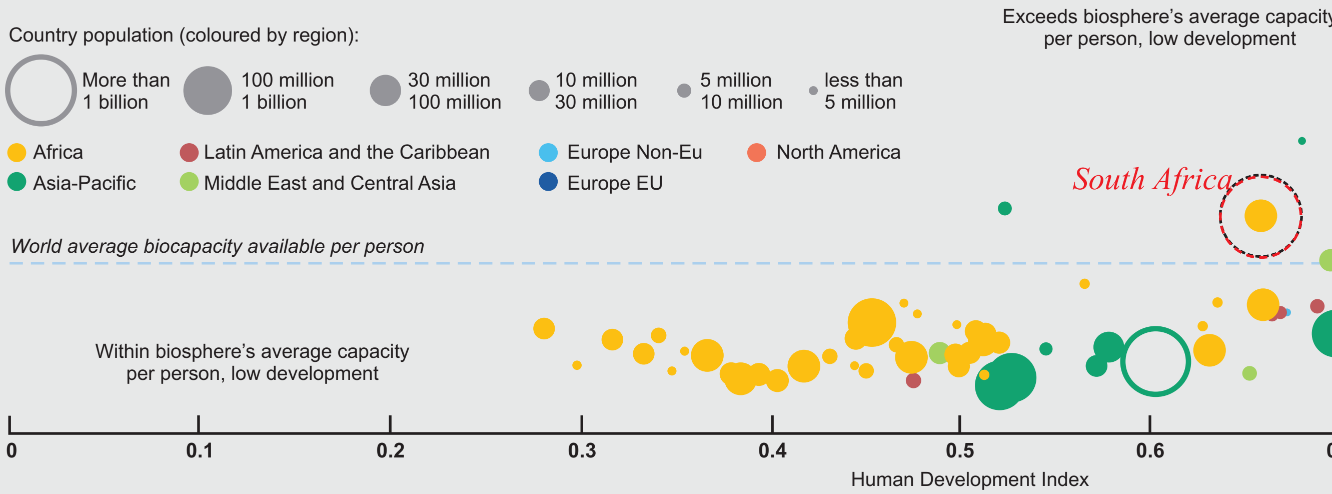
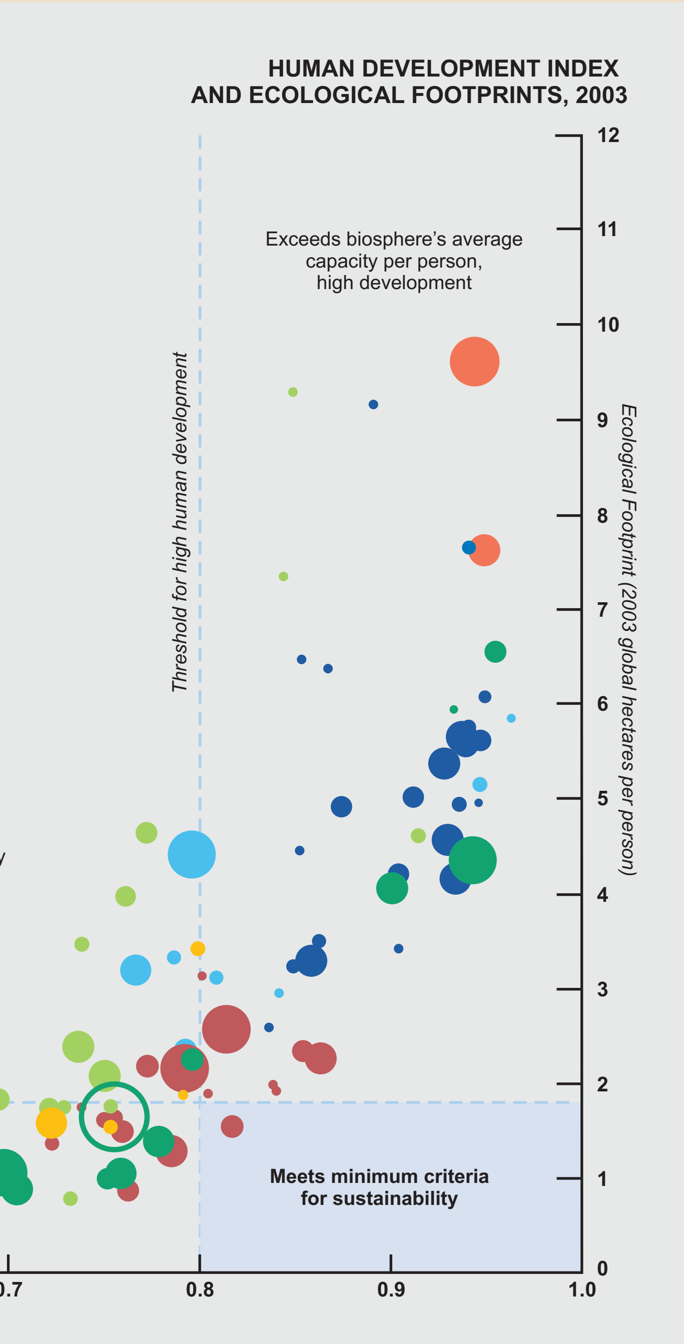


Figure 3: Countries characterised in terms of their quality of life and ecological footprint. Only one country (Cuba) meets the minimum criteria for sustainability.



Strategy on Climate Change was developed in 2007. The waste sector is recognised to make a significant contribution to greenhouse gases that result in global warming and climate change, in particular due to the current practice of disposal of biodegradable municipal waste to landfill.

Any research agenda that aims to improve waste-minimisation methods and technologies must address reduction, reuse, recycling and the recovery of waste. Such a research agenda would aim to generate relevant science to inform policy making around waste-minimisation methods and technologies.

Research focus areas

The following are key questions:

- What waste-minimisation methods and techniques are currently being applied? Which materials are currently being recycled and in what quantities across the country?
- What are the alternative solutions (policy, economic and technological) for increasing waste minimisation and reuse for priority waste streams (exacerbating climate change, e.g. biodegradable municipal waste)?
- How can new waste-minimisation methods and technologies be implemented by different institutions and stakeholders, especially municipalities in South Africa?

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Theme B2: Conserving biodiversity and ecosystem services

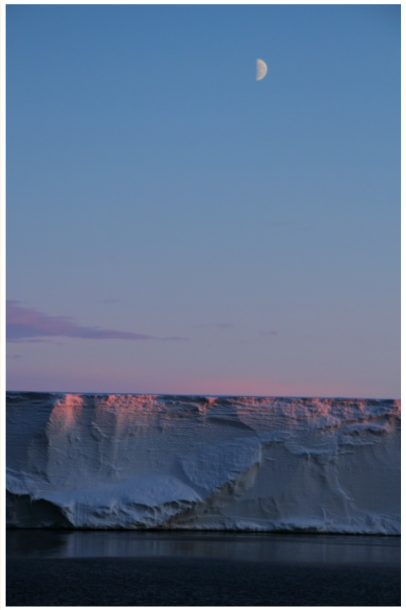
South Africa is the third most biodiverse country in the world. As custodians of this unique diversity, we have a national obligation as well as a global one to look after it for posterity. Our biodiversity supports important formal and informal biodiversity-based economies, e.g. nature-based tourism, which is a major and growing earner of GDP in the country, as well as our large fisheries and medicinal plant trade. It is the basis for the provision of what are called "ecosystem services", the benefits we get from nature including food and fibre, fresh water, clean air, the decomposition of waste and recreational and spiritual well-being. South Africa's ecosystems harbour eight times more species than the global average, and support formal and informal economies in unique ways. As such, it is an attractive destination for ecological research.

Ecosystem services can be grouped into four categories (provisioning, supporting, regulating and cultural services). Provisioning services deliver products for human use. Support services underpin basic life-support processes like soil formation. Regulating services control the flow of benefits and treatment of wastes, pests and diseases. Cultural services include spiritual, aesthetic and religious values ascribed to ecosystems, as well as recreational and tourism activities. Human well-being is ultimately determined by the continuing supply of these services, which can be delivered by natural, as well as highly managed, ecosystems. As elsewhere in the world, South Africa's ecosystems and the services they deliver are under threat. Many terrestrial ecosystems have been converted to crops, and much of the remainder has been degraded. Our oceans have been depleted of their fish stocks, and our freshwater supplies are polluted and overused.

The challenge here is to find sustainable ways of reducing the human footprint on local and regional ecosystems and their services, while at the same time finding new ways of making use of the opportunities provided by our biodiversity and its ecosystem services. It is essential to manage both of these aspects if our biodiversity is to persist and support ecosystem services for future generations.

Key areas for special research focus in this part of the world include the following:

- Savanna ecosystems – Savannas are globally extensive, important for carbon storage and sensitive



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to variation in rainfall. As such, they provide fertile ground for science that has relevance in southern Africa and elsewhere in the world. South Africa is an acknowledged research leader in savanna, thicket and shrubland ecology, woody plant-shrub interactions, grass ecology and systematics, fire ecology and the palaeo-ecology of Africa.

- The Southern Ocean – The oceans south of southern Africa are important in shaping the greenhouse-gas feedbacks that influence global warming. Their other equally important roles – such as modulating albedo – are less well understood. South Africa's location as a key logistics base for Southern Ocean and Antarctic studies, its satellite-receiving capability for the region, the record of marine research, and the long-established research bases at Marion Island and in Antarctica all provide comparative advantage in Southern Ocean studies.
- Benguela upwelling system – coastal upwelling off South Africa is not only an important contribution to regional food security but also a provider of a range of ecosystem services, such as biodiversity and coastal tourism. South Africa remains an internationally recognised centre in upwelling ecosystem science, which, because of its biogeochemical characteristics, now offers additional competitive advantages in the global need to better understand the impacts of high levels of CO_2 on ecosystems and species.

- Agulhas system – the Agulhas sub-tropical east coast system, in sharp contrast to the upwelling west coast, is a high-biodiversity environment sensitively dependent on its links to terrestrial water systems through the network of estuarine ecosystems. Land-use pressure is accelerating the rate of change on these land-ocean couplings with uncertain future outcomes which offer formidable challenges.
- Winter rainfall ecosystems – Although the winter rainfall region (fynbos and Succulent Karoo) occupies less than 10 % of South Africa, it has one of the richest concentrations of biodiversity anywhere on the planet. Ongoing experimental research that addresses important global change questions currently builds on a solid basis of ecological and transdisciplinary understanding. The experience being developed in this region promises to provide models for conservation management elsewhere in the world.
- Biodiversity-based economies – The challenge is to determine how South Africa can maximise the opportunities provided by its wealth of biodiversity to

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enhance the well-being of the vulnerable, while ensuring the continued survival of this globally significant biodiversity.

- Invasive alien species – Invasive alien species are widely accepted as the second largest threat to biodiversity after direct habitat destruction. The threat needs to be quantified and management priorities need to be defined.

Research focus areas

Research on the conservation of biodiversity and ecosystem services in South Africa and the region will focus on three high-level groups of questions:

- Understanding ecosystems and their services – how have the region's ecosystems and the societies that live within and depend upon them evolved; what are the links and what do changes in ecosystems mean for their resident societies?
- Managing ecosystems – what, and how much, needs to be protected where; and how is a continued and equitable supply of ecosystem services to be ensured?
- Ensuring ongoing benefits – what management and governance models would be best suited to the management of the ecosystems and their services; and how can these models be promoted?

Theme B3: Institutional integration to manage ecosystems and the services they offer

Management of the human environment and, indeed, of daily life, is made easier by reducing the world's complexity into manageable compartments. In South Africa, for example, separate departments oversee water, agriculture, conservation, forestry, fisheries, and town and regional planning. However, this reductionist approach fails when the actions taken by one department have unforeseen or unintended consequences for another sphere of interest. Whereas such approaches may have sufficed in the past, growing human populations are placing increased pressure on finite resources and the situation demands an integrated approach to environmental management. The holistic management of ecosystems in an integrated manner will require the establishment of governance mechanisms to ensure effective institutional collaboration. South Africa's work to set the scene for collaborative governance has included the formation of, for example, fire protection agencies, catchment management agencies and local conservancies.

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Research focus areas

Key questions to be addressed include the following:

- What are the priority environmental and developmental issues that require integration?
- What generic lessons can be learnt from the experiences associated with establishing fire protection agencies, catchment management agencies and local conservancies?

Theme B4: Doing more with less

In order to function, the global economy depends on a flow of materials that are extracted from the Earth, processed via production and consumption processes to meet human needs, and then disbursed as wastes generated by the extraction, production and consumption processes. The most important materials extracted for use are biomass, fossil fuels, ores, industrial minerals and construction materials. The two key factors that determine material flows are population numbers and resource consumption per capita. These material flows are therefore referred to as the **metabolic rate** and are measured in tonnes per capita or per unit of GDP (tonnes/$1 billion of GDP).

Highly industrialised countries with only one fifth of the global population have until recently been responsible for rapid increases in global resource consumption (ranging between two and four times the world average metabolic rate of between 8,5 and 10 tonnes per capita per year), while developing countries have played the role of resource exporters and therefore have metabolic rates of almost half the world average (5-6 tonnes of resources used per capita per year). This has begun to change, however, with newly industrialised economies in the developing world (including SA) now playing an increasingly important role.

It is necessary, therefore, to relate strategies dealing with resource use to developmental status. While it seems fully justified to discuss resource use reductions (i.e. decoupling economic growth from resource use) for industrialised countries, this is not in the same way applicable for many, if not most, developing countries. Low metabolic rates in developing countries often reflect a lack of satisfaction of basic needs and a low standard of material comfort, and there needs to be the environmental and economic space for them to resolve these problems. However, this cannot be a completely unrestrained space given that there are finite resources. It is for this reason that it is necessary to make a distinction between relative and absolute decoupling, with the former more applicable to developing economies and the

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latter more applicable to developed economies. **Relative decoupling** is when resource consumption rates grow at a lower rate than the economic growth rate. This signifies increased efficiencies and resource productivity. **Absolute decoupling** takes place when the rate of resource consumption is negative while the economic growth is positive. If a sustainable world means converging at a point where every country is consuming the equivalent of 6 tonnes per capita of resources, this will create the space that developing countries need to grow to eradicate poverty. However, the developed economies will have to reduce substantially from nearly 30 tonnes for low-density developed economies (like the USA and Australia) or half this for high-density developed economies (like Europe).

Research focus areas

If we accept that there are physical limits to the absolute quantity of materials that can be extracted for human use and our goal is sustainability, then it follows we need to –

- quantify what the limits to the quantities of materials that can be extracted are, including declines in the quality of deposits, and thus the projected increases in costs of extraction;
- determine the historical patterns of domestic material consumption relative to economic growth as a point of departure for a base-case scenario in terms of what is currently being extracted and used and what is most likely to occur in the future under a "business-as-usual" scenario;
- develop context-specific interventions (policy, technological, institutional and integrated approaches) that will facilitate the decoupling of economic growth from rates of resource extraction and use (dematerialisation) , including the role that decoupling plays in the overall economic development strategy of reducing dependence on primary production by shifting over to a knowledge economy;
- provide evidence-based research that will assist policy makers, businesses and trade unions to understand how it will be possible to dematerialise industrial sector strategies (by making greater use, for example, of cleaner production approaches, life cycle management, zero waste and resource substitution); and
- demonstrate, using various modelling techniques, the linkage between decoupling and 'green- collar jobs', i.e. jobs that are created through investments that will ensure long-term sustainability and resource security (e.g. public transportation systems that are less dependent on oil, solar energy alternatives for cities, sustainable agricultural production using organic farming techniques, embedded knowledge networks that link R&D generators to SMMEs with respect to sectors like construction, infrastructure, eco-system services, fishing and food processing).

3.3 KNOWLEDGE CHALLENGE C: Adapting the way we live

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

These changes will take two forms. The first involves altering the activities that are driving change, with the express aim of slowing or reversing the adverse consequences that are predicted. Actions in this sphere include reducing human levels of fossil-fuel consumption. The second form involves making changes that will help us to avoid the negative consequences and benefit from the opportunities offered by change that we cannot avoid; such measures are known as "adaptation". This key focus area outlines four themes designed to address these issues.

Theme C1: Preparing for rapid change and extreme events

The generation of greenhouse gases has initiated changes to the Earth's climate that cannot be reversed in the foreseeable future. In addition, it is likely that the activities that generate these gases will continue, even if at a reduced rate. Some changes are therefore unavoidable at this stage, and scientists need to predict where these changes will have negative effects and how serious these are likely to be, so that plans can be made to avoid or tolerate them as far as possible. The kinds of changes that can be expected include increases in the magnitude and frequency of both floods and droughts; changes to fire regimes that will place people and property at higher levels of risk; rises in sea level and accompanying increases in the magnitude and frequency of storm damage along the coast; and changes to the dynamics of diseases affecting humans and livestock.

Research in this theme needs to focus on the areas in South Africa that are most at risk, including –

- the coastal zone (especially the east and south coasts where the most people live);
- water-stressed ecosystems and regions, where freshwater resources are "over-allocated", and where climate predictions suggest that rainfall will decrease;
- riparian and other low-lying areas that could be subject to flooding;
- areas of high fire danger, especially where climate predictions suggest that weather conditions conducive to the spread of veld fires will increase; and
- people and animals at risk from diseases.

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Research focus areas

Key research focus areas include the following:

- What methods should be developed to better understand uncertainty and risk?
- Which areas are most at risk from rapidly changing conditions?
- What can be done to avoid, or ameliorate, adverse effects of change?
- How can South Africa's biodiversity – especially threatened, rare or otherwise important species – be protected from adverse change?

Theme C2: Planning for sustainable urban development in a South African context

Africa has the world's highest rate of urbanisation, and by 2005 almost 350 million Africans (about 40 % of the continent's total population) were living in urban areas, which are collectively increasing at a rate of nearly 4 % per year. This urbanisation differs in three ways from trends in the past. First, for the first time in history there are more people living in cities than in rural environments. Second, the sheer size of urban agglomerations is new, with 20 cities already achieving megacity status (that is, having human populations numbering more than 10 million), and some (including Tokyo, Mumbai and Mexico City) comfortably exceeding the 20 million mark. The third difference is that cities, and the way they function, have become a major driver of regional and global environmental change.

The great challenge of 21st-century urban development lies in finding ways for city planning and management to address not only the needs of urban dwellers in large, rapidly growing, and mainly poor cities, but to do so in a manner that acknowledges the interdependence of cities and the ecosystems of which they form part, including global regulating services such as climate regulation. The slow rate at which cities adapt, their reliance on an ever-increasing hinterland and their entrenched dependencies on specific delivery mechanisms for critical services, make them particularly vulnerable to threats posed by a changing climate. There is increasing recognition that the sustainability of urban social-ecological systems is a function of their functional integrity and resilience. The application of the concept of resilience (well developed in ecological studies) to urban social-ecological systems is still immature (both locally and internationally) and the opportunities it presents need further definition.

Research focus areas

Important research focus areas would include the following:

- What are the factors that would determine urban resilience? The research would consider the ways in which ecosystem concepts such as diversity, redundancy, vulnerability and ecological variability apply to the urban social-ecological system, and would include biophysical factors as well as social factors such as regulations, values and aspirations.

- How does a city's physical form and infrastructure affect its resilience?
- How can cities, their infrastructure, and the control and management systems that regulate their functions be designed so as to improve the resilience of the conurbation?
- What would be appropriate monitoring and assessment tools with which to evaluate a city's ongoing resilience?
- What are the implications of climate change risks and declining ecosystem services for decision making and policy development regarding resource allocation, settlement planning and design, development in rural areas and growth and management of major city regions?

Theme C3: Water security for South Africa

South Africa is a dry country where water is a vital but limited resource. Current climate-change trends could lead to an average rise in global temperatures of 2 to 3°C within the next 50 years or so. This could lead to a 20 to 30 % decrease in water availability in some vulnerable regions, including southern Africa. Currently, all available freshwater resources (97,3 % of the total local yield in the year 2000) in South Africa are allocated for use and consumption; although much of this water is wasted through inefficient supply (i.e. inefficient rainfall harvesting, storage and transmission) and inefficient use. Clearly, the effects of climate change on water security are of exceptional importance to South Africa and its people. South Africa faces significant challenges in the sustainable supplying of water to support ongoing and new economic activity, population growth, improved quality of life and regional equity. This includes water security for industry, especially for electricity and liquid fuel production.

The first-order effects of climate change (such as the amount of rainfall) are often the focus of discussion on mitigation measures and adaptation strategies. It is, however, very likely that secondary effects could be much more significant.

Research focus areas

This theme will focus on the following questions:

- Can we develop dynamic predictive models that will allow water planners to move away from a dependence on data from the past 50 years (which will not reflect future trends)?
- What are the important secondary effects of a changing climate on water security?
- What are the limits within which freshwater ecosystems can maintain their integrity, and where are these limits likely to be exceeded?
- What transboundary effects can be expected, considering that a number of South Africa's major river systems are shared with our neighbouring countries?
- How do we best change human behaviour in terms of existing wasteful and inefficient ways of supplying (storing, transmitting) and using / consuming water?
- What role can market mechanisms, such as payments for ecosystem services and water trading, play to facilitate water security?

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Theme C4: Food and fibre security for South Africa

Food and fibre security is one of the most important challenges facing nations at present, and several effects associated with climate change are predicted in this regard. The area suitable for agriculture and forestry, the length of the growing season and yield potential are all expected to decrease by as much as 50 % by 2020 as a result of decreases in rainfall. At the same time, changes in fire regimes, as well as factors controlling pest and pathogen outbreaks, are expected to exacerbate the situation further, while the positive effects of increased carbon dioxide are not expected to be substantial in Africa.

Regions where humans rely in part on wild plants and animals for their food will also be affected, as many wild plants and animals will suffer decreases in the extent of suitable habitat, causing local or even global extinctions of species that serve as a food source. Strategic reserves of food could also be badly affected as a result of decreases in surplus food production, as could problems with the efficient distribution of food reserves. The effects of climate change on food security are difficult to predict at present, and research is needed to deepen our understanding of the issue.

Research focus areas

This theme focuses on the following questions:

- How and where will southern Africa's main crops and livestock be affected by climate change? Can the most vulnerable crops and livestock types be identified with a view to replacing them, or ensuring ongoing production?
- What new crop or livestock species, or production methods, can be developed to offset the effects of climate change?
- Can cropping systems be developed to derive multiple benefits from the same area (for example by using tree crops for food, fodder, energy and to enhance cash income)?
- Which wild plant and animal species are important sources of food? How will these be affected by climate change, and do alternative sources of food exist to replace such species?

3.4 KNOWLEDGE CHALLENGE D: Innovation for sustainability

It has been demonstrated that the quality and availability of the planet's ecosystem services, on which human populations depend, are deteriorating, with serious detrimental consequences for social development and welfare. The relationship between humans and the environment is complex, interconnected and interdependent. Responding to the challenges presented by global change brought about by this relationship would require a range of technological, methodological and systems innovations involving collaboration between earth system science and the social, economic and engineering sciences. In addition, the South African context requires that responses have to consider the local challenges of a developmental agenda within a financially constrained delivery system. From within a social-ecological paradigm, a transdisciplinary systems approach to innovation offers a way to reconcile what is currently seen as competing agendas.

Innovation is not just a process of technological change, but of change at the institutional and social levels. The lessons learnt from innovation studies over the past 20 years is that innovations only take root when there is an investment in social learning and social-learning systems, and support for the role of human agency in social change across the spectrum (such as social entrepreneurs, change agents, facilitation, capability enhancement and formalisation of competencies).

A further significant challenge for global change research is to understand the interplay between two important change phenomena: "environmental change", the study of which is an established tradition in earth system sciences, and "innovation for sustainability", which reflects the human response to environmental change. Understanding feedback relationships between the two change phenomena is important in the context of the effect that innovation can have on accelerating or retarding rates of environmental change and driving transitions. The study of innovation is a relatively new research field, which has been maturing globally over the past decade. To date, its core focus has been the relationship between economic growth and innovation in the context of the emerging global knowledge economy and the role of states in fostering social learning. Its insights are relevant for global change, specifically regarding the implementation of a "green economy" approach. Parallel with the study of innovations, research into global industrial transitions has established useful frameworks for understanding the relationships between technological change, industrial development and state intervention.

Drawing from both of the above fields, the International Panel for Sustainable Resource Management,[5] on which South Africa is strongly represented, approaches transitions and innovations on the basis of research into ways of "decoupling" economic growth from resource consumption and environmental degradation. This creates what has been termed "non-material" growth. Aligned with this concept of growth, this key focus area integrates the study fields of innovations and transitions, creating opportunities for South

[5] The International Panel for Sustainable Resource Management (IPSRM) was established by the United Nations Environmental Programme in the wake of the 4th Assessment Report of the Intergovernmental Panel on Climate Change, to consider ways and means of restructuring the global economy to make it more sustainable.

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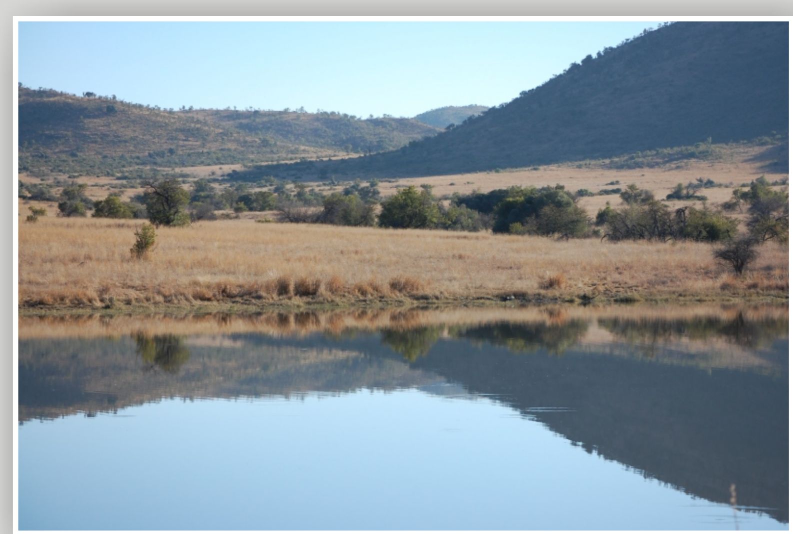
African researchers to make important contributions to sustainability.

As in many mid-level developing countries, South Africa's sophisticated economic core is used as the basis for dealing with the challenge of poverty. Its carbon dioxide emissions and levels of resource consumption are high, however, and closer to those of more developed countries. This makes South Africa a useful place for research on innovation for sustainability, with the knowledge gained having both local and global relevance. The country's history of innovation research, combined with its experience of transition and rapidly rising investments in sustainability science, makes it well placed to become a world leader in global change research.

Current research gaps relate to the fact that technological innovation and innovation research are not normally connected to global change research, which tends to be biased towards environmental change, especially relating to degradation. In South Africa, technological development, as well as research that tracks technological changes (whether nationally or internationally), is fragmented into sectors (such as energy, water and waste), rather than integrated in a way that is directed towards promoting sustainability. Economics and economic policy tend to ignore both the outputs of South Africa's sustainability science research and global shifts towards a "green new deal". The country's approach to development is centred on investments in economic growth, seemingly at all costs, ignoring the implications of resource limits. Environmental research, in turn, tends to be premised on impact assessment rather than on finding ways to redefine development within environmental limits, while research relating to institutional development is still relatively ignorant of the vital importance of innovation.

In summary, this research area focuses on the following challenges:

- The decoupling of economic growth rates from rates of non-renewable resource consumption (for example by means of materials and energy flow analysis, by means of calculating South Africa's GDP per capita and Human Development Index, and by means of ecological footprinting).
- Innovation processes and outcomes, especially in South Africs’s rural communities.
- Stimulating technological and institutional innovations that lead to the efficient functioning, resilience, regeneration, evolution and overall well-being of global and local social-ecological systems by addressing the urgent need for improvement of quality of life, job creation and service delivery through addressing global change challenges.
- The resilience of ecological, social and social-ecological systems (future proofing, increasing reliance on local resources and the role of indigenous knowledge systems).



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Fragmentation of the country's research system (research councils, universities and research-orientated NGOs) compromises the ability of researchers to respond to the above challenges. Knowledge-bridging institutions and a centre of focus are required to foster collaboration among leading researchers working in energy, water, sanitation, waste, soils/food, ecosystem services, industrial design and construction in the following broad research sectors: applied engineering, economics, social sciences, ecology, life sciences, institutional development (public and private sector management) and development studies.

Five research themes are addressed through this key focus area.

Theme D1: Dynamics of transition at different scales – mechanisms of innovation and learning

It is now generally accepted that the world faces the twin effects of critical upheavals in the global economy and a global ecological crisis. How the global community, South Africa, cities, places and sectors respond to these twin crises will depend on the rapidity of social learning and behavioural change, the capacity for institutional change and appropriate decision making. The dynamics of transition are expected to be uneven, both spatially and temporally. Coordinated global responses, driven by scientific conclusions (such as those of the Intergovernmental Panel on Climate Change) or by challenges to international policy makers will be slow, and limited at best to the creation of global incentive funds (such as those related to carbon emissions).

Reactions from national governments will diverge, depending on the links between the ideologies of governing parties and research findings. Some countries (such as Germany and Costa Rica) might make sustainability a cornerstone of national development policy. China, South Africa and the USA might gradually facilitate transitions, based on carefully tested innovations that are deemed not to pose threats to economic growth imperatives. Other countries may lag behind. Many of the most promising and far-reaching transitions could materialise at city level, as local governments recognise the substantial financial and economic advantages of changing the technologies of urban infrastructure in the fields of energy, water, sanitation, transport, food production and distribution, and waste. Research on this aspect of the theme will aim to track transitions to more sustainable use of resources driven by innovations, at global, national and local level.

A wide range of mechanisms for stimulating innovation and learning will continue to be deployed. They include regulatory interventions that stipulate constraints on consumption (such as banning certain kinds of lighting), prevent pollution or impose emission quotas. Others will be market-oriented, normally achieved by manipulating prices, taxes, tariffs and subsidies of various kinds. Research on this aspect of the theme will aim to monitor the application of these mechanisms and to review their relative successes and failures.

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energy and water re-use)? How is the decoupling manifesting within production and consumption systems as businesses respond to mounting resource threats combined with government incentives and penalties?

Research focus areas

Research aimed at tracking and monitoring the dynamics of transition and the mechanisms of innovation and learning will address the following high-level questions:

- Tracking the trends in global change with special reference to innovations that spur and catalyse transitions – What innovations are emerging, how they are being applied, and what kinds of transition are under way? To what extent is "decoupling" happening, with special reference to resource inputs, resource productivity, waste outputs and the potential for a transition to "non-material" economic growth?
- Tracking emerging trends within the South African context – What relative and absolute decoupling is occurring at a national scale (in terms, for example, of the effect of greener budgets) and at a local municipality scale (in terms of, for instance, the effects of improved public transport, energy efficiency, renewable

Theme D2: Resilience and capability

The rise of transdisciplinary approaches to integrated understanding of social-ecological systems has made it possible to reconsider what it means to build the social and ecological capacities/capabilities for managing rapid change. Resilience is an emerging concept. Instead of focusing on ways of "sustaining development" (which is often associated simply with maintaining what already exists), the new emphasis is on building the underlying social/institutional, technological and ecological capacities required for adapting to the consequences of global change. This means reinvesting in natural capital, in a manner that transforms the ways in which local and national economies operate. It might, for example, mean changing from the current view that localities must find their niche specialisations within a global trading system to localities rebuilding bioeconomic diversities and relevant skills sets.

The theory of capabilities for development emerges from the work of the Indian economist, Amartya Sen. Instead of using GDP per capita as the sole applicable measure of development, the quantitative and qualitative dimensions of individual and collective capabilities for identifying preferences, making decisions, and capturing and using resources have become the focus of new directions in research and policy making.

The combination of resilience and capability approaches offers a conceptual framework for making sense of innovations at three different levels, namely technological innovations – specific techniques for managing/processing materials and energy (for example, the hydrogen fuel cell, the microchip or any process that achieves more with less); institutional innovations – for managing (on a

The new emphasis is on building the underlying social/institutional, technological and ecological capacities required for adapting to the consequences of global change.

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society-wide or even global basis) incentives, transaction costs, rents, benefit distribution, dispersal, contractual obligations, precautions and individual obligations; and relational innovations – for managing cooperation, social cohesion, solidarity, social learning and benefit sharing.

Four key insights from innovation literature are relevant to this research theme:

- Innovations differ from inventions – an invention is created when a new idea emerges for a new product or process, whereas an innovation is the synthesis of the new idea with a complex set of financial and institutional arrangements to implement the new idea or concept invention on a broader scale.
- Innovations are not random events, but are rather the function of specific incentives and investments.
- Innovations do not arise from single individuals or single organisations, but rather from well networked economic agents working collaboratively with knowledge institutions (such as universities), in ways that are open, creative, problem-driven and connected to learning from practice.
- Innovations are not concerned with building up stocks of knowledge capital (such as patented ideas) created for trade in what is called the "knowledge economy", but are continuous learning processes, responsive to the fact that in a complex globalised world, fixed bits of knowledge rapidly become obsolete. This notion of innovation suggests that it belongs to "a learning economy", not a "knowledge economy".

The contemporary developmental state should focus on investments in social learning, knowledge development, research and development, and human capabilities

Research focus area

Research focused on the concepts of resilience and capability optimisation for sustainability will address the following high-level question:

- The dynamics of innovation processes are central to resilience and capability building: How do we determine progress towards creating the most appropriate environment for innovation as a means for building resilience and capabilities for sustainable living?

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Theme D3: Options for greening the developmental state

Since 2002, the South African government has been formally committed to the strategic concept that a "developmental state" needs to be built in order to address both growth and poverty. The underlying dynamic at play was the gradual decline of (debt-driven) domestic consumption spending as a driver of growth and the need to replace it with public-sector-driven infrastructure investments. A related concern was to enlarge investments in pro-poor welfare and developmental benefits (such as housing delivery). For success, however, two conditions need to be met.

First, there is broad consensus that the contemporary developmental state needs to be different to the developmental state model of the state as the forceful centralised driver of modernisation, which emerged in Asia in the 1960s. The new view to be researched further is that the contemporary developmental state should focus on investments in social learning, knowledge development, research and development, and human capabilities if it is to equip the country for a globalised learning economy. Second, it is commonly accepted that building a carbon- and resource-intensive national infrastructure base could undercut South Africa's ability to compete in a global economy dominated by competitors that are adopting green economic policy frameworks, such as the USA, EU and the People's Republic of China.[6]

Research focus area

Research focused on the options for greening South Africa as a developmental state will address the following high-level question:

- Low-carbon, post-oil sustainable national and local economies: What are the various ways and best options, including policy frameworks, available to South Africa, to promote a developmental state that is committed to a sustainable economy that leads to the eradication of poverty and the resilience of social-ecological systems?

[6] The US President, Barak Obama, has referred on a number of occasions to the need for a Green New Deal. This refers to the strategy of making sure that public sector investments in infrastructure to counter the economic recession triggered by the 2008 financial crisis are coupled with the investments needed to counter global warming that were defined in the Stern Report commissioned by Gordon Brown. Examples include public transportation, renewable energy, waste recycling and energy-efficient construction. The green economy policy adopted by the European Union is very similar to the US Green New Deal, except that it envisages much greater regulatory interventions, e.g. specifying the maximum size of car engines or levels of waste recycling. China's 'circular economy' policy originated in concerns with the massive build-up of unrecycled waste and air pollution in Chinese cities. However, it has extended to include a commitment to decoupling and dematerialisation via the manipulation of the prices of primary resources. China is extremely worried about resource limits that could retard growth if production and consumption systems continue to be resource intensive and wastes remain unrecycled.

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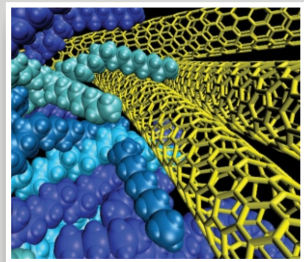
Theme D4: Technological innovation for sustainable social-ecological systems

This theme addresses the pragmatics of finding new technological pathways that address national strategic priorities and development goals through addressing global concerns such as climate-change mitigation and adaptation, the efficient use of resources (e.g. energy, water, materials and nutrients) and ecosystem degradation. This calls for holistic solutions that seek to reconnect the creative processes of humans and nature in technological systems that support the functioning, regeneration and evolution of the global social-ecological system. The emerging approaches in technological innovation for sustainability builds on a new domain of 'ecological technology' that uses nature and its processes as a root metaphor from which to generate new types of solutions.

There are three main overlapping streams of research that drive this agenda: ecological engineering, industrial ecology and biomimicry. Ecological engineering uses biological species and ecosystems to do the work (e.g. clearing pollution) that in an environmental/infrastructure engineering approach would have been done by mechanical means such as scrubbers, filters and chemical precipitators. Industrial ecology is the application of ecological theory to industrial systems or the ecological restructuring of industry to combine environment, economy and technology in such a way that the waste from one process becomes the input of another process. It can also be used to combine a number of technologies in different fields (e.g. renewable energy, waste water treatment, aquaculture and material science) in one integrated system, thus enabling new opportunities to emerge which increase the commercial viability of the individual technologies, as well as the scope of problems that can be addressed by these technologies. Biomimicry is described as "the conscious emulation of life's genius" to inform the development of materials, technologies and systems for facilitating flows (e.g. energy, water, waste, transport and communication systems). Biomimicry also explores effective and efficient spatial and structural forms, and methods for creating these forms, using nature as a functional model.



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Research focus areas

- Ecological engineering/industrial ecology approaches to providing municipal services (e.g. energy and potable water supply, storm water management, the collection and treatment of waste, and the 'harvesting' of resources such as energy, water, materials and nutrients) that would achieve multiple objectives of social development, ecosystem regeneration and climate change mitigation and adaptation.
- Developing the management/ control systems and business models for such approaches to the provision of municipal services and harvesting of resources.
- Developing novel 'ecological' technologies, systems of technologies and design solutions that respond to the pressures and problems introduced by global change, especially climate change.

Theme D5: Social learning for sustainability, adaptation, innovation and resilience.

Learning, and social learning in particular, is at the centre of the successful translation of research results in society. The scientific programmes proposed here may not achieve what is needed unless the knowledge developed within them can be appropriately translated and taken up in society – hence the significance of an underpinning research theme on social learning for sustainability, adaptation, innovation and resilience.

We already have substantive evidence in South African society that producing science does not necessary lead to social change (e.g. HIV/AIDS pandemic). Failures of science communication and/or knowledge brokering with regards to HIV/AIDS is increasingly recognised as being associated with inadequate social-learning expertise and research that is able to take account of the cultural and gendered power relations in society, and thus the uptake of scientific knowledge in society.

Education- and learning-system interventions are repeatedly criticised for being superficial and for not taking account of the socio-cultural context of human agency and social change. This science-policy-society problematic is also visible in the environmental/ global-change sector – despite knowledge of excessive CO_2 production and its projected impacts on economies, societies and critical ecosystems and ecosystem services (e.g. water and biodiversity), economies, politicians and the public are slow to respond. Consequently cutting-edge researchers in environmental education are now examining learning and learning systems from a socio-cultural perspective to find more appropriate approaches to

social-learning and learning-system development than past approaches to awareness creation have provided.

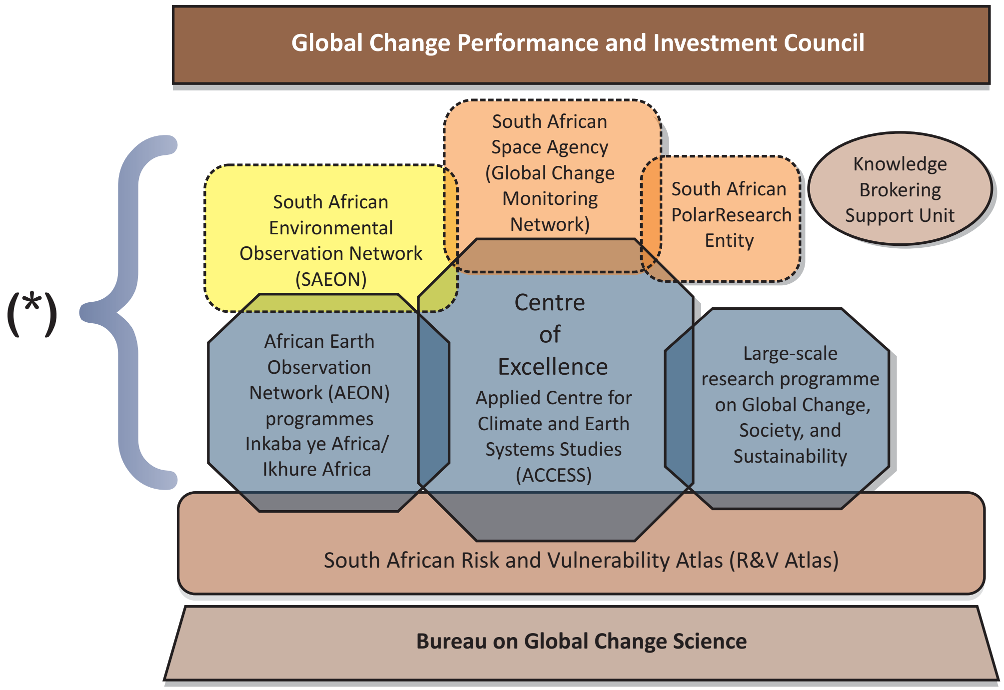
Education and learning systems need to be better prepared and oriented towards innovation and social change. In South Africa this is a critical priority for human development, given the history of the education and learning systems which are still plagued by issues of poor quality, inadequate resources, poor and inadequate teacher education, and 'outdated' epistemologies, modes of teaching and delivery in many higher education contexts. Environment- and climate-change education trajectories are employed both inside and outside of formal education boundaries, and learning systems for global-change responses are being developed in schools, colleges, universities, workplaces, communities, faith-based and other community-based organisations, and through new media technologies. This indicates that global-change learning-systems are *broad-based, and affect all sectors of society*.

A stronger emphasis on these sciences is particularly necessary because of the complex social, cultural and epistemological fabric of South African society and the complexities in its learning systems. There should not be an over-reliance on policy as mechanism for change.

Research focus area

Note that this theme is strongly cross-cutting. It asks that each underlying theme should address the question of "What kinds of social-learning processes and systems would be most effective for creating or enabling appropriate and effective responses to various societal problems brought about by, or contributing to, global change?”

4. IMPLEMENTING THE PLAN



The Global Change Grand Challenge will be coordinated and managed within the organisational framework depicted above.

4.1 The Research Core (*)

At the centre of the framework lie the institutions that focus on generating the scientific knowledge required to address the research questions defined in the research plan. The necessary capacity to undertake the work is developed through collaboration of the relevant scientific institutions and programmes.

4.2 The South African Risk and Vulnerability Atlas (RAVA)[7]

The RAVA is conceived and designed with the intent of providing up-to-date information for key sectors to support strategy development and decision-making in the areas of risk and vulnerability, helping to support South Africa's transition to a resilient future.

4.3 The Bureau on Global Change Science

The principal role of the Bureau is to achieve the desirable outcomes of the Global Change Grand Challenge Strategy. The establishment of the Bureau is an attempt to enhance policy making in the face of global change as a structure that will provide a forum for researchers and policy makers to jointly issue proposals and recommendations based on the latest science. Strong business participation on the Bureau will be important. The Bureau is tasked with providing strategic high-level guidance to policymakers and taking the lead in strengthening relationships between the various stakeholders who form part of the Global Change landscape. This is achieved through the implementation of the Science-Policy-Practice Strategy.

4.4 The Knowledge Brokering Support Unit

The Knowledge Brokering Support Unit is responsible for ensuring that the outputs of research activities can be practically implemented within the targeted stakeholder groups.

4.5 The Global Change Performance and Investment Council

The activities and associated investment within the Global Change Grand Challenge are reviewed and directed by a multi-disciplinary and inter-departmental committee, the so-called Global Change Performance and Investment Council. Chaired by the Director General of the DST, this Council meets once a year and has oversight of the return of investment across the range of activities being funded under the Global Change Grand Challenge.

[7] *Available at www.rvatlas.org*

4.6 Monitoring success

As seen in the previous section, the Global Change Performance and Investment Council has the responsibility of overseeing the performance of the implementation of the Global Change Grand Challenge.

Implementation progress is assessed based on an agreed-to performance scorecard consisting of a basket of key measures that relate to the aims and objectives of all components of the Global Change Grand Challenge Strategy. An annual report is published by the Bureau on Global Change Science.

The performance scorecard consists of the following categories of measures with the more specific metrics underpinning each category defined by the Global Change Performance and Investment Council:

- **Overall implementation progress.** A qualitative assessment based on solicited and unsolicited feedback from the targeted stakeholder groups. Examples of the criteria are the growth of critical mass in the scientific capacity in South Africa and the achievement of balance in the ratio of time commitment by senior researchers on research, management and stakeholder engagement.
- **Quality of Science & South Africa as a recognised International Science Destination.** A quantitative measure of progress, for example, the number of high-impact publications; the Rand value of international funding on collaborative Global Change research; and the number of international researchers working in southern Africa as recognition of the region as a Science Destination.
- **Impact on Education, Skills development & Transformation.** A quantitative and qualitative assessment of inter alia the development and growth of home-grown natural scientists; the emergence of a new generation of leaders in climate science; and the number and rate of growth of scientists in scarce skill areas.
- **Impact on Societal Needs (including Commerce & Policy).** Examples of the specific measurement criteria include the number and rate of increase of new knowledge-based jobs in southern Africa; the number of publications and knowledge products available and in use by policy makers and policy implementers; and the number of research results translated into technology demonstrators and used in policy processes.
- **Growth and sustainability of southern Africa-based research assets.**[8] Metrics include the Rand value of capital investment in scientific infrastructure specifically for global change science and innovation. Examples of assets include the existence, accessibility and quality of national spatial and non-spatial information via an efficient system that facilitates the curation, discovery, sharing, integration and interoperability of "living" national data sets; the existence and sustainability of a National High Performance Computing Facility for Earth System Science; and the existence and sustainability of a National Marine Research Fleet Facility.

[8]Assets include the National Skills Base (research competences, capabilities including capacity) and facilities, infrastructure and data available and accessible.

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