Observations on

ENVIRONMENTAL Change in South Africa

SECTION 1





Editor | LARRY ZIETSMAN

Table of Contents

ACKNOWLEDGEMENTS 1

FOREWORD 2

INTRODUCTION 5

SECTION 1 – PEOPLE AND ENVIRONMENTAL CHANGE 9

Introduction 11

Human population trends in South Africa 12

Drivers of natural resource use by rural households in the Central Lowveld 17

Environmental change in Bushbuckridge 20

Living with drought: Adaptation, alleviation and monitoring 26

Climate change: Risks, adaptation and sustainability 36

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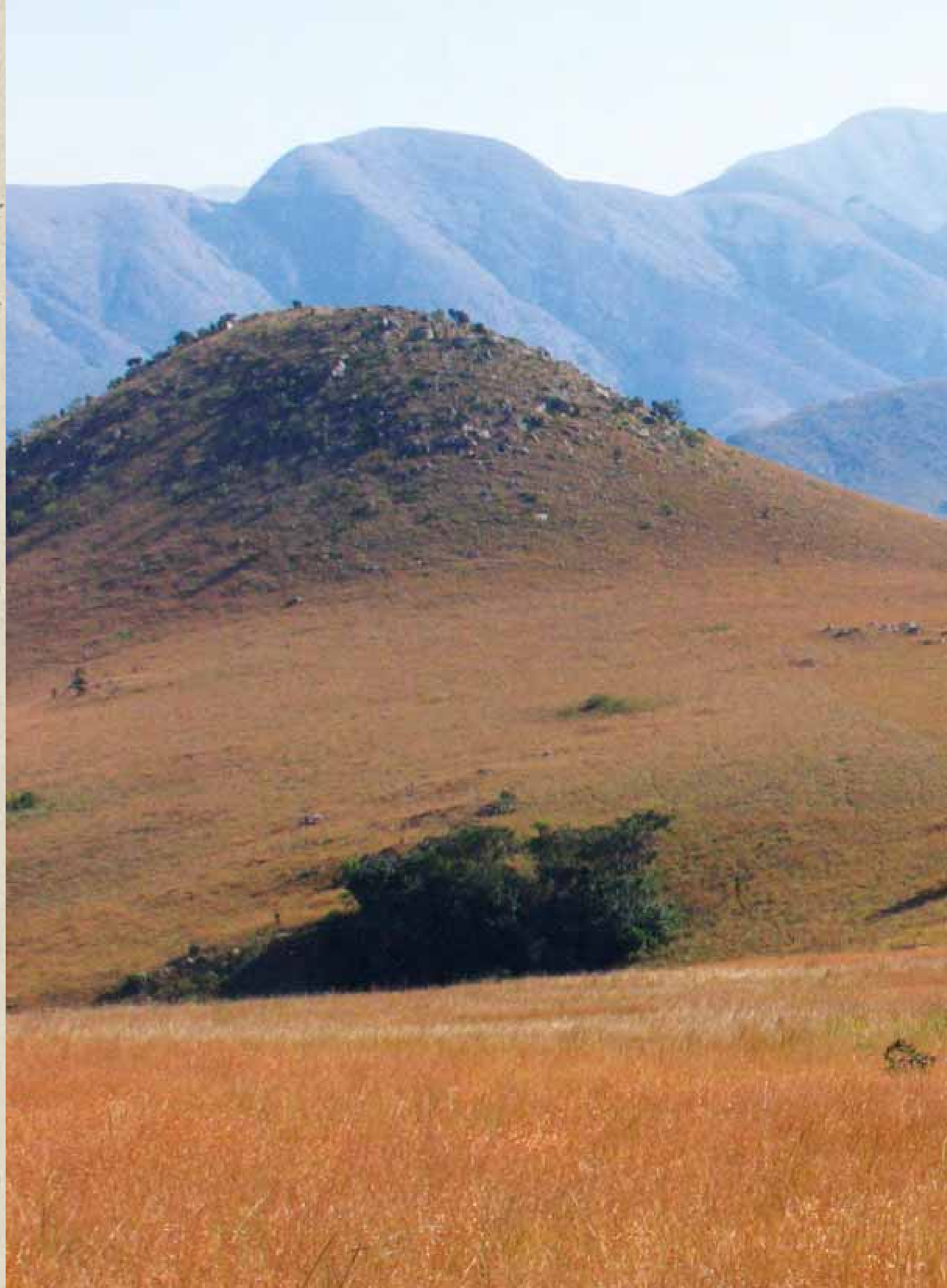
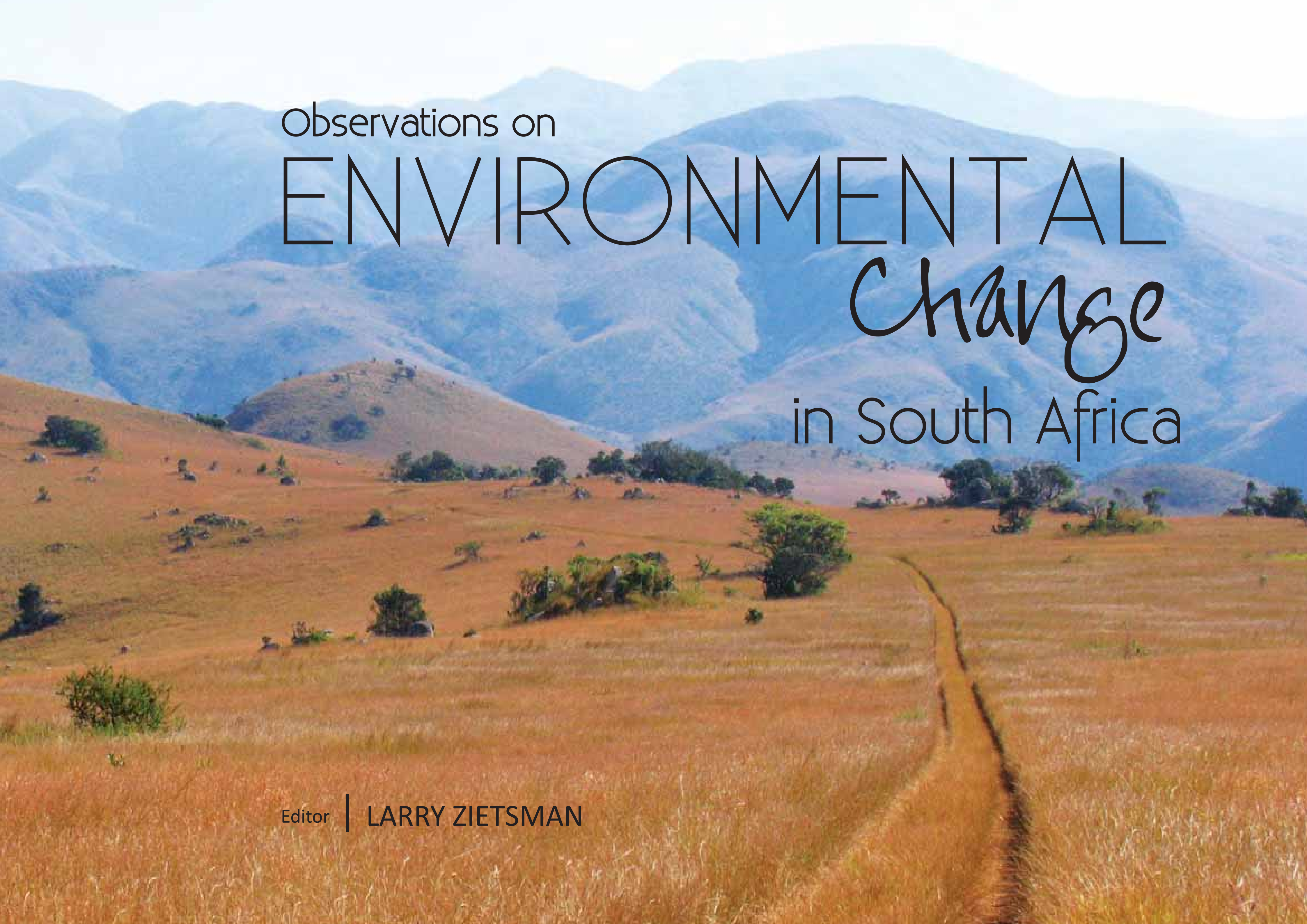
RIGHT Grasslands [Barend Erasmus]





Observations on ENVIRONMENTAL Change in South Africa

Editor | LARRY ZIETSMAN

Editorial Committee

RIGHT African Reed Frog [Barend Erasmus]

The mandate of the South African Environmental Observation Network (SAEON) is to establish and maintain state-of-the-art observation and monitoring sites and systems; drive and facilitate research on long-term change of South Africa's terrestrial biomes, coastal and marine ecosystems; develop and maintain collections of accurate, consistent and reliable long-term environmental databases; promote access to data for research and/or informed decision making; and contribute to capacity building and education in environmental sciences. Its vision is: A comprehensive, sustained, coordinated and responsive South African environmental observation network that delivers long-term reliable data for scientific research, and informs decision-making for a knowledge society and improved quality of life. SAEON's scientific design is adaptively refined to be responsive to emerging environmental issues and corresponds largely with the societal benefit areas of the intergovernmental Group on Earth Observations (GEO).

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The vision of the Department of Science and Technology (DST) is to create a prosperous society that derives enduring and equitable benefits from science and technology. Our mission is to develop, coordinate and manage a national system of innovation that will bring about maximum human capital, sustainable economic growth and improved quality of life.

We are guided by the corporate values of professionalism and competence. We will strive to deliver top-class, quality products and services, seek innovative ways to solve problems and enhance effectiveness and efficiency.

The DST strives toward introducing measures that put science and technology to work to make an impact on growth and development in a sustainable manner in areas that matter to all the people of South Africa.

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Acknowledgements

The idea for this book came from Albert van Jaarsveld. He discussed the possibility of a 'coffee table book' showing 'before and after' images of environmental changes in South Africa with Johan Pauw, who saw the relevance and necessity for such a book and its value for promoting the work of the South African Environmental Observation Network (SAEON), especially amongst politicians and decision makers, who by the nature of their work may not have much time to delve into the intricacies of scientific papers on environmental change, but need to advance sustainable policies for development. Together with Konrad Wessels, they developed the idea and approached me to act as project co-coordinator and to test the feasibility of the idea and set out a proposed table of content. Together we drafted a document listing broad topics or themes to be addressed and then went about listing potential contributors from the scientific and research community in South Africa. I then drafted a document formulating the goals that we would like to achieve and the approach to be followed by contributors to the proposed book. The potential authors were contacted and invited to participate in writing a book on 'Earth observation and environmental change in South Africa'. The scientific and research community responded positively to the idea and a set of guidelines were sent to those willing to contribute to this publication. These authors sent in proposed titles and abstracts of what they had in mind. Their submissions were evaluated and most were accepted for inclusion. The vast majority of these authors honoured their commitments and submitted their full texts within a reasonable timeframe. A tentative table of contents was drawn up and circulated. Valuable inputs, especially from Sue Milton, led to a revised, restructured and reordered table of content very similar to the final version. Barend Erasmus, Charles Griffiths, Lauri Laakso, Johann Lutjeharms, Matlala Moloko, Sue Milton, André Theron, Rudie van Aarde, Brian van Wilgen and Alan Whitfield generously supplied supplementary photographs.

The book that has materialised from this process is probably not quite what Albert van Jaarsveld had in mind. It took on a life of its own, in spite of my best efforts to keep it in line with out initial intentions! Although every effort was made to ensure that it would be '... an attractive, richly illustrated and easily readable book on the causes consequences and responses to environmental changes in South Africa', its scientific nature became much more prominent. We now have a publication '... conveying scientific evidence based on local case studies using examples to graphically illustrate these trends and impacts with a variety of satellite imagery, photo's, maps and other illustrative materials.'

The book gives a picture of environmental change and proposed responses on a range of themes and topics. It draws together work from as many scientific disciplines as possible, extracts the most pertinent information and presents it in a condensed format. As such this book should be very useful to inform the general public and senior political and public executive officials involved in policy formulation and decision making on environmental issues and implications of policies as initially intended. However, it will undoubtedly also be of value to lecturers and students at institutions of higher education.

I would like to acknowledge the time and efforts of all the authors and co-authors who graciously contributed their work without remuneration in the interests of science and our fragile environment. I also thank the editorial committee (Johan Pauw, Albert van Jaarsveld and Konrad Wessels) for their foresight, confidence and support in helping to bring this publication to fruition.

Hendrik L Zietsman
Editor
December, 2010

Foreword

Mrs G.N.M. Pandor, MP

South Africa has a rich history of scientific excellence and of undertaking pioneering work in the environmental sciences. This richly illustrated publication is yet another valuable contribution to that heritage. According to a report by Thomson Reuters, between 2004 and 2008 South Africa ranked above average in the scientific fields of Environment and Ecology, contributing 1,29% of world output, with a citation rate averaging above 5 per paper.

South Africa can also be proud of its strong tradition of exploiting scientific knowledge to support effective policy and practice in sustainable development. Supported by my department, the South African Environmental Observation Network (SAEON) emerged from that tradition to establish six strategic nodes that jointly cover South Africa and its adjacent oceans. These nodes function as observation systems and platforms that enable the environmental sciences community to perform longitudinal studies of environmental change, and ultimately to support sustainable development objectives. This work has made a valuable contribution to science-based initiatives such as the Southern African Millennium Ecosystem Assessment in identifying possibilities for improving human wellbeing, taking into account the capacity of ecosystem services to support these improvements.

South Africa continues to face crucial social and economic challenges. A set of 12 priority outcomes has been identified for focused attention over the next few years. Effective management of our natural environment and assets is not only a key outcome in its own right, but also has an important contribution to make in supporting outcomes such as a long and healthy life for all South Africans, food security for all, and sustainable human settlements.

The natural environment is a complex system with many interconnected strands. A range of human pressures combine with natural processes resulting in many and varied impacts and responses. Science investments are vital for the development of a knowledge base that can assist decision-makers to make sense of the complexity and to respond through policy measures and interventions. Science investments range from the development of long-term environmental observation capabilities, the effective integration of new and existing datasets and the initiation of longitudinal studies, to ensuring maximum exploitation of the data through appropriate knowledge products such as forecasts, early warning systems and impact maps.

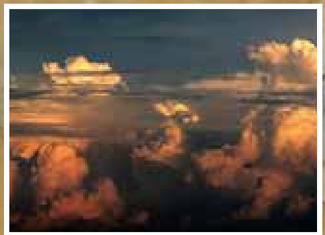
Notwithstanding the strong foundation in environmental observation and research that already exists in South Africa, the Department of Science and Technology continues to prioritise this area for further development and investment within the context of its Innovation Plan. For example, we have committed to the development of satellites that will provide fine resolution and space-based data that we can exploit for areas ranging from environmental management to early warning systems for better disaster management.

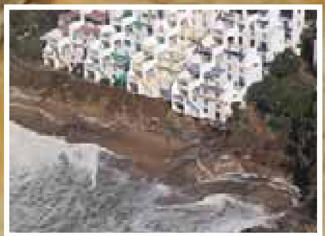
Over the next 10 years, through the Space Science Grand Challenge, we will be investing in satellites as well as supporting infrastructure that will constitute a stronger earth observation system. Coupled to these efforts are a range of other initiatives, under the umbrella of the Global Change Grand Challenge, which will support analysis and research on the basis of the available observation data sets as well as building a new generation of skilled scientists and practitioners.

I would like to take this opportunity to congratulate the National Research Foundation, SAEON and the many scientists who contributed their time and expertise to this publication and to the work being done to maintain and strengthen our environmental science heritage.

More importantly, I would like to acknowledge the attempts being made to enhance the accessibility of complex and technical scientific material in ways that empower all sections of society.

Mrs G.N.M. Pandor, MP
Minister of Science and Technology
December, 2010





Introduction

Johan C. Pauw
Hendrik L. Zietsman
Albert S. van Jaarsveld
Konrad J. Wessels

Environmental conditions on earth are changing rapidly. The degree to which these changes are human-induced could be debated, but the fact that changes are taking place is indisputable. As custodians of finite natural resources we do not have the luxury of being complacent. This highly illustrative book provides a glimpse into the environmental changes that have been observed. It is not a compendium of all changes, as that would require numerous volumes. The book highlights some pertinent aspects of environmental change and introduces ways in which satellite technologies and other observation systems are used to measure and monitor some of these changes. In many cases, the book describes the principle problems and discusses why these issues are considered problematic. The book also describes the main drivers of these changes, how the environment is responding, and how these problems can be solved. In addition, the book outlines the potential consequences of failing to act.

Why a book about environmental change in South Africa?

The key understanding that the reader will gain from reading this book is that scientific observation of environmental change is ubiquitous in South Africa and that these changes are progressively affecting the future of South Africans through their combined impacts on human livelihoods, security and prosperity. A conscious effort is made to distinguish 'environmental change' from 'natural environmental variability' in order to determine if the root causes of environmental change may be considered attributable to human activity. Natural environmental variability is normally of a periodic nature whereas environmental change can be experienced as a directional trend; either gradual or drastic, but with a high probability of being irreversible.

From the above, it follows that both the public and private sectors should rapidly mainstream environmental considerations and trends into their policy making, strategic planning, operations and market positioning. Consequently, the primary audiences for this book are decision makers and advisors at all levels of society, from government to civil society. The purpose is to provide them with a snapshot of pertinent scientific evidence to assist them in formulating intelligent and responsible policies and practices for the betterment of our society and to ensure the long-term futures of South Africans. Yet, the scope, breadth and depth of subject matter covered also renders this text useful reading for teaching and for further studies in related disciplines.

Making sense of environmental complexity

The natural environment is often illustrated as a spider's web consisting of interconnected strands. Although each strand is fragile on its own, the intricate and beautiful web structure provides it with resilience against external forces. Similarly, global-scale earth systems (i.e. biogeochemical cycles of the atmosphere, oceans and land) can be viewed as nested and multi-scaled ecosystems integrated through interactive processes. These systems are systemically afflicted by natural and human forces that act at multiple scales.

Amidst the obvious complexity of ecosystem studies, a standardised conceptual model of ecosystem function has emerged over time. This model was adopted by the United Nations Commission on Sustainable Development in 1995 and forms the basis of most state of environment reports, including those from South Africa [1]. The model is called the Driver-Pressure-State-Impact-Response (DPSIR) model (See Figure A) and it forms a golden thread that permeates the work presented in this book.

Batho Pele

Batho Pele – 'People First' – is the well-known slogan of the South African Government. It is therefore appropriate that the opening section of this book addresses issues of 'People and Environmental Change'. The subsequent chapters describe a variety of pertinent environmental issues grouped into broad large-scale ecosystem topics spanning the atmosphere to the oceans. The book ends with a concluding chapter.

South Africans, across the board, are dependent on these vital life-supporting systems and what is presented should serve as a reality check about the status of these systems. From our understanding of environmental change, people are collectively and rapidly transforming the environment for short-term economic and lifestyle gains, whether by choice or purely in order to survive. Yet, it should be clear that the longer-term impacts of irreversible environmental change will undermine the quality of human livelihoods and may compromise the essential life-support benefits derived from ecosystem services. In most instances, due to disparate access to resources, services, education and infrastructure, it must be anticipated that environmental justice and equality will suffer in the face of environmental change.

Environmental change is a global concern and requires ongoing observation, interpretation and responses from South African government and civil society. This book is therefore a bona fide 'science for society' contribution.

The GEO-4 CONCEPTUAL FRAMEWORK

The GEO-4 conceptual framework (Figure A) enhances our understanding of the relationships between the environment and development and how these affect human well-being and vulnerability. The main components of the framework are 'Drivers', 'Pressures', 'States', 'Impacts' and 'Responses'.

'Drivers' or driving forces are the fundamental processes in societies that motivate certain decisions and activities which lead to changes in the environment. Examples of drivers include demographic, economic, technological, institutional and political patterns and systems.

'Pressures' emanate from emissions, waste, inputs, modifications, extractions and other activities that lead to environmental change. Examples are pollutants, fertilisers, irrigation, resource extraction, deforestation and land-use changes.

'State' includes trends and pertains to natural conditions and induced changes in the environment. These changes are often linked in subtle ways, so that changes in one part of the system lead to changes in another part. Examples of natural processes are those that operate in the physical, chemical and biological systems. These are monitored by measuring levels, concentrations, compositions and movements such as solar radiation, temperature, moisture, gasses, chemicals, land use, species and services.

'Impacts' are the effects that these environmental changes have on human well-being, social and economic sectors or environmental services, whether negative or positive.

'Responses' refer to the policies, legislation, regulations, programmes and projects undertaken to reduce human or natural vulnerability, reduce or mitigate negative effects, or strengthen positive consequences to environmental change.

The conceptual framework also shows that these components are interrelated, scale and location dependant and operate differently at different scales (local, regional and global), in different geographical and social contexts.

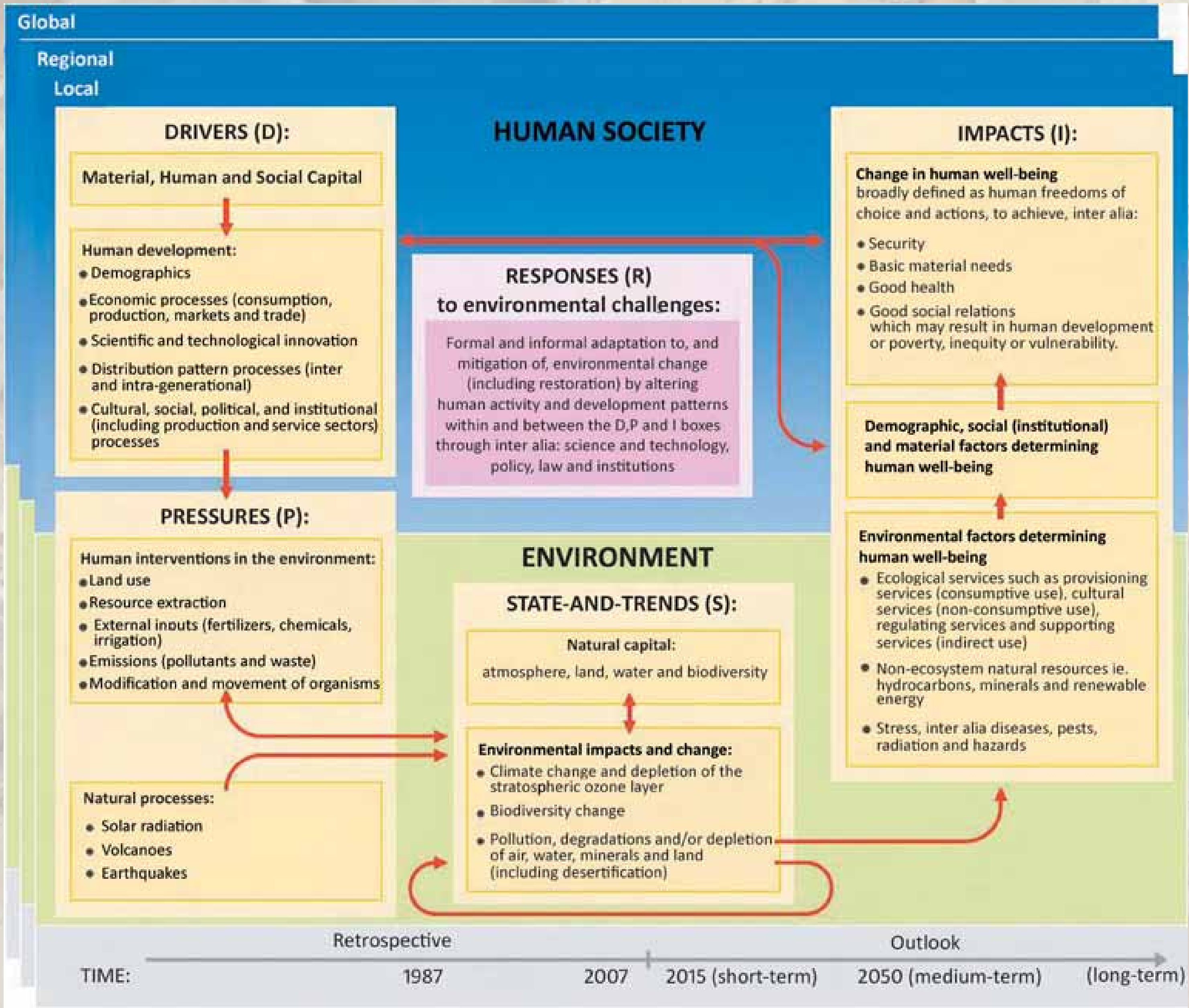


Figure A GEO-4 DPSIR conceptual framework. [Reproduced with permission from the United Nations Environment Programme. Global Environment Outlook – environment for development (GEO-4 Report, 2007). United Nations Environment Programme: New York]

Extensive non-sustainable low-density urban residential development in Maun, Botswana. [Barend Erasmus]

SECTION 1 People and Environmental Change

Introduction

Coleen Vogel

Environmental changes often exhibit the interactions between people (for example, social 'drivers or causes' of change) and the environment (for example, resource utilisation and wider, biophysical factors such as climate variability and change). People can impact the environment in complex, non-linear ways. Population pressure, for example, could result in various responses including different types of migration of people to alternative environments. Such interactions, however, are not only negative but can also result in improved environments, enhanced livelihoods and overall well-being.

Chapters in this section reflect on such complex interactions and show how changes in environmental resource use and climate can impact on environmental and social well-being which then feeds back into the environment driving another chain of reactions and changes.

Various causes are probed and found to explain environmental change. Land use changes, for example in the Lowveld areas of South Africa and in the former homeland areas, are shown to be shaped and driven by various biophysical and social factors. Dramatic and clear 'footprints' of settlement expansion and land are detectable in some cases as areas with decreased woodland.

However, no singular driving factor can be used to explain such changes. Poverty, often cited as a key driver of change and a cause of resource degradation in some areas, is shown in some cases to be only one of the factors driving environmental change. Wealthier rural households are also shown to have a particular and distinctive environmental footprint. They use a wide range of natural resources, including luxury products such as bush meat. Gender also plays a role in environmental resource use and preference of resources used to sustain livelihoods (for example, females make more use of fuel wood whereas males make use of wood for construction purposes). Households also use natural resources to help buffer them against natural and other shocks, such as the loss of a household member to HIV and AIDS. This further increases environmental resource use. Socio-economic policies, together with the influence of past and current institutions and management policies interact to shape the environment in various ways, often producing distinctive 'cultural' landscapes in the region.

It is also argued that climate change, when considered together with such factors of environmental change, shapes change in noticeable ways. This is already happening and is expected to continue to happen in the future. Climate change, together with environmental change, may reduce the overall resilience of such landscapes and peoples. Changes induced by extreme events, as well as by daily incremental changes in climate and weather, are shown to have a range of impacts. These impacts and resultant losses are often costly, particularly when coupled to other factors driving vulnerability in a place.

Finally, the chapters in this section show that because of these emerging interactions a range of complex responses are required if environmental sustainability is to be ensured. Such responses may require various monitoring activities as well as a range of adaptations and responses including response-farming technologies, water conservation practices and rethinking the design of local and formal institutions (for example, early warning systems). Societies are, however, not mere passive victims and the chapters provide several examples that show how people could adapt and in certain cases are already adapting to such complex environmental changes.

LEFT Township development transforming natural landscapes into cultural landscapes, Vosloorus. [Chris Kirchoff, MediaClubSouthAfrica.com]

Human population trends in South Africa

Pieter C. Kok
Louis van Tonder

For several decades the worldwide demographic divide has been widening with 'little growth or even decline in most wealthy countries and continued rapid population growth in the world's poorest countries' [1]. In the case of South Africa, the growth rate of the population is declining but its size continues to increase, especially in urban areas. This chapter investigates the nature, trends and extent of this growth and its main drivers (natural increase and migration). The chapter concludes by discussing some environmental implications of the country's population growth.

Introduction

South Africa, which is classified by the World Bank as an 'upper-middle-income economy', has Africa's largest economy. The country covers only one-twentieth (5%) of sub-Saharan Africa's total surface area, yet in 2007, while containing only 6% of its population, it contributed a third (33%) of that region's total GDP (in current US$). Sub-Saharan Africa's economy has grown faster in recent years than in the 1990s (at 4,7% a year between 2000 and 2006, compared to 2,5% a year during the 1990-2000 period), but the [region's] loss of natural resources has also accelerated. With 64% of its population still living in rural areas – and rural population growing at 1,9% p.a. – slush and burn agriculture continues to take its toll. Forests are shrinking at an alarming rate of 7% each decade (based on 1990-2005 estimates), and it is drawing down its energy and mineral resources as well [2]. Furthermore, while the per capita carbon dioxide emissions in sub-Saharan Africa were 0,9 metric tons in 2004, the emissions generated by South Africa were 9,4 metric tons per capita in that year – by far the highest in the region [2].

So what is it about South Africa's situation that we need to consider here? Firstly, we need to look at the nature, trends and extent of the growth of its population. Then we need to investigate the main drivers and spatial distribution of this growth. Finally we should consider some of the environmental implications of South Africa's population growth.

Population growth

Figure 1.1 shows the growth of South Africa's total, urban and rural population from about the beginning of the 20th century up to 2007. Note that the overall population figures for 1980, 1985, 1991 and 2007 are based on estimates. For the census years during the period 1980-1991 the estimates are based on interpolations. This is because the South African censuses excluded the former homelands of Transkei, Bophuthatswana, Venda and Ciskei. For 2007 they are based on the StatsSA medium variant midyear population estimates for 2008 [3]. The urban/rural population estimates for 2001 are based on the outcome of the procedure described by Kok and Collinson [4], and those for 2007 are based on extrapolations from 2001.

Figure 1.1 shows that South Africa's urban population became dominant somewhere in the 1980s and has been growing faster than the rural population ever since the 1950s. The growth rate of the total population is declining compared to the 1970s but its size continues to increase, especially in urban areas. In fact, according to the United Nations [5], the rural population of South Africa may currently already be experiencing negative growth – a possibility that would indicate even more rapid growth of the urban population than that depicted in the graph.

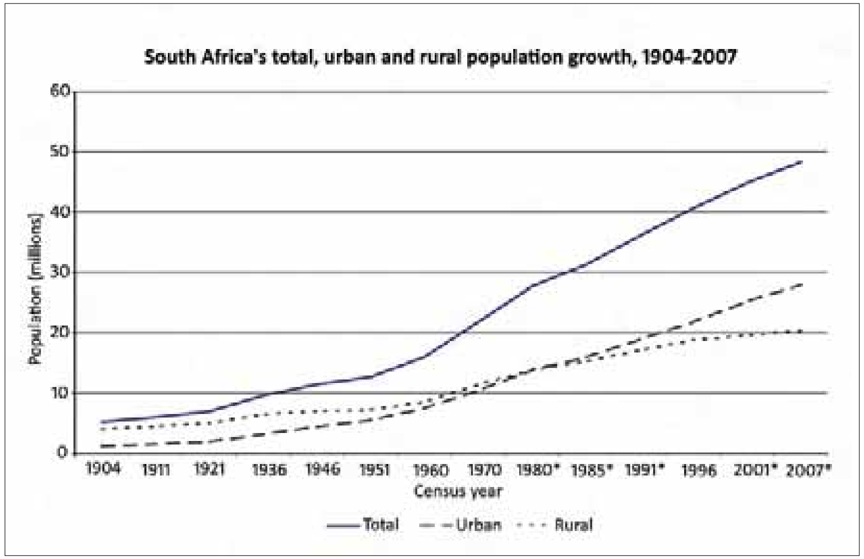


Figure 1.1 South Africa's total, urban and rural population growth (1904-2007).
*Some of the population figures for these census years have been estimated.

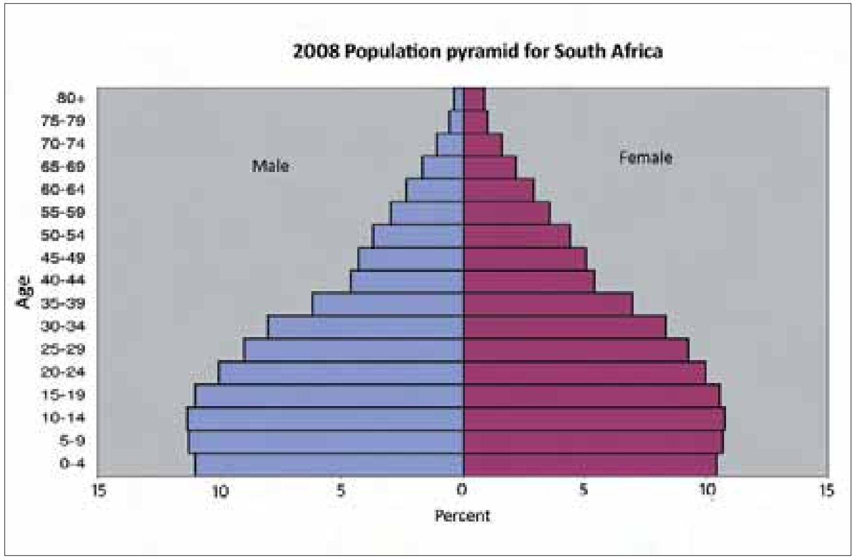


Figure 1.2 South Africa's gender and age distributions (2008).

Population projections

Looking into the future, it is clear that South Africa's current youthful population structure (see Figure 1.2) will inevitably lead to further overall growth in coming years. The United Nations [6] has recently published long-term population projections for, amongst others, South Africa, that show that this country's population can be expected to grow from approximately 50,5 million in 2010 to an estimated 56,8 million in 2050, using the medium variant. While perhaps slightly too high, this translates into an average growth rate of 0,29% per annum over the coming 40 years. It is important to note that most of this growth will take place in the age categories 15-64 years (0,39% p.a.) and especially among those being 65 years or older (2,21% p.a.). In fact, the population sizes of the younger age categories are expected to decline. Figures 1.3 and 1.4 on the next page should aptly illustrate the points made here.

Figures 1.3 and 1.4 clearly show the expected population declines in the 0-4 and 5-14 years age categories. This indicates a continued future decline in the overall population growth rate. As you will see in the graphs, the opposite applies to the older age categories, 15-64 and 65+ years. The sharp expected increase in the top age category is particularly noteworthy (see Figure 1.6). The expected ageing of the population is also reflected by the UN projections that indicate the median (middle) age of the South African population increasing from 24,7 in 2009 to 31,9 in 2050 [6].

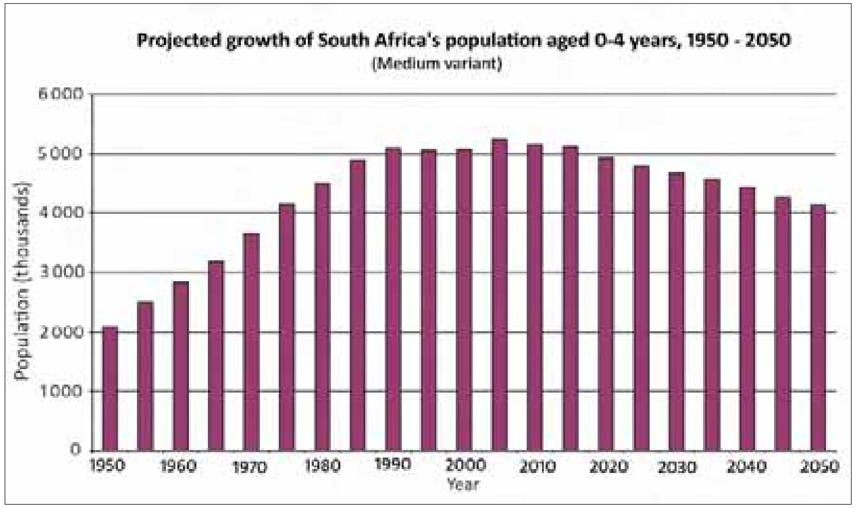


Figure 1.3 Projected growth of South Africa's population aged 0-4 years (1950-2050) [United Nations, 2009].

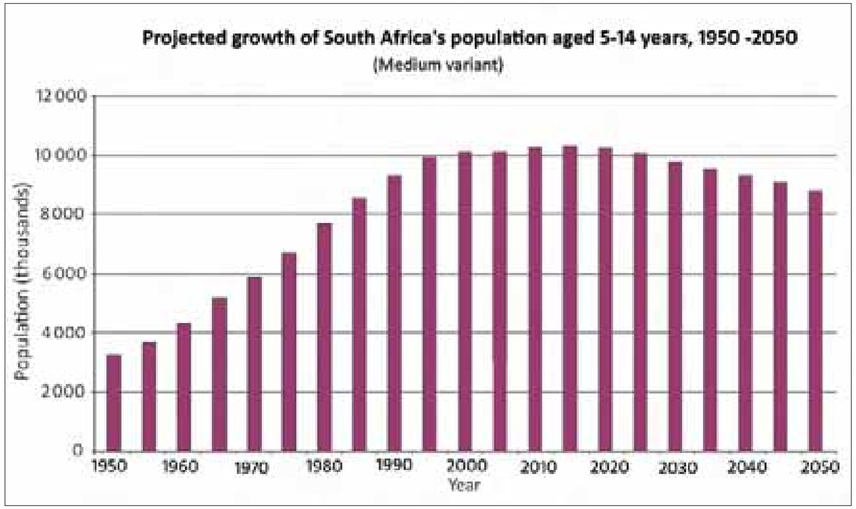


Figure 1.4 Projected growth of South Africa's population aged 5-14 years (1950-2050) [United Nations, 2009].

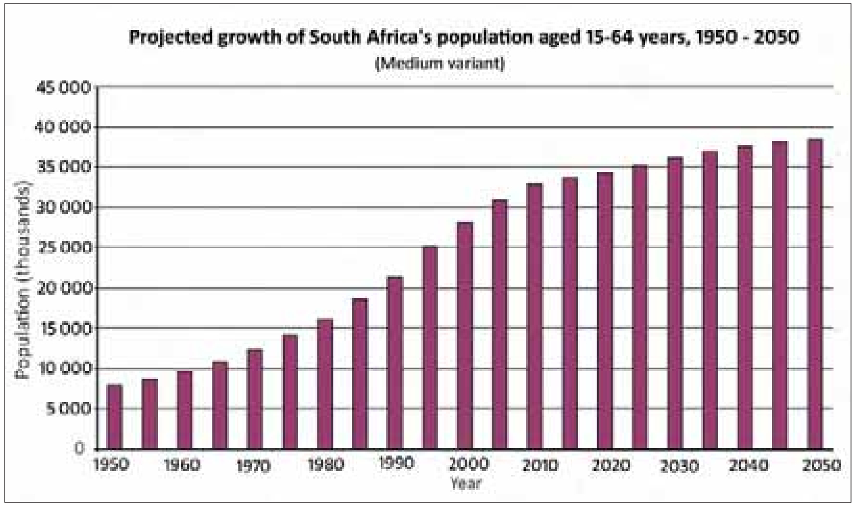


Figure 1.5 Projected growth of South Africa's population aged 15-64 years (1950-2050) [United Nations, 2009].

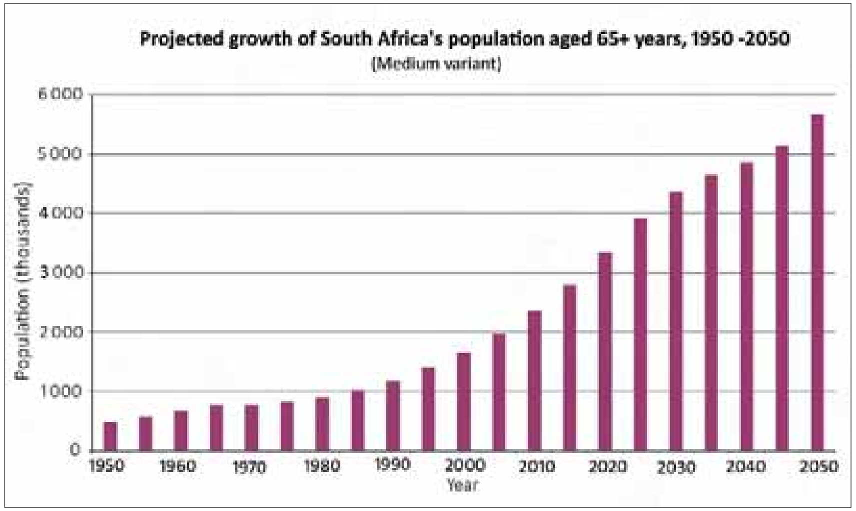


Figure 1.6 Projected growth of South Africa's population aged 65+ years (1950-2050) [United Nations, 2009].

Population growth components

What drives this expected growth scenario? The main component is natural increase (births minus deaths). The analyses by the United Nations [6] show that although total fertility (essentially the average number of children per woman[1]) in South Africa is expected to decline from 2,42 during the period 2010-2015 to 1,85 in 2045-2050, births will remain to be the most important contributor to population growth because of declining mortality. It is particularly the expected decline in child and infant mortality[2], the latter from 37,3 per 1 000 live births in 2010-2015 to 18,0 in 2045-2050, that is noteworthy in this regard. South Africa's life expectancy at birth[3] for both sexes combined is therefore expected to increase from 52,9 years during 2010-2015 to 62,3 years in the period 2045-2050. This increase is mainly due to an expected decline in HIV prevalence from 18,8% in 2009 to 16,4% in 2025 [6].

Secondary to but far more volatile than natural increase are the component of population growth known as the level of net migration (immigration minus emigration). This volatility is illustrated clearly in the United Nation's [7] estimated net migration rates for South Africa over five-year periods between 1950 and 2050 (see Figure 1.7). The unpredictability of future net migration should be evident from the past instability that was actually observed between the early 1950s and late 1990s. A further major problem with current net migration estimates – let alone forecasts – is that the number of undocumented migrants in a country is never known. People illegally in a country do not provide information on their past whereabouts, making it very difficult to 'count the uncountable'. International migration to and from South Africa therefore remains an unknown quantity, with the curve depicted in Figure 1.7 representing a mere guesstimate.

1 The formal definition provided by United Nations [6] is as follows: 'The average number of children a hypothetical cohort of women would have at the end of their reproductive period if they were subject during their whole lives to the fertility rates of a given period and if they were not subject to mortality'.

2 Infant mortality is the probability of a baby dying between birth and the exact age of one year [6].

3 Life expectancy denotes 'the average number of years of life expected by a hypothetical cohort of individuals who would be subject during all their lives to the mortality rates of a given period' [6].

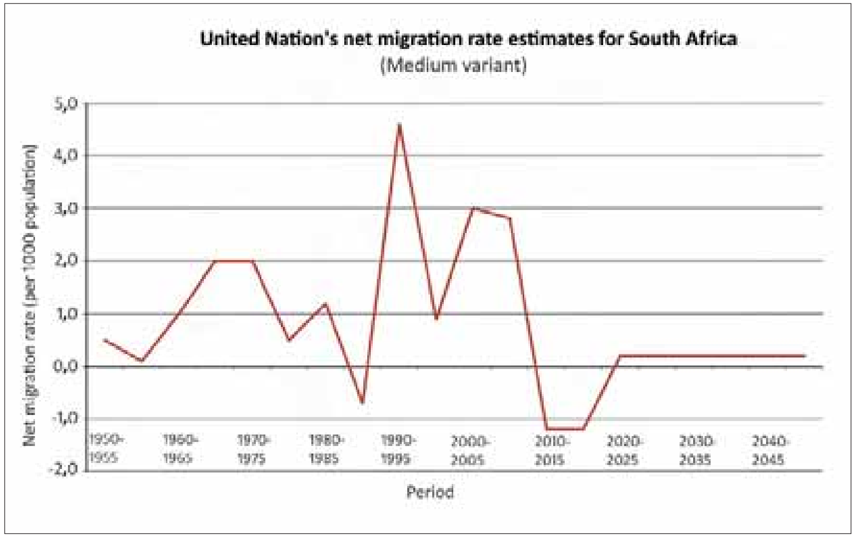


Figure 1.7 United Nations' net migration rate estimates for South Africa [United Nations, 2009: Panel 2 detailed data].

Population and environment interface

Population numbers can have important negative effects on the environment, as in the case where increasing numbers of people lead to the depletion of natural resources and other manifestations of environmental degradation. An example of this is the deforestation or even desertification from the continual felling of trees to make room for development or to obtain firewood. However, at the same time, environmental conditions, and especially changes in the environment, such as climate change, can sometimes have crucial impacts on the population.

Migration, in particular, provides a key example of the population-environment nexus and the linkages between migration and climate change have recently begun to receive a great deal of research attention [8-10]. Implied in many of these studies is the assumption that migrants leaving areas of severe environmental conditions have very few options but to move. Graeme Hugo [11] puts this assumption into a proper perspective by suggesting that population mobility is best viewed along a continuum of causal factors from 'totally voluntary' migration, where choice and will are the decisive elements on the one extreme, to 'totally forced' migration at the other extreme, 'where the migrants are faced with death if they remain in their present place of residence'.

Four types of 'environmental migration' have been identified [11], namely, migration that is (a) suddenly induced by environmental disasters, (b) caused more gradually by environmental degradation, (c) brought about by climate change over time, and (d) forced by environmental change that is caused by large-scale ('mega') projects. The demographic impacts of these causal environmental factors vary. Hugo indicates that environmental disasters have so far caused many people to leave their places of residence.[4] Particular ecosystems, especially in less developed countries, are especially vulnerable to environmental degradation and subsequent environmentally induced out-migration. There have been various estimates of the expected impact of climate change factors alone (see Box 1.1), but Hugo correctly warns, 'all of these estimates have little empirical basis but gain a totally unwarranted credibility with repetition' [11:31]. Displacement by large projects, especially dam construction, has become quite common, especially in less developed countries 'where there are escalating demands for electricity and water associated with rapid urbanization' [11:41].

People at risk of SLR by 2050: 162 million [13]
People at risk of droughts and other climate change events by 2050: 50 million [13]
People potentially at-risk of being displaced because of desertification: 135 million [14]
Number of people who have fled because of floods, famine and other environmental disasters: approximately 24 million [15:12]
Environmentally displaced people by 2010: 50 million [16]
Refugees due to climate change by 2050: 250 million [Christian Aid in 17]
People estimated to become permanently displaced 'climate refugees' by 2050: 200 million [18]

Box 1.1 Some estimates of environmentally-displaced population due to climate change impacts [12:6].

4 Arguably the largest of these was the Asian Tsunami of December 2004 that reportedly killed 298 055 people in 12 Asian and African countries abutting the Indian Ocean. It left about 5 million people in need for immediate assistance [UNHCR 2006, 11:21].

As Hugo [11:43] correctly confirms, ' … the causality can also be in the other direction'. He shows that refugee flows and other 'mass migrations can both exacerbate existing environmental problems and create new degradation issues'. He hastens to point out, though, 'all the impacts of mass influxes of groups like refugees are not negative' [11:44]. While migration can and does have negative environmental consequences, migration is often a scapegoat for problems such as environmental degradation, which, in fact, are caused more by 'a failure to adopt sustainable policies of land and other resource use in the destination areas' [11:45-46]. Furthermore, the area of environment and migration is often replete with 'unsubstantiated exaggerations on the numbers of environmental migrants' [11:49]).

In the case of South Africa, the redistribution of its population, especially through rural-to-urban migration but also rural non-migration, causes some environmental strains. At the urban end of the spectrum the development of informal settlements to cater for a growing population that is not housed in formal accommodation and the absence of services, such as electricity and sanitation, creates not only unsightly and unhealthy housing conditions but also environmental pollution. At the rural end one finds a depletion of natural resources such as trees because of the inability of the unattended environment to cope with the large, often very poor and immobile population. Rural-urban migration can therefore have both negative and positive consequences.

Conclusions

The relationship between population and the environment is not linear (as in 'more people create more environmental problems') and is consequently far more complex than is sometimes expected. It should thus not be a matter of blaming population growth for the environmental problems being experienced but we should also look at mining, industry and transportation, as well as inadequate environmental control, for some of the causes.

Drivers of natural resource use by rural households in the Central Lowveld

WAYNE TWINE

The former-homelands of the Central Lowveld can be thought of as modern cultural landscapes which are shaped by complex interactions between society and the natural environment. Because humans are key drivers of environmental change in such landscapes, it is important to understand the patterns of local resource use as well as the drivers that shape these. This chapter draws together a wealth of research on the region to investigate the drivers, at various levels, of environmental change in the Central Lowveld, focussing on resource harvesting.

Introduction

There has been dramatic environmental change in the former-homelands (Gazankulu and Lebowa) of the Central Lowveld over the last four decades [1]. Resource harvesting, heavy grazing pressure and shifting cultivation have resulted in changes in the composition and structure of the landscape, ecological communities and species populations (Figure 1.8) [1-6]. Nevertheless, these ecosystems are highly resilient [7] and still harbour a surprising diversity of plant and animal species [8, 9]. On balance, it seems that these are unique ecosystems in their own right, but that sustainability is under threat for particular components of biodiversity under particular circumstances. An adequate understanding of environmental change in this context must be underpinned by an understanding of the pressures being placed on the environment and the factors driving them.

Local extent of resource harvesting

Most rural households in the Lowveld rely on land-based livelihood strategies to supplement their cash income from sources such as migrant labour and social grants [10]. Until relatively recently, most scientific attention focussed on agriculture in this context, and the value and extent of natural resource harvesting was largely unappreciated. However, while an average of 71% of local households cultivate crops in fields [1, 11, 12] and roughly 43% and 37% own goats and cattle respectively [1, 13, 14], over 90% use locally harvested indigenous natural resources to some extent (Table 1.1). User households consume an average of 4 465 kg of fuelwood, 106 kg of wild fruit and 94 kg of edible wild herbs per year [13, 15-17]. These resources are used to meet domestic needs, save money, and generate income, thus serving as a livelihood 'safety net' [18]. However, resource use is not uniform and is shaped by a range of drivers at various scales reviewed in the following sections.

Figure 1.8 A cultural landscape in a former-homeland of the Central Lowveld. [Wayne Twine]

Table 1.1 Prevalence of household use of indigenous natural products in the Central Lowveld, averaged across three studies.

Natural resource	Percentage of households (%)
Wooden utensils	99
Twig hand brooms	98
Fuelwood	95
Edible herbs	94
Grass hand brooms	91
Edible insects	82
Wild fruit	74
Reed mats	61
Fence poles	56
Medicinal plants	45
Housing poles	43
Thatching grass	40
Bushmeat	40

Sources [13, 16, 17]

Drivers of resource use

Regional level and beyond

The region is characterised by closely packed villages and high human densities. This is a legacy of the creation of the Apartheid homelands in the late 1950s, resulting in a massive relocation of 'surplus' black residents on white-owned farms who were forcibly removed and resettled into villages [19]. As a result, population densities in the homelands soared, doubling between 1955 and 1969 [20]. In the Central Lowveld, human densities range from 146 to 303 people/km^2 [8], resulting in severe land shortages and pressure on local natural resources.

Since the homelands essentially served to reproduce cheap migrant labour [21], the government made little investment in local economic development. This, coupled with land shortages, geographic isolation and the 'bantu education' system, resulted in high levels of chronic poverty in the region [22]. In this context, diversification of livelihoods and a high reliance on natural resources are common household coping strategies [10]. Rising levels of unemployment due to the national and international economic climate compound the problem, resulting in increasing numbers of households engaging in commercial trade in natural products [1, 23].

Land tenure in the former-homelands is still largely communal, meaning that the local residents have rights of access to the land and its resources without private ownership or exclusive rights. In communal tenure systems, local institutions are central in shaping people's resource harvesting behaviour [24]. Without effective institutional regulation, communal systems usually become 'open access' systems, vulnerable to abuse and unsustainable resource use. The traditional authorities in the Central Lowveld regulate resource harvesting by issuing permits and enforcing laws and taboos. However, these institutions have become progressively weakened and marginalised in this role, resulting in rising harvesting pressure in many cases [1, 25]. This includes increased felling of live trees, harvesting by 'non-local' harvesters, and commercial harvesting of wood and traditional medicine [26, 27].

Local level

The local availability of resources influences resource use behaviour. For example, purchasing fuelwood and using alternative sources of energy are more common in communities experiencing fuelwood shortages [28]. Dwindling resources also require harvesters to travel further and spend more time collecting resources [29]. Resource shortages are often associated with larger settlements [29]. The population of many villages in the Lowveld grew by almost a third in the mid-1980s due to the influx of Mozambican refugees fleeing the civil war [30]. Because they required new residential stands, construction materials and fields to cultivate crops, the arrival of the refugees had a noticeable impact on the local environment [1]. Access to services, most notably electricity, also influences resource use patterns. Although fuelwood remains the dominant cooking energy source due to economic constraints, a higher proportion of households cook with electricity in those villages which have been electrified for longer [28].

Household level

Household characteristics are probably the most important direct drivers of natural resource consumption. Household size, age and gender composition are key drivers. For instance, larger households consume greater quantities of key resources [31, 32], younger households are less likely to use edible wild herbs and fuelwood [17], and consumption of fuelwood increases with the number of females in the household [31]. Households headed by a male are more likely to use bushmeat and wood for carving and house construction [17]. Female-headed households are often poorer and more vulnerable than male-headed households, possibly explaining why they are more likely to sell natural products compared to their male-headed counterparts [23].

The wealth status of a household is another important factor. However, the commonly held assumption that poorer households are greater consumers of natural products does not always hold. Wealthier households often utilise a wider range of natural products [13] and use more 'luxury' products such as bushmeat, wooden utensils and poles for fencing and construction [13, 33]. However, poorer households consume relatively larger quantities of 'essential' resources like edible wild herbs and fruit [13, 33]. Although slightly fewer wealthy households use fuelwood, it is still the dominant cooking energy source across all wealth categories, and quantities consumed by user households are not influenced by wealth status [31, 33]. A significantly greater proportion of households selling natural products are poor compared to the general population [23]. Thus, although the additional income from resource sales is an important livelihood supplement, it seldom provides a way out of poverty.

The use of natural resources is a common livelihood strategy in times of crisis [18]. Therefore, household shocks (events or circumstances which thrust households into crisis) are important to consider as drivers of household resource use. Rapidly increasing numbers of households have to cope with the impacts of the illness or death of prime-age adult members due to HIV/AIDS. HIV/AIDS and TB (often associated with HIV) are the leading causes of death among adults between the ages 15 and 49 years in the Central Lowveld [34], and mortality among young adults increased five-fold over the decade between 1992-1993 and 2002-2003 [35]. One way of coping with the economic impacts of losing an adult member is to rely more heavily on local natural resources, especially to save or make money [23, 36]. Roughly 10% of women selling hand brooms and mats in Bushbuckridge entered the trade after they had been left with grandchildren to care for following the death of the children's parents [23]. Although using or selling wild natural resources may buffer households against severe hardship following a household shock, this seldom fully mitigates against these impacts [23, 36].

Individual level

Resource harvesting is a strongly gendered activity. For example, fuelwood and edible wild herbs are usually harvested by females (Figure 1.9), while bush meat and wood for carving, fence poles, and construction are typically collected by males [17]. Females usually sell hand brooms, marula beer and reed mats, while woodwork and carving are the preserve of males [23]. Resource harvesting is also influenced by age, so that the collection of resources like wild fruit and edible insects is mainly the responsibility of children, while adults and the elderly collect resources such as weaving reeds [17]. The collection of other resources, like edible wild herbs, is not age-specific. Mainly older people sell natural products, partly because age is a barrier to finding employment [23]. Level of education may also have an influence, illustrated by the fact that women selling natural products often have fewer years of education than the population average [23]. As in the case of old age, a low level of education is likely to be a barrier to securing employment, making income generation from local natural resources an attractive livelihood option.

Conclusion

Ecological sustainability is clearly important for livelihood security in the poor rural communities of the Central Lowveld. The state of the environment in these landscapes is strongly shaped by pressures resulting from use of local biodiversity, and these in turn, are influenced by a range of drivers. These drivers interact across scales and change over time. Long-term observation of both the natural and the human components of these integrated systems is necessary for a solid understanding of the state, pressures and drivers of environmental change as a basis for formulating appropriate policy and programme responses.

Figure 1.9 Women collecting fuelwood. [Lori Hunter]

Environmental change in Bushbuckridge

Barend F.N. Erasmus
Kaera L. Coetzer
Julia Mambo
Emma R.M. Archer
Jolene T. Fisher
Gregory P. Asner

Bushbuckridge is a typical cultural landscape where the interdependency of people and the environment shape the savanna ecosystem goods and services upon which many people are dependent. The forced resettlement of people in the Apartheid era, together with Mozambican refugees, has resulted in high human densities. The majority of people rely heavily on the rural rangelands for a variety of natural products, and the ability of these ecosystems to continue delivering these products under conditions of climate change and woodland land cover loss is in doubt. Historical trends show that settlements are expanding, with an increasing corresponding footprint around each village, where woodland resources are depleted. People can and do adapt to environmental change, but the severity and extent of predicted changes are without historical precedent. This raises doubts about the effectiveness of adaptation without focused integrated land use planning.

Why Bushbuckridge?

Bushbuckridge faces many of the same challenges that the rest of the country faces, such as high HIV/AIDS prevalence, poor institutional governance capacity and high unemployment rates. An additional challenge is that the majority of people in this area rely heavily on natural resources for food, fuelwood and building material. Population increase and a transition from subsistence farming to commercial activities are causing an increased demand for these natural resources, stressing the ability of this ecosystem to provide these goods and services.

Bushbuckridge is a good example of a socio-ecological system, and more specifically a cultural landscape [1]. Such landscapes are characterised, and shaped, by interdependencies between natural resources, high human population density, communal land tenure and a population that is heavily reliant on natural resources for a variety of resources. One study [2] found that almost 90% of rural households sampled use wild edible herbs, and they do so two to five times a week.

Bushbuckridge is bounded by conservation areas (Figure 1.10). The landscape is a heterogeneous patchwork of cultivated and fallow fields, open woodlands, shrublands, privately owned game farms and tourist lodges, rural towns, commercial tropical fruit farms and exotic forest plantations. The high human density is due to forced displacements during the Apartheid era when Bushbuckridge was part of the former homeland of Gazankulu, as well as the arrival of Mozambican war refugees during the 1980s.

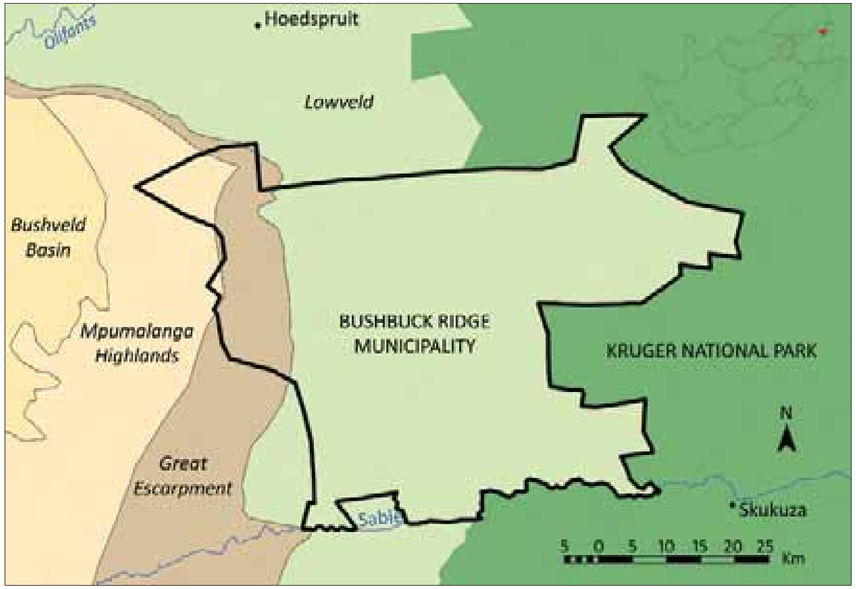


Figure 1.10 The regional location of the Bushbuckridge municipality.

Environmental change in savannas

Environmental change includes all the changes that we can observe over different periods of time and in different places in the landscape. For this study we will distinguish between land cover change and climate change. Land cover change is typically the result of human activities – when we change the way we use the landscape, or use it in the same way but more intensively, then we may change the land cover. Land cover change is usually quantified using satellite image analysis, and together with field validation of observed changes on the images, we can quantify the extent of change. For Bushbuckridge, these changes are mostly in the structure and density of vegetation. Explaining the reasons for the observed changes is more challenging and needs background information, not only on the functioning of savanna ecosystems, but also how people use the natural resources that this savanna ecosystem provides.

Even without considering global change, savannas are highly heterogeneous environments, with soil nutrients, rainfall, fire and herbivory interacting to determine the structure, function and composition of any particular bit of savanna. In cultural landscapes such as Bushbuckridge we have the added effect of natural resource extraction by humans (see the chapter by Twine for more details) that add even more complexity to the spatiotemporal dynamics of patches. The resulting mosaics of different land cover types are easily quantifiable from aerial photography and satellite imagery, and we will start by discussing some studies that used these methods to quantify change. It is important to note that people have always been a part of this living landscape, but the intensity and type of land use has changed in response to a variety of recent, novel factors, resulting in higher rates of change and associated concerns about sustainability.

Land cover change around villages

Land cover change between 1974 and 1997 for three villages in the area showed that all these settlements expanded over the period, and this was associated with a general loss of woodland land cover, and a corresponding loss in tall woody vegetation [3], which was replaced by shrubs. Figure 1.11 on the next page shows this change moving from image (c) to (b). The texture in image (c) is coarser and shows more and higher, heterogeneous woody vegetation. Fuelwood extraction and overgrazing are two of the factors that may result in the change to shrubland in (b), where the smoother texture reveals vegetation of uniform height, and more purple colours show lower woody cover, and almost no large trees.

Cropland (Figure 1.11a) did not show a simple increase with population increase, and local factors, such as the availability of arable land, distance to neighbouring villages and local governance (i.e. prohibiting Mozambican refugees from clearing new fields for a period of time), determined the nature and rate of cropland cover change. Long crop rotational periods allows for extensive herbaceous invasion of fallow fields, which make it difficult to distinguish between uncultivated sparse woodland and old fields without local knowledge.

In this study, the nature of settlement expansion and woodland cover change was village specific, dependant on the settlement history of the village as well as the sum of villagers' response to environmental change. The transition to democracy has contributed to woodland loss: some villagers associated the rules and regulations that governed rangeland use with the Apartheid government and subsequently felt entitled to use the rangelands without these restrictions [3]. Another factor was the settlement of Mozambican refugees in the 1980s. These communities were typically poorer, since they have no access to South African social grants, and subsequently were less likely to follow local customs on where and which resources can be extracted, resulting in conflict in some communities [5].

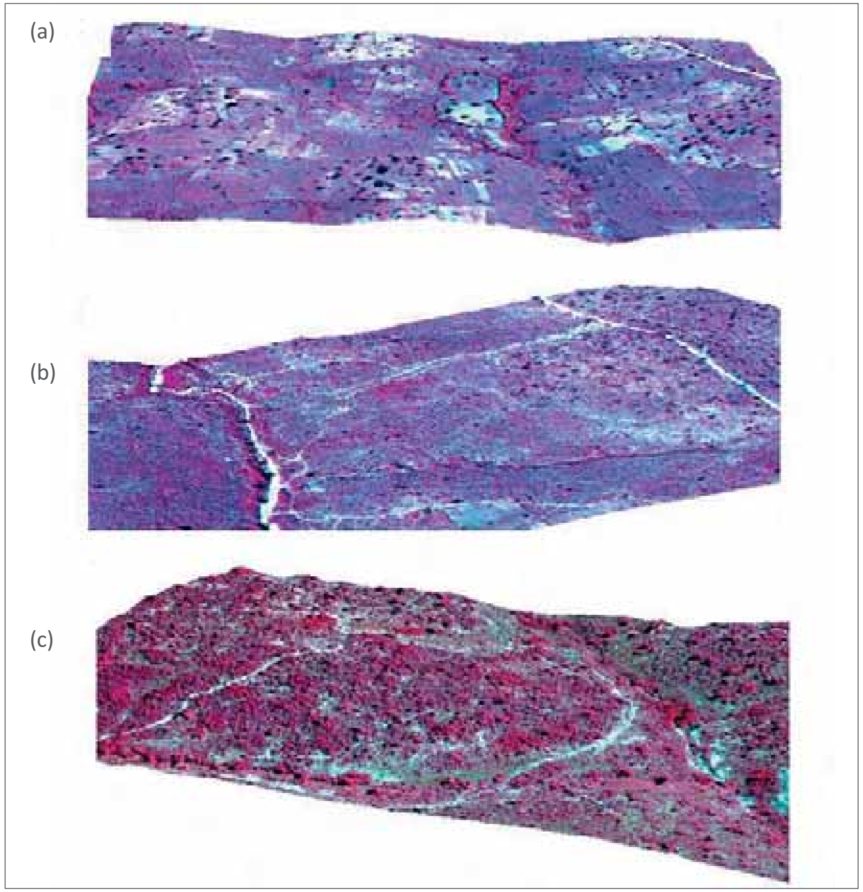


Figure 1.11 Three dimensional images of typical land cover types in Bushbuckridge: (a) A mosaic of fallow and cultivated fields. (b) Shrubland with very few large trees, typically caused by overgrazing or heavy fuelwood extraction. (c) Intact woodland with trees of different sizes. The images were created by a high resolution airborne laser scanner and hyperspectral sensor (see [4] for a complete technical description of the system, and http://cao.stanford.edu for more applications of the same system). Reddish colours represent green vegetation, blue shows bare soil and purple hues denote areas with lower vegetation cover, usually herbaceous in nature.

Land cover change at broader scales

Another ongoing study confirms these general trends in land cover change at village level with a broader scale analysis of the entire region. Satellite imagery (Landsat 5) was used to quantify annual land cover change between 1993 and 2006. Here we only report a comparison between the start and end points of the analysis. Over 40% of the landscape has been directly transformed and can be classified as either 'settlement' areas or as 'impacted vegetation'. The latter is a catch-all class for areas where heavy resource extraction, grazing and croplands occur, to the extent that the vegetation structure tends toward (a) and (b) in Figure 1.11. The comparison between 1993 and 2006 land cover reveals that 'settlement' areas have increased, accompanied by an increase in human-'impacted vegetation' and a decline in 'intact vegetation' (Figures 1.12 and 1.13).

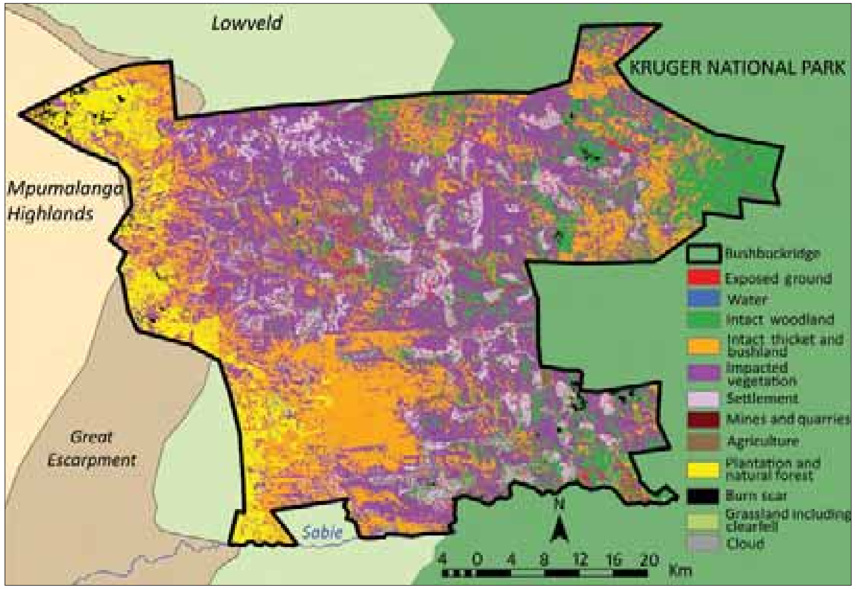


Figure 1.12 Land cover classification map of Bushbuckridge, using a 1993 Landsat 5 image.

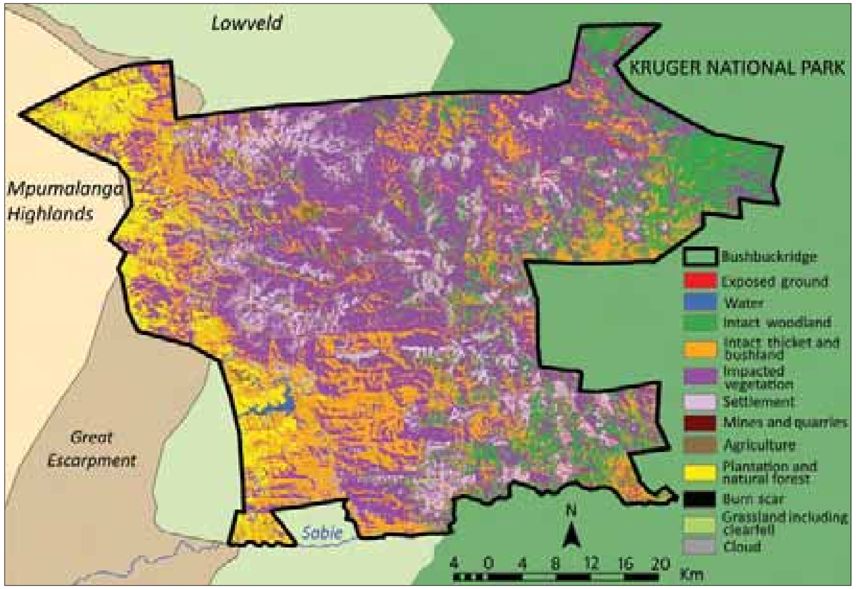


Figure 1.13 Land cover classification map of Bushbuckridge, using a 2006 Landsat 5 image.

Apart from net changes in land cover, the spatial dynamics of the landscape are a function of spatially explicit gains (G), losses (L) and areas of persistence (P) for a specific land cover class. The configuration of gains, losses and persistence affects integrated land use planning. For example, for conservation management, 'salt & pepper' losses of conservation-friendly cover classes, such as intact vegetation, may be preferable to losing large stands of the same type of cover. Conversely, 'salt & pepper' gains of conservation-unfriendly cover classes may be *more* difficult to manage regionally for conservation purposes than 'block' gains would be. From a socio-economic development perspective, block gains of settlement areas may be preferable over 'salt & pepper' gains for municipal service delivery and -management.

Figure 1.14 on page 24 shows that existing settlements are expanding and becoming denser. The direct transformation of vegetation to settlement areas remains contained around persisting settlement units (Figure 1.11). Settlement expansion starts with intact vegetation changing to impacted vegetation and then settlement. This nucleated expansion of settlements eventually fragments the remaining intact vegetation into smaller, less functional patches, limiting options for integrated land-use planning with multiple uses. Evidence from village-level data [3] show that villagers have to move greater distances to collect enough fuelwood. This supports the broader scale finding.

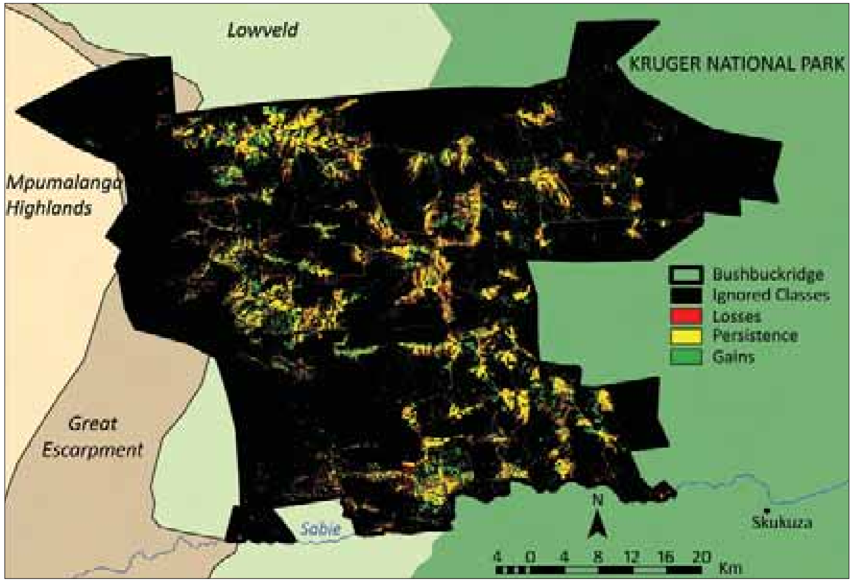


Figure 1.14 Spatial configuration of land cover change in the settlement cover class, between 1993 and 2006. (Gains, losses and persistence in green, red and yellow respectively.)

Transformation by humans is only one of the drivers of land cover change. Rainfall and soil characteristics interact to provide plants with the necessary soil moisture conditions to grow and reproduce. Since soil characteristics are constant over short time scales, rainfall sets an upper limit to the type of vegetation that can develop in the area, and local land use determines whether this potential is realised. A vegetation greenness index, the Normalised Difference Vegetation Index (NDVI), is derived from measurements of reflectance in the red and near infrared regions of the electromagnetic spectrum. From the MODIS satellite system we can construct time series images of vegetation greenness indices and create composites every 16 days. Figure 1.15 shows the mean annual NDVI values for all the 16-day composite images for each year. It is clear from these images that greenness patterns are spatially variable within each year, as determined by existing patterns of land cover, but also between years, as determined by regional rainfall. 2003 and 2005 are drier years with much less green vegetation on average than the other years.

This variability is even more apparent when we plot the greenness for specific areas, for each 16-day period from 2000 to mid 2008. Figure 1.16 shows that the eastern parts of Bushbuckridge always have lower greenness values than the western part, which is consistent with the local rainfall gradient. Even though the general timing of rainfall seasons are predictable, the between-year variation in greenness suggests that the amount, spatial configuration and timing of the rainfall varies. August 2003 was a very dry period, and it confirms the low mean annual greenness for this year, as seen on Figure 1.15.

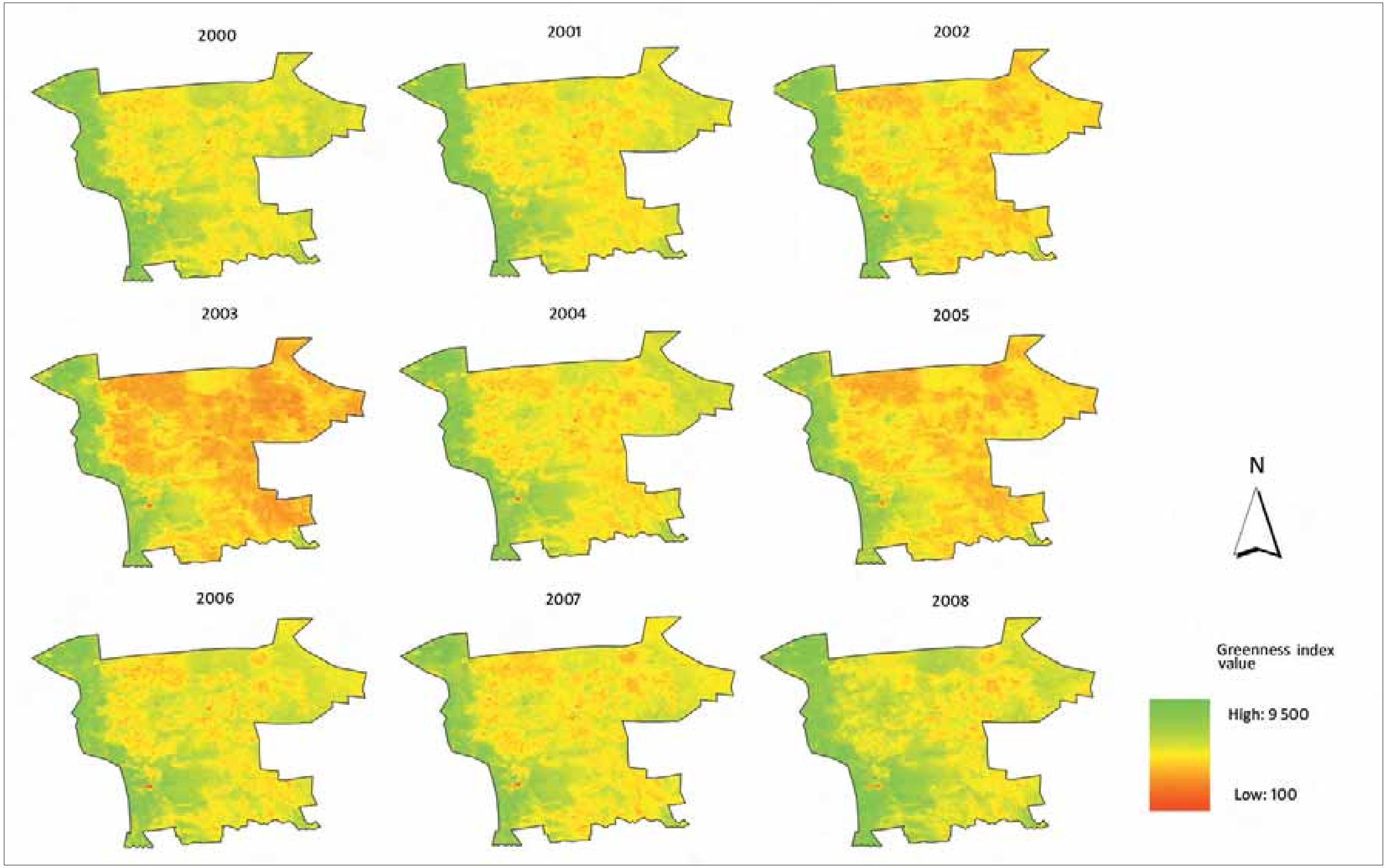


Figure 1.15 Mean annual vegetation greenness, as measured by MODIS-derived NDVI, from 2000 to 2008 for Bushbuckridge. [Data provided by the Agricultural Research Council Institute for Soil, Climate and Water, Pretoria]

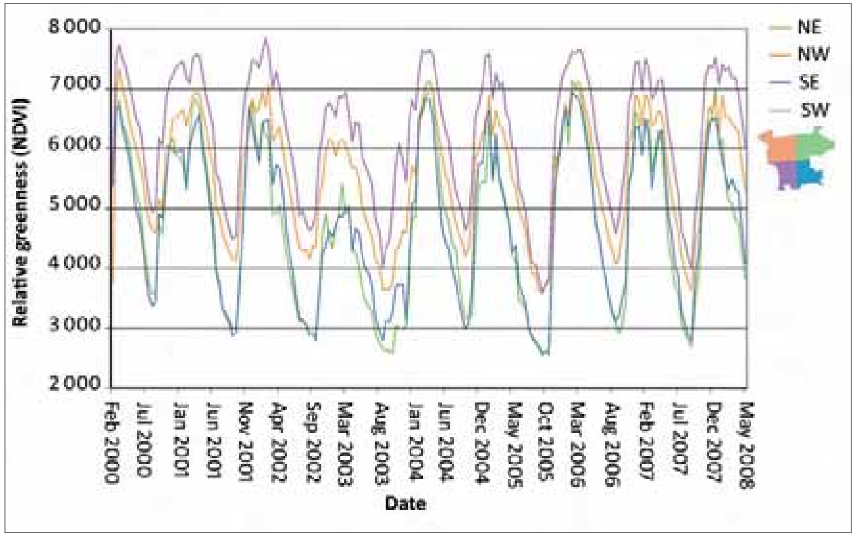


Figure 1.16 Time series data on NDVI, measured at 16-day intervals, for the period 2000 to 2008. The data is aggregated according to the coloured insert showing the four quarters of the region.

Conclusion

Land cover change at broad and local scales confirms our knowledge of the underlying mechanisms of change. The fundamental research question in this area is not so much whether the savanna ecosystem can provide the needed goods and services, but whether it can do so in the face of increased climate variability due to global change and increasing human population pressure. Savannas are by their nature variable and unpredictable, and people have devised various livelihood strategies to cope with this uncertainty. The question is whether the transformation of woodlands (driven by human densities) and associated changes in rainfall regimes (driven by local land cover changes and regional climate change) will present the inhabitants with novel conditions that are potentially beyond their adaptation abilities. This would be a decoupling of the age-old processes that led to the integrated cultural landscape of Bushbuckridge.

Living with drought

Adaptation, alleviation and monitoring

Dawie van Zyl
Johan Malherbe
Terence S. Newby

The term drought refers to a period of time with a water scarcity. Drought in South Africa is driven by natural climate variability resulting in water-limiting pressures on agricultural production. Grazing capacity and crop production varies significantly from year to year due to inter-seasonal climate variability. Agriculturalists produce in a continuous state of uncertainty and risk, exacerbated by the unpredictability of South Africa's climate. Successful farmers are those that implement risk management, response farming technologies and water conservation practices. Climate change is seen as a threat in the future, thus effective monitoring of drought is crucial.

Introduction

Drought in South Africa is driven by natural climate variability. South Africa has an average annual rainfall of 450 mm, with 65% of the country receiving less than 500 mm per annum. Years with below-normal rainfall are more common than years with above-normal rainfall. South Africa is therefore affected more by drought events than by severe flooding.

Drought events put severe pressure on South Africa's already limited water resources and agricultural production. Agriculturalists produce in a continuous state of uncertainty and risk and grazing capacity and crop production vary significantly from year to year due to inter-seasonal climate variability. This situation is exacerbated by the unpredictability of South Africa's climate. Although irrigation is used in many of the South African farming systems

(Figure 1.17), it is affected by lowering levels of groundwater, dams and rivers across the country during drought events.

Drought events are a limiting factor for livestock farming and game range activities throughout the country. To be successful, farmers need to implement risk management, response farming technologies and water conservation practices. Drought has a negative effect on overall food production and food security. In some instances, food has to be imported to augment a poor harvest.

During periods of prolonged drought, water resources come under threat. Due to water scarcity in these periods, water restrictions are implemented to manage the problem on a short-term basis. New boreholes are sunk to provide water to livestock and game, but levels are monitored. Fodder is usually imported but in some instances, if stocking rates are not lowered, overgrazing occurs which increases the risk of soil erosion.

Figure 1.17 Irrigation along the Orange River. [Reproduced with permission: Agricultural Research Council (ARC), Pretoria]

The impact of drought can be managed and reduced by appropriate policies and actions. The development of early warning systems puts emphasis on the prevention and mitigation of, as well as the adaptation to drought events.

The development of institutions, methods and capacities at government through to community level can assist in the mitigation of drought. Committees such as the National Agro meteorological Committee are examples of how government, academic and scientific institutions work together to provide early warning to the agricultural sector. Figure 1.18 shows the user interface of an information system <www.agis.agric.za> that provides regular drought-related information to the government and the public and Figure 1.19 on the next page is an example of the newsletter created using the system.

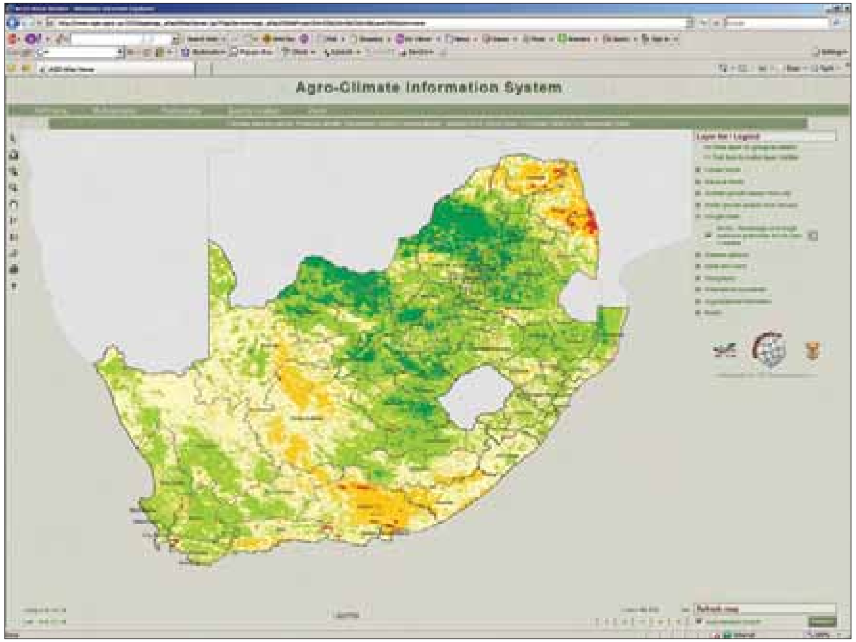
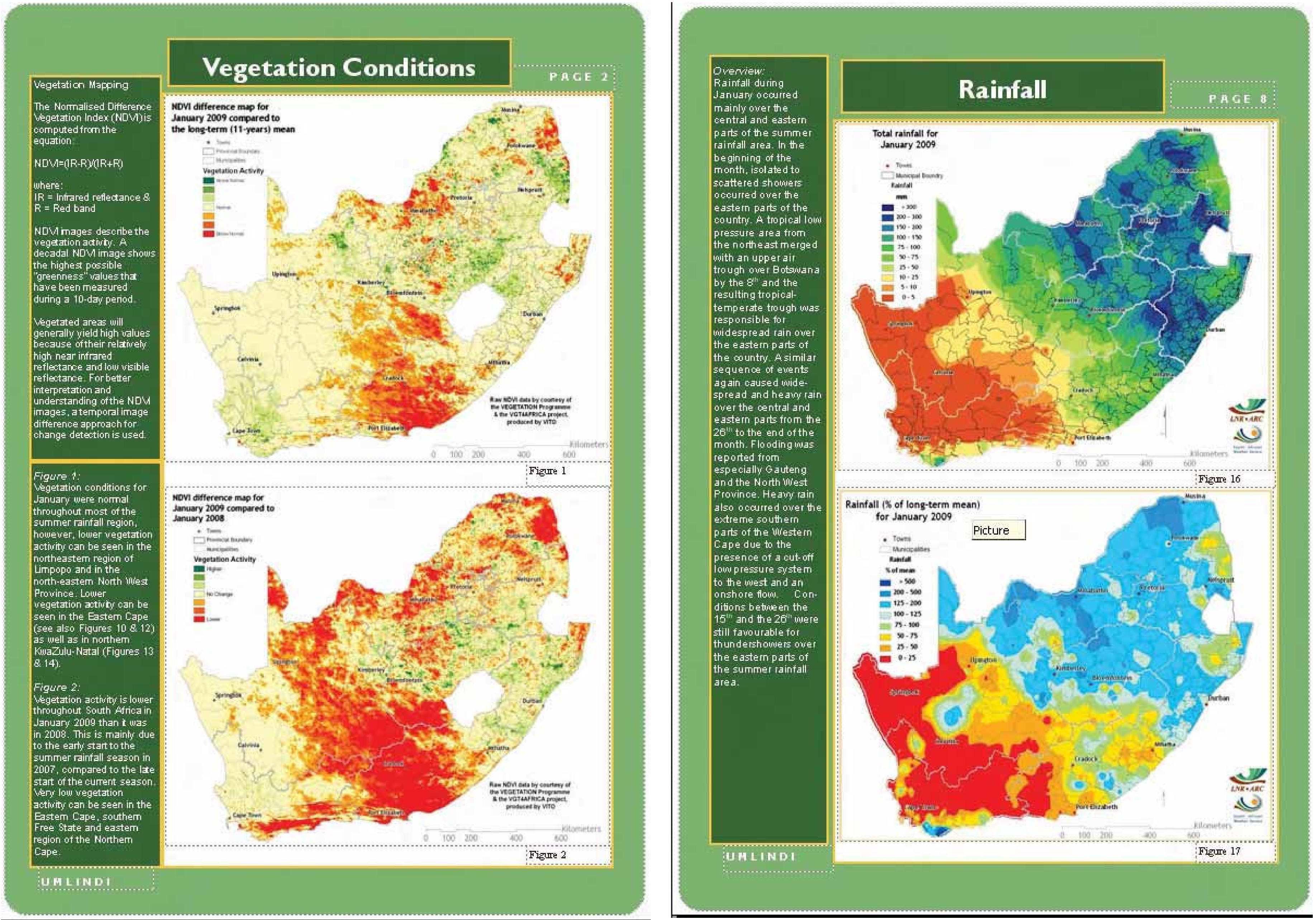


Figure 1.18 Agro-Climate Information System. [Reproduced with permission: ARC, Pretoria]



Vegetation Conditions

PAGE 2

Vegetation Mapping

The Normalised Difference Vegetation Index (NDVI) is computed from the equation:

NDVI=(IR-R)/(IR+R)

where:
IR = Infrared reflectance &
R = Red band

NDVI images describe the vegetation activity. A decadal NDVI image shows the highest possible "greenness" values that have been measured during a 10-day period.

Vegetated areas will generally yield high values because of their relatively high near infrared reflectance and low visible reflectance. For better interpretation and understanding of the NDVI images, a temporal image difference approach for change detection is used.

Figure 1:
Vegetation conditions for January were normal throughout most of the summer rainfall region, however, lower vegetation activity can be seen in the northeastern region of Limpopo and in the north-eastern North West Province. Lower vegetation activity can be seen in the Eastern Cape (see also Figures 10 & 12) as well as in northern KwaZulu-Natal (Figures 13 & 14).

Figure 2:
Vegetation activity is lower throughout South Africa in January 2009 than it was in 2008. This is mainly due to the early start to the summer rainfall season in 2007, compared to the late start of the current season. Very low vegetation activity can be seen in the Eastern Cape, southern Free State and eastern region of the Northern Cape.

UMLINDI

Rainfall

PAGE 8

Overview:
Rainfall during January occurred mainly over the central and eastern parts of the summer rainfall area. In the beginning of the month, isolated to scattered showers occurred over the eastern parts of the country. A tropical low pressure area from the northeast merged with an upper air trough over Botswana by the 8th and the resulting tropical-temperate trough was responsible for widespread rain over the eastern parts of the country. A similar sequence of events again caused wide-spread and heavy rain over the central and eastern parts from the 26th to the end of the month. Flooding was reported from especially Gauteng and the North West Province. Heavy rain also occurred over the extreme southern parts of the Western Cape due to the presence of a cut-off low pressure system to the west and an onshore flow. Conditions between the 15th and the 26th were still favourable for thundershowers over the eastern parts of the summer rainfall area.

UMLINDI

Figure 1.19 The Umlindi Newsletter provides drought-related information monthly. [Reproduced with permission: ARC, Pretoria]

Drought adaptation and alleviation

Adaptation to drought conditions consists of initiatives and methods to reduce the vulnerability of natural and human systems against actual or predicted effects.

The safeguarding of water resources is the first step in the process of adaptation. This may include the development and use of alternative water resources, including desalination of seawater, sinking of new boreholes, building canals to redirect water or the development of new dams, such as the Katse Dam in Lesotho (Figure 1.20).

The recycling of water, rehabilitation and protection of wetlands and the prevention of water pollution is critical to the safeguarding of water resources during drought periods.

Adaptation to climate changes has led to the development of new crop and seed banks, which focus on drought and heat resistant, faster growing crops. An increase in water-use efficiency and conservation agriculture (Figure 1.21) helps maintain production levels within a changing climate.

Figure 1.20 The Katse Dam, Lesotho. [Reproduced with permission: ARC, Pretoria]

Figure 1.21 Conservation agriculture, Bergville. [Reproduced with permission: ARC, Pretoria]

Monitoring drought

Although the characteristics of drought can vary from region to region, it occurs in all climate zones throughout the world. Even though some regions are arid with low mean annual rainfall, it should always be remembered that drought refers to a state of negative deviation from the norm.

The World Meteorological Organization (WMO) identifies five types of drought [1]. These are:

- Meteorological Drought – defined in terms of precipitation deficiencies in absolute amounts for a specific period.
- Climatological Drought – defined in terms of precipitation deficiencies as a percentage of normal values.
- Atmospheric Drought – defined in terms of deficiencies in precipitation, temperature, humidity and/or wind speed.
- Agricultural Drought – defined in terms of soil moisture and plant behaviour.
- Hydrological Drought – defined in terms of a reduction in stream flow, lake or reservoir storage and lowering groundwater levels.

To effectively monitor drought, a long-term dataset is needed to monitor the balance between precipitation and evapotranspiration. Other factors to consider when monitoring drought are the start of the rainy season and the effectiveness of rain and other climate influences, such as temperature, wind and humidity. The first evidence of drought can be found in rainfall records (Figure 1.22). Soil moisture shows the effect of low precipitation after a short period, with vegetation cover showing the effect soon after. Groundwater is lost by evaporation and through transpiration by plants. The combined process is called evapotranspiration. The effect of drought on rivers and reservoir levels is noticed several weeks or months later.

Earth observation allows synoptic and repeated collection of information about the earth's surface. In many developing countries, capacity for ground-based data collection and observation is limited and restricted by poor infrastructure (roads, vehicles, field instrumentation, etc.). Remote sensing offers a practical and cost-effective means of collecting land surface data regularly. One major and unique advantage of using remote sensing data is that it provides information beyond the visible range and has a large spatial coverage.

Figures 1.23, 1.26 and 1.29 show total seasonal rainfall (July-June) from 1985 to 2008 for the Eastern Cape, Free State and Limpopo provinces, respectively. These graphs clearly show the difference in total rainfall during dry seasons, compared to normal and wet seasons. Figures 1.24, 1.27 and 1.30 show examples of wet and dry season monthly rainfall distributions. Although these graphs have a typical irregular appearance, the difference in rainfall between wet and dry years can clearly be seen.

Figure 1.22 An ARC Automatic Weather Station, Western Cape. [Reproduced with permission: ARC, Pretoria]

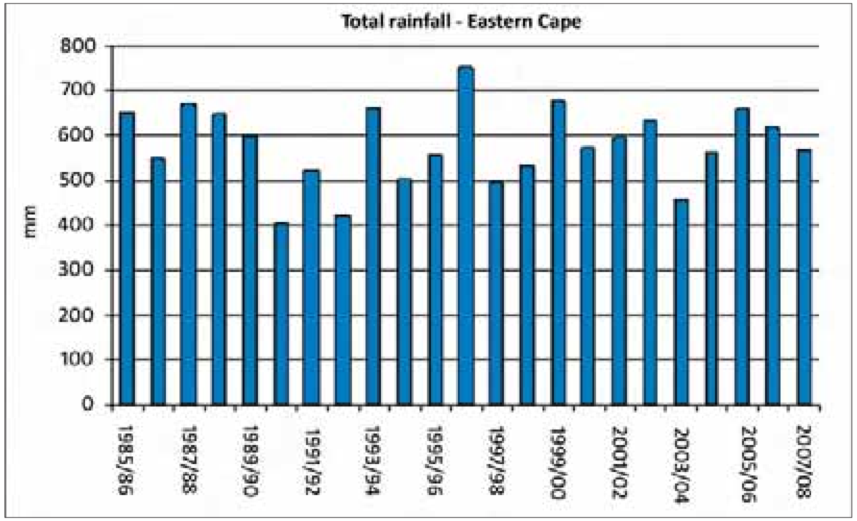


Figure 1.23 Total rainfall for the Eastern Cape from 1985 to 2008.

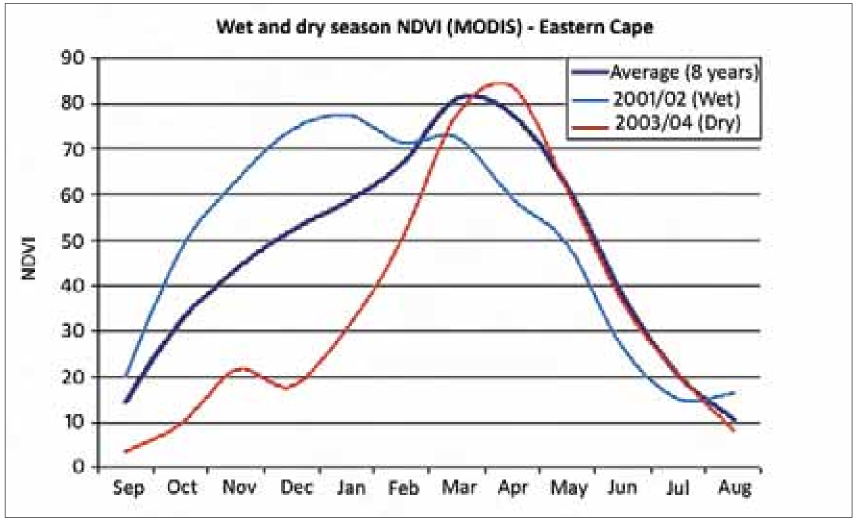


Figure 1.25 Monthly NDVI for the Eastern Cape.

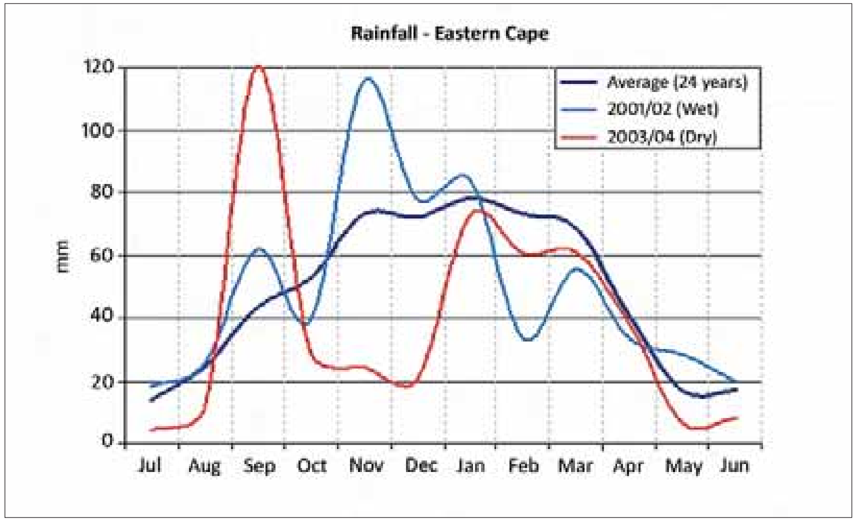


Figure 1.24 Monthly rainfall for the Eastern Cape.

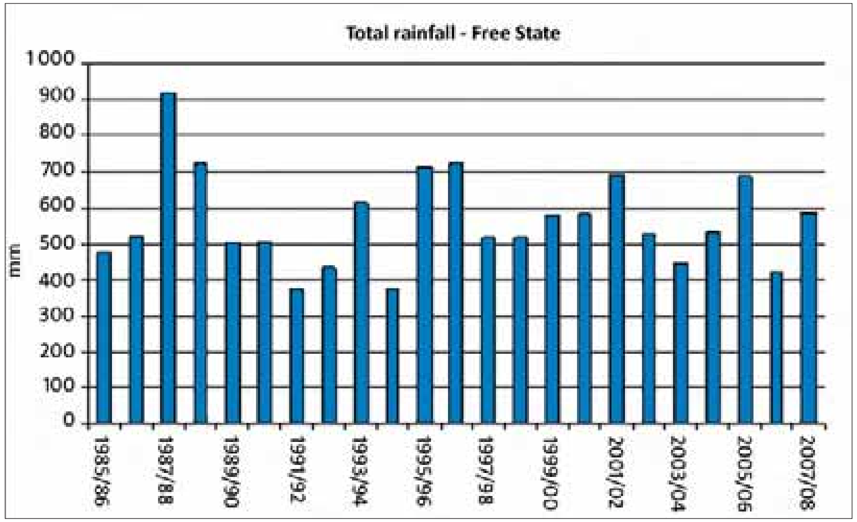


Figure 1.26 Total rainfall for the Free State from 1985 to 2008.

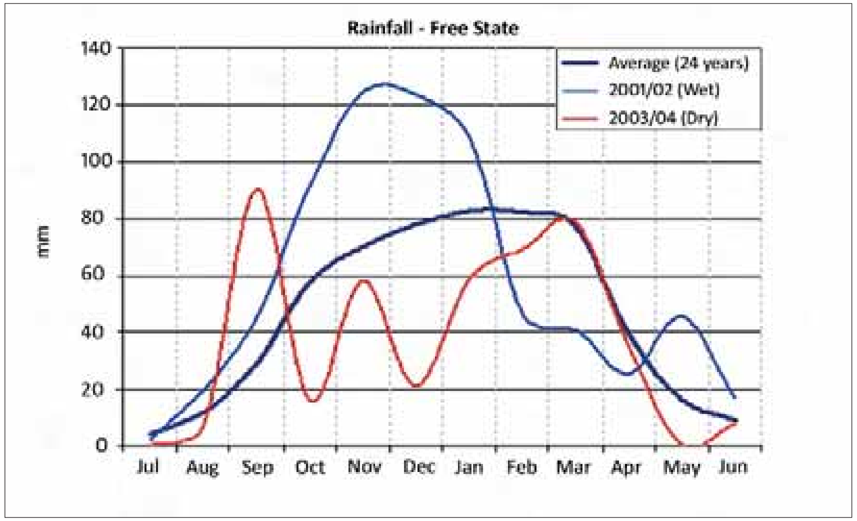


Figure 1.27 Monthly rainfall for the Free State.

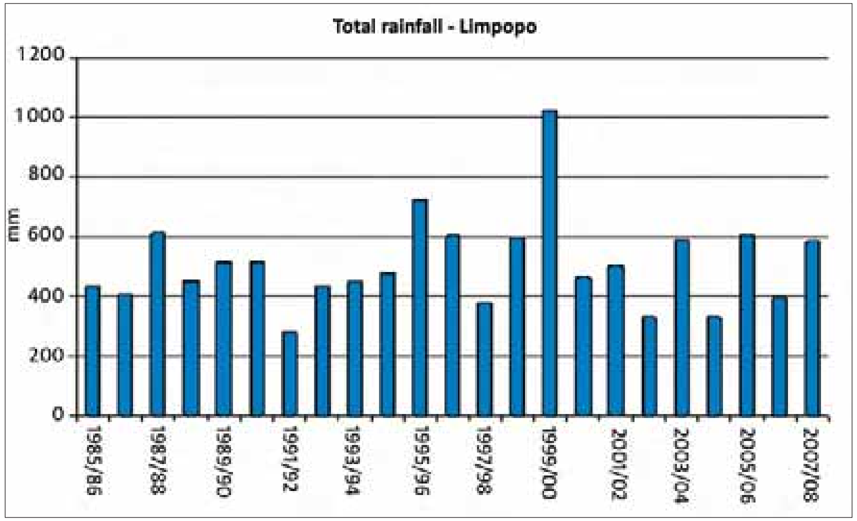


Figure 1.29 Total rainfall for Limpopo from 1985 to 2008.

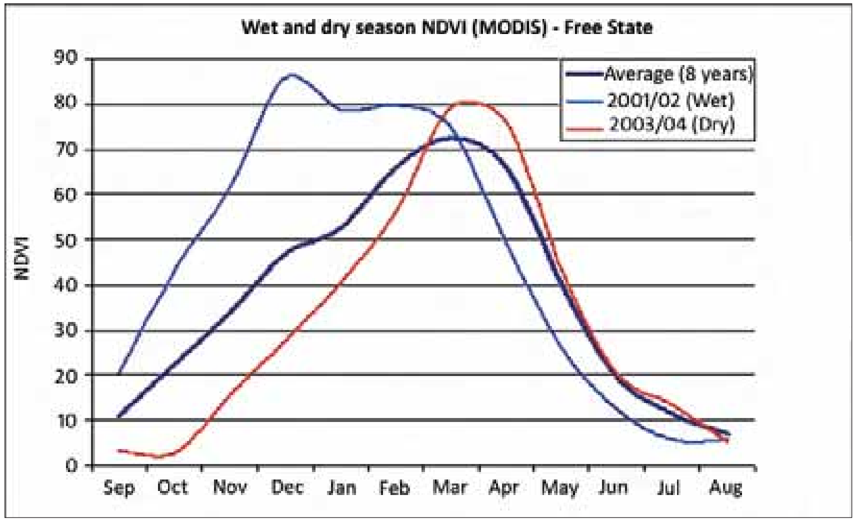


Figure 1.28 Monthly NDVI for the Free State.

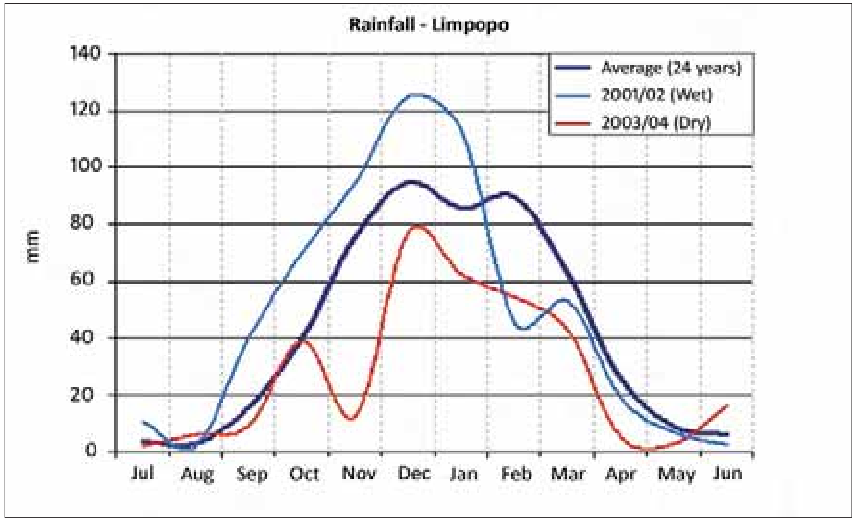


Figure 1.30 Monthly rainfall for Limpopo.

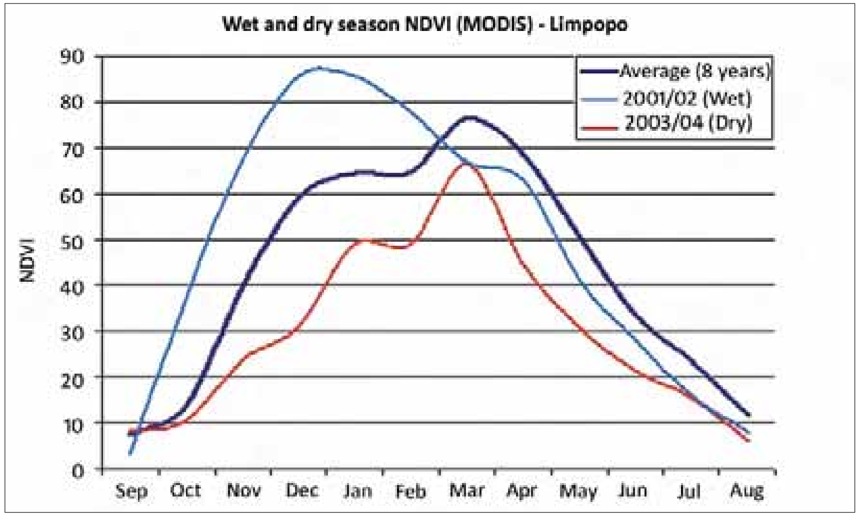


Figure 1.31 Monthly NDVI for Limpopo.

The Normalized Difference Vegetation Index (NDVI) has been shown to be sensitive to vegetation activity. The NDVI in principle measures the reflectance in the RED and near-infrared (NIR) bands. Healthy vegetation has the characteristic of showing high absorption in the RED band, and higher reflectance in the NIR band. The opposite is true for stressed vegetation which normally shows lower absorption in the RED band and lower reflectance in the NIR band (Figure 1.32). This quality of vegetation is calculated and expressed in the following formula:

NDVI = (NIR – RED) ÷ (NIR + RED)

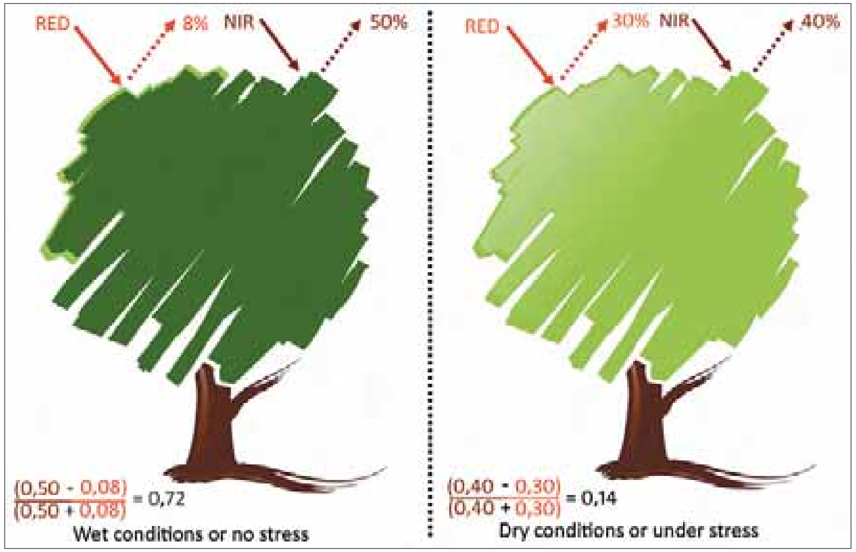


Figure 1.32 Illustration of NDVI.

NDVI images describe the vegetation activity and show the highest possible 'greenness' values that have been measured during a specific period. This relationship makes it possible to monitor stressed vegetation or agricultural drought. Rainfall data cannot show the spatial extent of drought conditions, but remote sensing data, through the NDVI, can be used to map drought conditions.

The NDVI responds in a very predictive manner to rainfall events. The resulting vegetation growth after a rainfall event can be detected between 5-10 days after a rainfall event. Drought conditions, in contrast, can only be detected after 20 days since the last rainfall event. This relationship does, however, differ according to different biomes and the availability of groundwater. The NDVI is less sensitive to high rainfall events and tends to saturate, and in some instances may show the effect of water stress.

Figures 1.25, 1.28 and 1.31 show the vegetation phenology as extracted from MODIS NDVI data (MODIS is a satellite equipped with a moderate resolution image spectrometer). The difference in vegetation growth during anomalously wet and dry seasons can be distinguished. By comparing these NDVI trends with that of the rainfall, the rapid reaction of vegetation to high rainfall and the slow reaction of vegetation to low rainfall events is evident.

Time-series analysis further enhances the mapping of drought conditions. Images are often compared to a long-term average to show the spatial extent of drought conditions. Various statistical methods exist to calculate these kinds of maps. The Percentage of Average Seasonal Greenness (PASG) compares the accumulated greenness (NDVI) up to a specific point in the growing season to the historical average accumulated greenness.

$$PASG = (NDVIi) \div (NDVIa) \times 100$$

where:

i = accumulated since start of season; and
a = long-term accumulated average.

Figures 1.33 to 1.35 show the spatial distribution of drought conditions for the Eastern Cape, Free State and Limpopo provinces, respectively. Figures 1.36 to 1.38 shows an example of a wet season for the same provinces. This information is updated and distributed regularly through the Agro-Climate Information System and the Umlindi Newsletter.

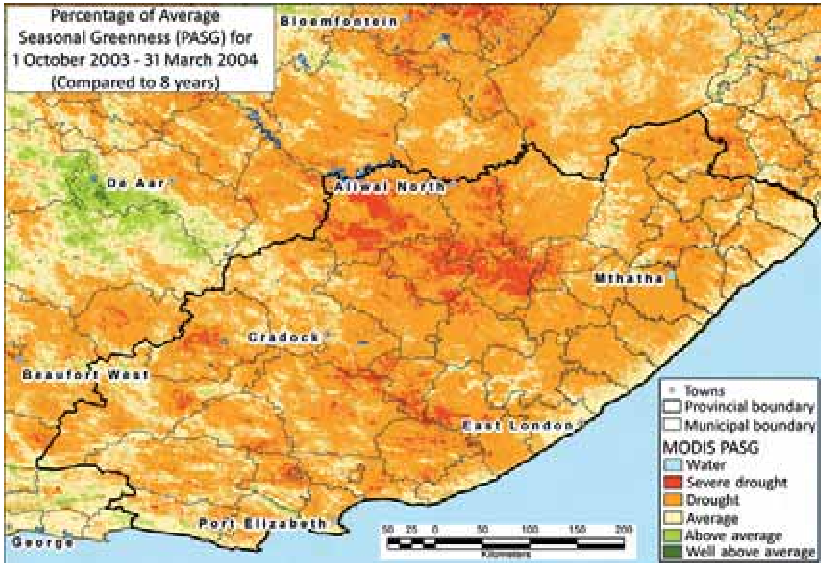


Figure 1.33 Drought conditions in the Eastern Cape, 2003/2004 season.

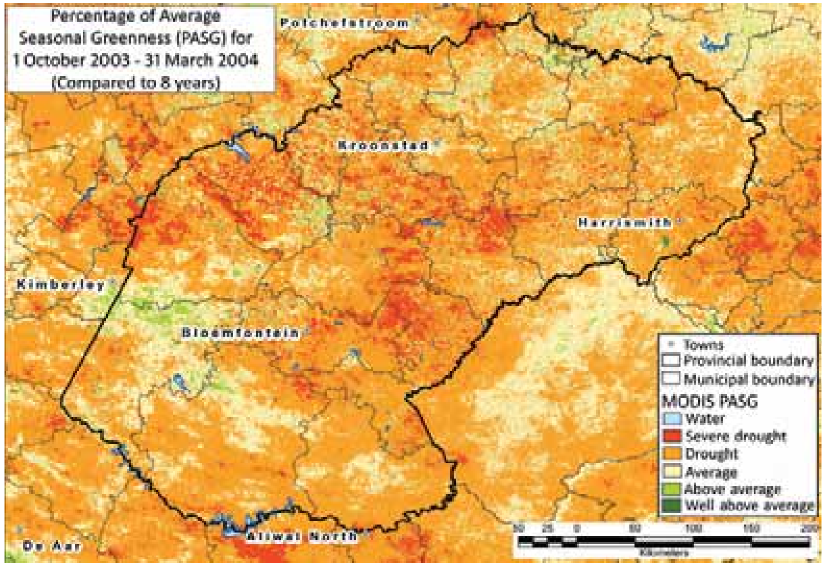


Figure 1.34 Drought conditions in the Free State, 2003/2004 season.

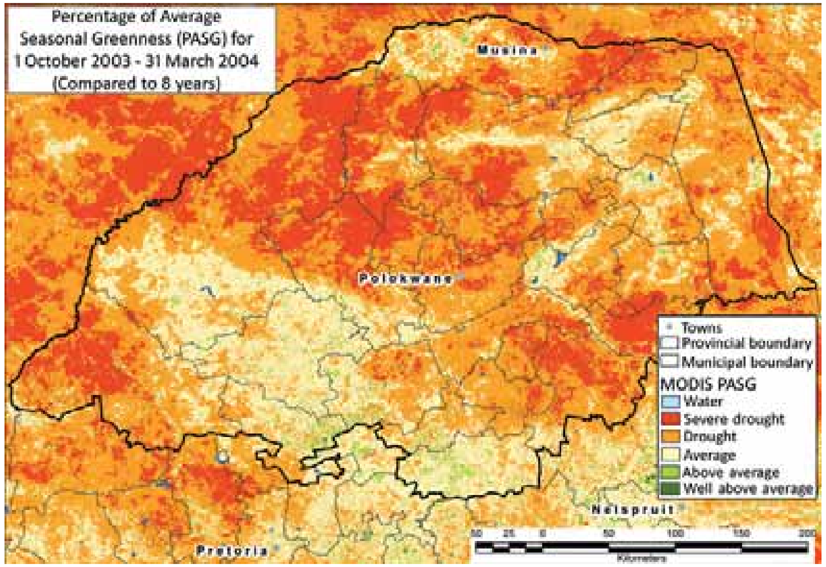


Figure 1.35 Drought conditions in Limpopo, 2002/2003 season.

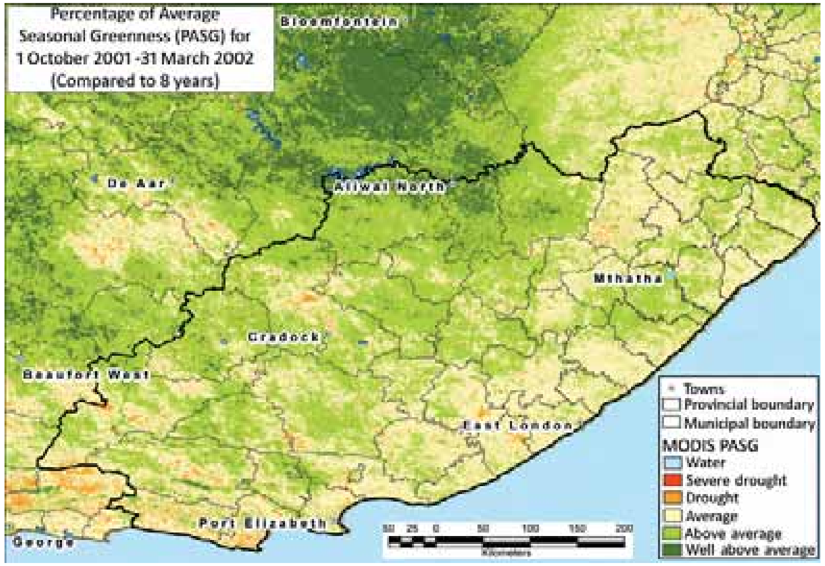


Figure 1.36 Wet conditions in the Eastern Cape, 2001/2002 season.

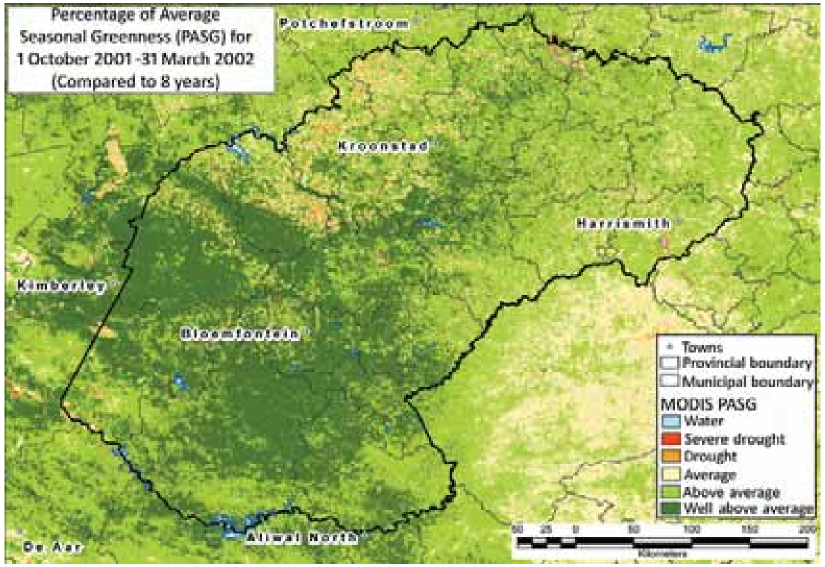


Figure 1.37 Wet conditions in the Free State, 2001/2002 season.

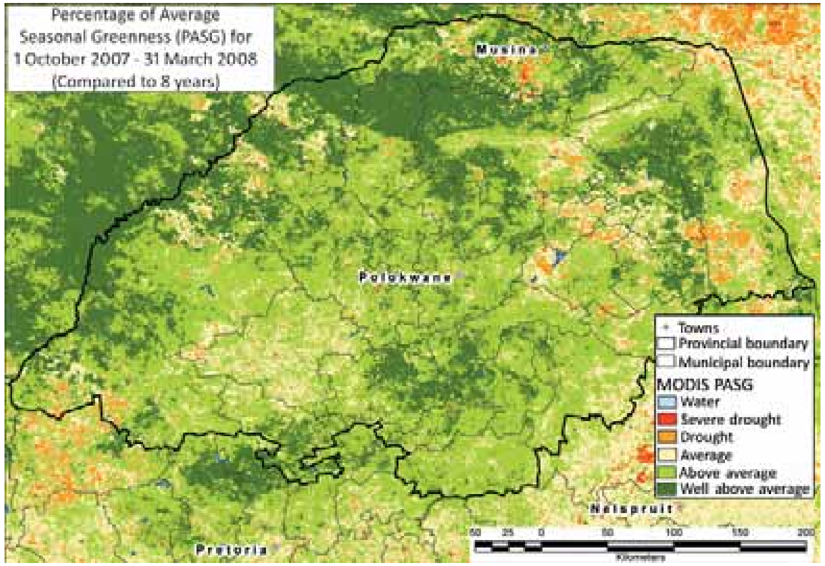


Figure 1.38 Wet conditions in Limpopo, 2007/2008 season.

Conclusion

Continuous drought monitoring plays an important role in the prevention of man-made drought-related degradation. The identification and monitoring of areas affected ensures that relief can be forwarded to those that need it most. Accurate information can assist in the prediction of drought conditions and can therefore allow management of the economic risks.

Acknowledgements

MODIS data is distributed by the Land Processes Distributed Active Archive Center (LP DAAC), located at the US Geological Survey's EROS Data Center http://LPDAAC.usgs.gov.

MODIS data was downloaded, processed and archived by the Agricultural Research Council - Institute for Soil, Climate and Water, as part of the Coarse Resolution Imagery Database project that is funded by the Department of Science and Technology and the Department of Agriculture.

Rainfall data was downloaded, processed and archived by the Agricultural Research Council - Institute for Soil, Climate and Water.

Climate change

Risks, adaptation and sustainability

COLEEN VOGEL

Climate change, including climate variability, has been profiled as presenting serious risks to the southern African region. Climate change may exacerbate periods of extreme climate (for example, droughts and floods) and could change the intensity of heavy rainfall events. Climate changes could also produce elevated terrestrial temperatures. The biophysical stresses may exacerbate a number of other existing socio-economic and political stresses and vice versa. The nexus of such complex interactive stresses will not only test the environment but will also prompt serious investigation of the flexibility of current policy and governance structures. This chapter examines some of these themes with particular reference to the southern African region.

Introduction

Climate variability and change are important challenges facing many regions and locations including southern Africa. These challenges co-occur with other risk factors, such as health, environmental degradation and other stresses, which can compound the overall impact of changes in a place and region (Figures 1.39 and 1.40) [1, 2]. Much literature is now available that clearly shows that climate variability and change often heightens or accentuates an already vulnerable situation. It is therefore critical that we strive to better understand the intersection of such interacting factors, vulnerability and climate change if we are to successfully live with and adapt to future changes [3].

Although sophisticated climate models cannot give us precise information on climate change outcomes [3, 19 and the IPCC Fourth Assessment Report, 2007] there is current agreement that vulnerability to various changes will be heightened by climate change. Thus, while we do not know for certain what may occur with a changing climate in the longer term, we do have a

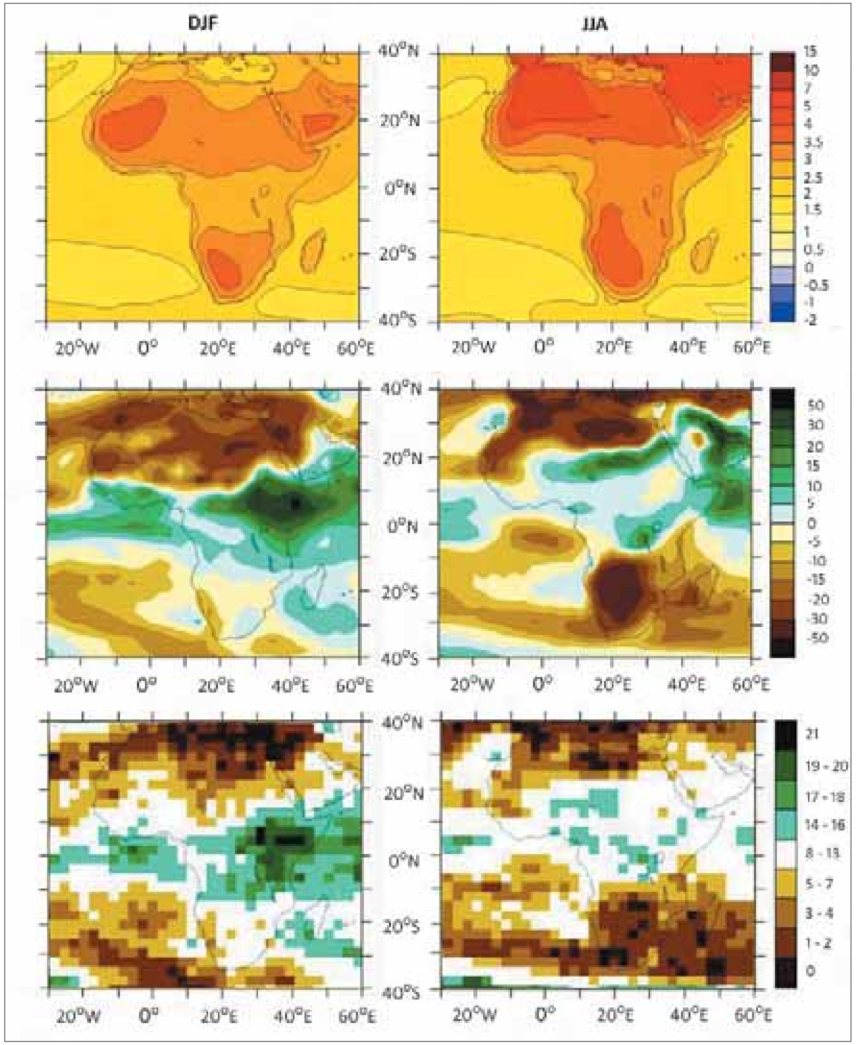


Figure 1.39 Temperature and precipitation changes over Africa. Top row annual mean, DJF and JJA temperature change between 1990 to 1999 and 2008-2099. Middle row same as top but for fractional change in precipitation. Bottom row, shows the number of models out of 21 that project increases in precipitation. [Reproduced with permission from Cambridge University Press: Climate Change 2007 – The Physical Science Basis. Working Group I Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Figure 11.2.]

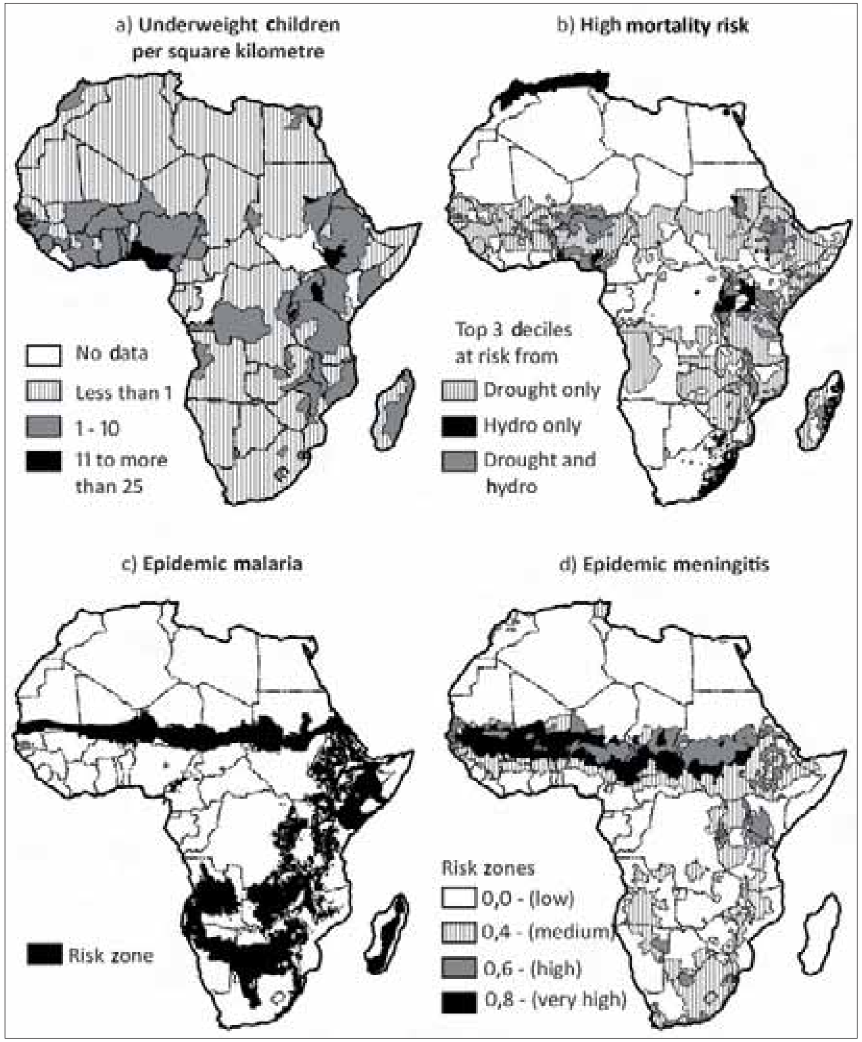


Figure 1.40 Vulnerability to climate change can be exacerbated by the presence of other stresses. [Reproduced with permission from Cambridge University Press: Climate Change 2007 – Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Figure 9.1.]

wealth of information of what risks and impacts are associated with current climate variability (for example, with slow-onset, climate-related disasters such as droughts, and faster-onset climate-related disasters such as floods, tropical cyclones and fires.) [2, 3]. The key question, however, is: How are we learning from such events and changes?

This chapter examines two climate hazards (others may be found elsewhere in this volume) that illustrate the need for a more nuanced understanding of the interaction between people and climate risks, challenges arising and opportunities for sustainability.

Trying to live with current climate stresses: the case of droughts and floods

Repeated droughts and hydro-meteorological hazards dominate mortality and economic losses in sub-Saharan Africa [4, 5]. Slower-onset droughts usually have a range of knock-on impacts including those related to the environment (for example, rangeland degradation, wild fires and water pollution and other wider impacts). When measured in monetary terms, such events usually result in significant downturns in GDP. Impacts are further highly differentiated and usually depend on the frequency of the hazard (for example, a meteorological drought event), vulnerability of the area and the people or environment impacted. One may thus focus efforts on economic impacts at the macro-level and/or on how such impacts enhance or are diminished at the more local scale. Significant local livelihood, resource-endowed asset losses, for example, while difficult to capture fully, may, in the longer term, result in reduced *resilience*, or the ability to 'bounce' back, to climate changes.

Estimating the costs associated with drought and flood

Estimating the costs of climate (including weather-related disasters) is an extremely difficult exercise. Regular drought and flood episodes have resulted in a number of direct losses. Such estimations are a result of both the hazard (for example, drought) and varying other factors contributing to vulnerability of an area under investigation. For example, in 1992 the aggregate impact of drought in Zimbabwe and Zambia was estimated at 8-9% GDP. Floods in Mozambique in 2000 cost an estimated $550 million and lowered that country's GDP growth rate to 1,5% (growth averaged 7,5% annually during 1994-2003) [5]. Earlier economic assessments have shown, however, that vulnerability to droughts is also highly differentiated across different geographical scales [6] and by various contributing factors, such as infrastructure linked to development (for recent assessments, see for example the United Nations Office for the Co-ordination of Humanitarian Affairs, OCHA <www.ochonline.un.org> for reports of flood impacts).

What may be equally important with a changing climate, however, is not only understanding possible 'big', extreme events but also other, regularly occurring, 'smaller' events. Rainfall events of various types can place a stress on local livelihoods. Available assessments show that rainfall events may change in intensity and frequency including the number of rain days in a season, the intensity and magnitude of storm events, and the amount of rain associated with such rainy days or periods [7]. Better understanding of the timing and types of climate-related events and what causes them is therefore needed. Improved estimations of what smaller, cumulative events currently may be costing us, however, is also needed so that we can factor in 'adaptation' costs that may be required given climate change (for example, adapted institutional arrangements, various social interventions).

Some detailed and comprehensive inventories of such impact costs and risks are emerging for flooding events. Examples of this are the damage estimates associated with various types of weather and climate events in southern Africa, such as cut-off lows and storm events in parts of the Southern Cape [8, 9]. Direct cost estimations for the past five years or so in parts of the Western Cape, South Africa, for example, have shown that overall costs were estimated at several billion rands over a period of six years for some communities (Table 1.2 and Figure 1.41) [8, 9].

Table 1.2 Examples of some of the costs associated with severe weather events in the Western Cape, South Africa.

Date	Area most affected	Loss (R million)*
March 2003	Eden	212,4
December 2004	Eden	>60,0
April 2005	Overberg	5,0
August 2006	Eden and Overberg	510,0
June 2007	West Coast	128,3
November 2007	Eden and Overberg	1,2 bn
July 2008	West Coast	74,1
November 2008	Overberg and Cape Winelands	943,0
Total	Four districts	R3bn in six years

[For more updated assessments see Holloway *et al.*, 2010.]

* Not adjusted for construction inflation. For recent assessments see www.riskreductionafrica.org.

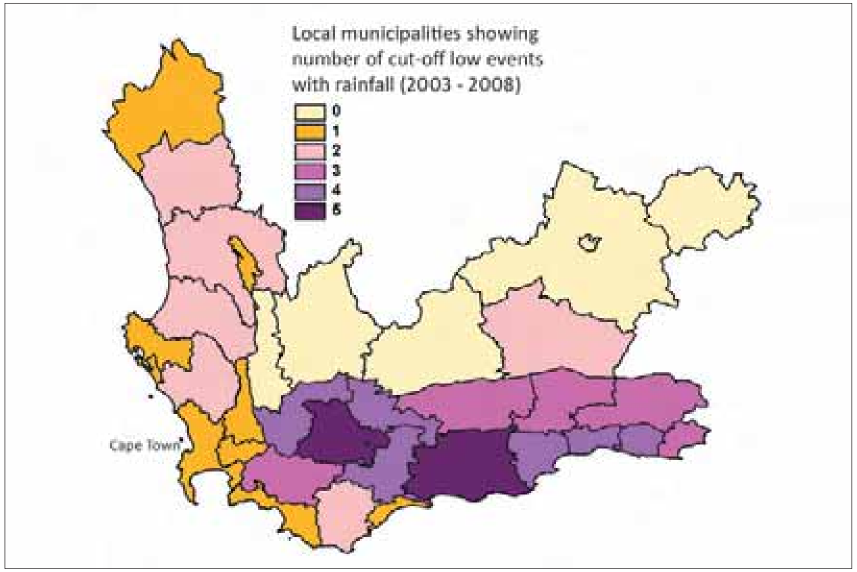


Figure 1.41 Areas impacted by recent severe weather events in the Western Cape, South Africa. [Adapted from: Disaster Mitigation for Sustainable Livelihoods Programme (DiMP), University of Cape Town]

Examples of the range of wider impacts associated with climate change

Up to now, much of the work on climate variability and change including impacts has been based on sectoral impacts – water, food, health and ecosystems and coasts. [3, 10]. While these remain critical areas, a number of other related areas have also begun to broaden the focus to include equally critical issues of climate change. These include climate change and various 'human' security issues including energy, water and health security as well as a range of climate change justice issues (see for example the Global Environmental Change Human Security Programme) [11, 12]. In such efforts, the focus falls not only on the traditional areas of interest, actors and voices, but also includes the voices of those often not heard in these debates (for example, children and the elderly).

These 'silent' voices are now being included in climate change arenas of action that focus on climate change including, for example, refugees [13], climate change and conflict amongst other research themes [14-18]. In a study undertaken by Save the Children (Legacy of Disaster), an estimated 175 million children every year are indicated as being likely to be affected by climate-related disasters of various types in the next decade. Children, however, much like all those impacted by climate change, are not merely victims of change. Children can also be proactive actors that can communicate and share best practice and can mobilise communities to be better equipped to face climate-related risks. Table 1.3 shows a range of community-based efforts to adapt to climate change.

Table 1.3 Some examples of participatory involvement in reducing risks and adapting to a changing climate.

Involving children – some examples of effort in Mozambique	Various community-based activities. Of interest in the work undertaken by Save the Children is the involvement of children in the selection of community-based organisations' projects aimed at supporting livelihood recovery in flood-affected areas.
Identifying those most vulnerable – various methods for example HEA	Use of the Household Food Economy Approach to identify households vulnerable to what hazards and more importantly why? Previous efforts have highlighted the linkages between climate-related risks (for example, drought) and structural drivers of poverty and increasing vulnerability to shocks such as drought and floods.
Interventions to build adaptive capacity for example, safety nets, welfare schemes and cash transfer schemes	Various efforts involving safety nets and social transfer, such as cash transfers, are being tried to ensure resilience both during times of shock and during periods of ongoing vulnerability (see for example, cases for southern Africa from the Regional Hunger and Vulnerability Programme).
Training, education and capacity building	A range of training and other materials that share lessons learnt and good ideas of practice to reduce risks to hazards and climate variability can be found (see for example, DiMP, University of Cape Town, La Red; Desenventar and Provention Consortium, among others).

What may be required to best cope and more importantly adapt to such changes? Some opportunities that may accompany climate change.

A number of areas require attention to enhance coping with weather and climate variability and adaptation to climate change. First, we need to improve our understanding of both the processes that currently influence weather and climate and how such processes may change with future climates. [7, 19]. Second, despite dramatic improvements and recognition of the role of the social sciences and climate change, much more urgent work is required to help us live with such risks and adapt to future changes. If we are to 'live' with change' effectively, we will need inputs from trans-disciplinary and inter-disciplinary sciences, as well as from wider civic society, government, non-government and business. The move for greater community-based efforts (including efforts both in climate change and disaster risk reduction) must continue.

Third, we need accessible and effective communication. This relates to communication in terms of what is meant by climate change as well as communication about possible impending climate events and longer-term projections of climate change. Here the scientific community has not done as well as one would expect given the dramatic changes and advances we have seen in technology and information distribution. Early Warning Systems may need a re-orientation that includes warnings for extremes and shocks as well as enabling actions to be taken with regards some of the daily changes that may accompany climate change [18, 19, 20]. Information on health status and nutritional information, when packaged together with information on possible seasonal rainfall changes, may be required and included into a more flexible system (for example, in municipalities and clinics).

Finally, improved institutional designs, including institutions that enable better 'horizontal' integration of information together with 'traditional', vertical information flows, is being suggested. The design, architecture and uptake and use of such information clearly needs to also start with user input, but such processes are complicated to facilitate and monitor.

Conclusion

Climate change and variability are challenges to all of us. For some, climate change is already occurring and is observable. Of concern, however, is our ability to understand the range of impacts we currently face with climate variability (for example, the causes, costs and consequences of our actions to address such climate risks) and how we interact with such changes. There are several cases from which we can learn and draw lessons. The challenge is: Will these actions be enough to help us live with future change? We may have to move beyond current business as usual and develop new sets of actions, institutions, plans and strategies amongst other efforts – this would enable us to better respond to future challenges associated with climate change.

RIGHT Dryland cereal crop farming on the Highveld, Gauteng. [Graeme Williams, MediaClubSouthAfrica.com]

Wildfires contribute significant amounts of greenhouse gasses and particulates to the atmosphere and destroy the soil. [Rudi van Aarde]

Environmental changes are progressively affecting the future of South Africans through their combined impacts on human livelihood, security and prosperity.

This book is about environmental change in South Africa, its causes, trends, implications, suggested solutions and the technologies and methodologies of observation and analysis. It draws together work from as many scientific disciplines as possible to inform not only the private sector and political decision makers, but also the general public on current environmental issues and challenges.

Observations on Environmental Change in South Africa provides pertinent scientific evidence to assist the people of our country in formulating intelligent and responsible policies and practices for the betterment of our society and to ensure the long-term sustainable futures of South Africans.

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