PROCEEDINGS

of the Agricultural Sector Workshop on Climate Change

7 & 8 February 2006

agriculture

COMPILED BY
I. Kgakatsi, R. Barnard, M. de Villiers,
G. Morakile, M. Motsepe
& S. Mugeri

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The designation employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the ARC-Institute for Soil, Climate and Water or Department of Agriculture.

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Preface

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. Either way, the climate system is extremely complex and relatively poorly understood. This is notably so in terms of extent, timing and impact.

South Africa is particularly vulnerable to climate variability and climate change as farming depends largely on the quality of the rainy season. Fluctuations in areas planted to arable crops and annual yield are directly related to climate conditions and notably to rainfall and rainfall pattern. According to scenarios on climate change, rainfall over most of the country could decrease; temperature could increase; runoff into main river systems could be reduced; veld cover and composition could deteriorate significantly; and the frequency of wild fires could increase. Perturbations in climate parameters and notably of rainfall could be largely amplified by the hydrological system. This could add a further layer of concern to the management of the country's already stressed water sector.

There are indications that climate change could have serious negative effects on food security, economic activity, human and animal health, water resources and biodiversity. Climate change could, furthermore, result in extreme weather events. Climate change could, therefore, affect both the first and second economy, jeopardizing the objectives of the Agricultural Strategy, the Accelerated and Shared Growth Initiative of South Africa (ASGISA) and of NEPAD. Climate change is an indisputable risk to poverty and threatens to undo decades of development effects.

Climate change is not fiction but a stark reality. Current reports on early warning research indicate a decided drying from the west while the occurrence and intensity of natural disasters, such as drought and floods, are on the increase.

Fully recognizing the importance and reality of climate change, the Department of Agriculture's (DoA) Directorate Agricultural Risk and Disaster Management (ARDM) hosted an Agricultural Sector Workshop on Climate Change in February 2006. This Workshop followed the National Climate Change Conference held in South Africa during October 2005. The Workshop was attended by 100 invited delegates from six state departments; eight provincial departments of agriculture; five universities; five NGOs; and other role players namely Agri SA, ARC, Eskom, the International Food Policy Research Institute, NAFU, SANBI and SAWS. The Workshop focused on the mitigation of climate change and adaptation to ensure a sustainable and profitable sector. The objectives of the Workshop were to provide a better understanding and awareness of climate change; to refine the climate change recommendations outlined in the draft Climate Change in Agriculture Discussion Document; and to obtain inputs for the Department's Climate Change in Agriculture programme and plans.

Following the workshop deliberations, draft recommendations for a DoA-ARDM plan of action on climate change activities (Annex 1) were compiled emphasizing aspects such as the importance of awareness campaigns, networking, advisories and training to promote risk management in agriculture and in related sectors; cooperation between strategic parties involved in climate change at both the national and international level; establishing a Departmental Working Group on Climate Change to implement recommendations and to set the scene with regard to climate change aspects; procuring funding for research into climate change science, vulnerabilities, mitigation and adaptation; and equally important, developing criteria for climate change-related research to ensure that both environmental and socio-economic issues are addressed within an agro-ecosystems approach and that capacity building addresses pressing agricultural challenges.

The plan of action proposed to DoA involves leadership by the Department in agricultural climate change activities and continued participation in and support of climate change activities under the aegis of other national and international initiatives. Through its current involvement in climate change activities, DoA is playing an important and proactive role in this important matter. It is considered vital, however, that impetus be maintained through active participation in local activities and governmental initiatives as well as through international negotiations and events.

Agricultural Sector Workshop
on Climate Change Organising
Committee:
Ikalafeng Kgakatsi (Chairperson)
Robin Barnard (Facilitator)
Mara de Villiers
Gontse Morakile
Matiga Motsepe and
Shumani Mugeri

Climate Change and DoA: Yesterday, Today and Tomorrow

I. Kgakatsi

Agricultural Risk and Disaster Management, Department of Agriculture, Private Bag X250, Pretoria 0001
Tel.:012 319 7955/6; Fax: 012 319 6711; E-mail:smarm@nda.agric.za

Introduction

Climate change is a key scientific and policy issue of great concern to all humankind. Climate change, attributed to surface temperature being elevated as a result of the escalation in greenhouse gases in the biosphere, is highly complex. As the effects of climate change are not immediately visible, climate change could be regarded as the silent enemy, likely to affect already high risk and stressed agro-ecosystems and socio-economic welfare.

Climate change has been accelerated since the 1800s as a result of industrialization, mechanization and a constant increase in population. As the effects of climate change manifest in different ways and at different times within the continuum, it was not recognized as a formidable phenomena requiring concerted mitigation and management. In South Africa, for example, throughout its long history, we have been accepting climate variability and isolated but devastating droughts and floods as recurring natural disasters within the already high-risk business of agricultural production – be it for financial gain or for food self-sufficiency – without paying much heed to the possibility of climate change.

The Department of Agriculture (DoA) has been positioning itself to effectively deal with climate change as it affects the agricultural arena. DoA is actively participating in international and national climate change and associated initiatives and national committee activities as described in the Discussion Document, while the Directorate Agricultural Risk and Disaster Management (ARDM) has progressed significantly with notably early warning systems, research, advisories and action plans, to facilitate the mitigation of and adaptation to climate change. A major challenge to these approaches and plans is to ensure that early warnings are effective, interpretable, understandable and accessible to all concerned with agricultural production. As information is useful only to the extent that people can use it to improve the outcome of their endeavours, the availability of information is a formidable challenge when you consider the spatial distribution of notably poor rural livelihoods and their access to information and information sources. These include the uncertainty of climate forecasts.

This paper describes a few selected of the many developments by DoA over the years, research needs, the challenges facing the DoA and the agricultural sector at large and plans to mitigate climate change and to facilitate adaptation to ensure a sustainable and profitable agricultural sector.

Developments by DoA

Climate early warning systems and advisories

Concerning the yesterday, meteorological data, also aimed at agriculture, was collected by the Cape Colony Department of Irrigation and the observatory prior to 1910. In 1940 the Department of Agriculture decided that the weather data did not meet with agricultural requirements and the Department established its first agrometeorological station at Bien Donnè in the Western Cape Province in 1941. This was soon followed by the installation of weather stations within other agricultural regions, one of their tasks being to predict detrimental climate-induced pests and diseases. Today, the agricultural weather stations network covers the whole of South Africa and as a public asset, maintained by the ARC, the network is being expanded annually to eliminate areas where weather stations are too sparsely populated. Data collected by the agricultural weather stations network supplements data collected by SA Weather Service (SAWS), as per committee agreement reached in 1957. The data populates the national agrometeorological databank and information system. The long-term data, collected for almost a century, forms the basis of informed early warning systems and advisories. One of the very first early warning systems developed, was for the angora goat industry, a warning still transmitted *via* radio and TV, but now under the banner of SAWS.

In 1988, the Department vested in the development of a geographic information system (GIS) to provide a structural framework for the acquisition, storage, retrieval, analysis and display of data within a spatial reference system. GIS formed the basis of the Agricultural Geo-referenced Information System (AGIS), South Africa's official information system for agriculture, launched in 2002. The soil, climate and veld information systems developed over the years, are the cornerstones of AGIS. Most important links accessible through AGIS include an irrigation information system; a flood damage assessing system; the monthly Umlindi drought risk management system and newsletters; and alien vegetation mapping information, all ideally suited for climate change studies. AGIS (www.agis.agric.za) is structured on national and provincial level in such a way that tasks are coordinated and integrated as provincial, regional and national sets of data, models and decision support systems. AGIS is a difficult source of information for rural poor to access but multi-purpose centers (MPCs) and internet cafes are being established to address this.

Another landmark in view of climate change studies, natural resource monitoring and auditing, and early warning systems, was the development of a remote sensing unit at the Soil and Irrigation Research Institute (now the ARC-Institute for Soil, Climate and Water) of the Department. This development resulted in a very useful public asset, namely the four coarse resolution satellite image and information systems (NOAA, MODIS, SPOTVGT and MSG) covering South Africa, southern Africa and the whole of Africa at different resolutions. Archived earth observation data is typically used for climate verifications and seasonal planning; for the monitoring and assessment of climate change, including the monitoring and assessment of above-ground carbon credits in view of carbon budgeting; for drought and fire early warnings; and for advisories on drought and vegetation conditions. These information systems are linked to AGIS. The extent of AGIS being utilized effectively as an information tool by end-users has not been quantified and the effective utilization of AGIS remains a challenge.

Today, in addition to the early warning systems described above, a committee of significant importance is DoA's National Agrometeorological Committee (NAC) established in 2003, tasked with facilitating the timely dissemination of information to farmers to warn them of impending climatic disasters and to advise on strategies to manage risks effectively and to ensure sustainability. This multi-institutional committee, comprising the ARDM, the SAWS, the ARC and the nine provincial departments of agriculture, distributes comprehensive monthly advisories and guidelines to extensionists. The NAC chaired by the ARDM Directorate meets four times per year. ARDM conducts weather and climate awareness training workshops for NAC members in all the provinces. During these workshops, spread over approximately five days, Provincial Early Warning Committees are elected. To date, 257 information/extension officers, economists and agricultural scientists from seven provinces have been trained. The provincial members of NAC submit provincial reports, which are incorporated into monthly advisories. These monthly advisories include advisories on land use; cultivation; crop choice; fertilization; and stock management. Detailed climate advisories can be accessed at www.nda.agric.za/docs/advisory.pdf. Updated seasonal forecasts can be viewed on the website www.weathersa.co.za. Seasonal forecasts are based on models used by SAWS and the Southern Africa Regional Climate Forum. Although not members of NAC, community involvement is of the utmost importance.

DoA's Early Warning Unit, in addition, has the task of monitoring and evaluating the effectiveness of the early warning system.

Key elements of an effective early warning system

Early warning can be defined as the issuing of accurate and timely information from an identified institution that is aimed at alerting individuals at risk to avoid or minimize the impact of disaster. For agricultural purposes, early warning can be any information on any risk that may hamper agricultural production, such as weather and climate conditions, pests and disease, market prices and other factors affecting the agricultural sector.

Bearing in mind the definition of early warning, early warning could be regarded as the foundation of decision-making, regardless the level of decision-making. The timely flow of information is, therefore, of the utmost importance. The Early Warning Unit, operating under ARDM, has been tasked to ensure the effective planning and implementation of early warning systems in support of risk management. ARDM subsequently adopted the following four key elements as basis for their early warning system:

- Prior risk knowledge;
- Monitoring and warning service;
- Dissemination of information/warnings; and
- Response capacity.

These key elements of an early warning system are integrated and interdependent. Ignoring even one of these elements would cause failure of the whole system.

Disaster management

In South Africa, with a highly variable climate, drought and floods are common and are increasing in frequency and intensity as a result of climate change. In addition, high summer temperatures and cloudless days cause a high evaporation rate while high-energy rainstorms, conducive to runoff, soil compaction and crusting, are the rule rather than the exception. Agricultural production in South Africa, bearing in mind the vagaries of climate and climate change compromising national and household food security as well as economic growth, is a very high-risk business, but decidedly so for the 2nd Economy lacking coping strategies. Underdevelopment, poverty and marginalisation most often characterize those caught in the 2nd Economy and in the vicious spiral of the poverty trap.

The agricultural history of South Africa reflects regular crises due to the cyclic nature of climate and the devastating effects of regular drought and floods, not only requiring disaster aid, but conducive to food shortages. The occurrence of seasonal rain directly affects the availability of food; crop planting dates; harvesting; the occurrence of pest and disease; access to markets; the pricing structure, even for staples; the success of agricultural production in the following season; and the condition and carrying capacity of rangelands and veld. The most recent crisis is the drought experienced in the second half of 2001 and in 2002, followed by, at present (Febr. 2006), heavy down pours, which brought welcome relief, but flooded the ecologically vulnerable Taung area in the North West Province. This is a typical scenario the ARDM Directorate is confronted with, quite often on an annual basis. It is postulated that the intensity and frequency of such natural disasters will increase as climate change progresses.

Disaster aid to farmers is not new to South Africa. Prior to the democratic dispensation in 1994, drought assistance and incentives to commercial farmers to promote sustainable agricultural production was common, despite the coping strategies of these farmers. The picture has changed significantly since 1994 as DoA's mandate is to serve all farmers and national as well as household food security. To form an idea of the extent of DoA's service required, it should be noted that, at present, there are an estimated 57 000 1st Economy and 240 000 2nd Economy farmers. In addition, an estimated 3 million household farmers, producing largely for family consumption, are located mainly in the communal areas of the former homelands. The imperative for DoA was, therefore, to move to an enabling disaster management approach rather than to follow the historical disaster aid pattern, which is not necessarily conducive to sustainable agricultural production and which the country simply cannot afford.

The above scenario is by no means endemic to South Africa. All SADC countries, and as a matter of fact, most Africa countries are faced with the same climate and climate change catch 22. In view of shared problems, DoA, and notably the ARDM Directorate, participates in SADC and Africa initiatives. These include participation in international conferences on disaster risk reduction and early warning.

Africa Ministers Meeting

During the African Union (AU) Ministerial Conference of Ministers of Agriculture (January/February 2006) held in Bamako, Mali, the following communal problems regarding agriculture were raised:

- Agriculture is the nexus of economic growth in Africa and the only means of ensuring food security;
- Inherent soil infertility and water constraints are the most limiting factors to agricultural production and agricultural productivity. As dryland agriculture constitute more than 95% of the sub-Saharan Africa farm output, water constraints are of critical importance;
- Limited land availability and land suitability for agricultural production result in encroachment into forests and marginal agricultural potential lands;
- Development encroaches into arable agricultural land. This encroachment is the result of, for example, infrastructure development, industrialization and population growth;
- The expansion of irrigated agriculture. Irrigated agricultural production is a stabilizing production factor in arid and semi-arid areas. In South Africa, for example, irrigated agriculture is responsible for about 30% of the total crop production but, in view of the availability of water, land suitable for irrigation and the increasing competition for limited water supplies by the domestic and industrial sectors, the area presently irrigated cannot be expanded significantly. South Africa, therefore, places a high priority on the revitalization and rehabilitation of existing irrigation schemes and, above all, on water use efficiency;
- Wetland conservation should gain in importance as an environmental management strategy. Wetlands act as natural water harvesting points and constitute a valuable agricultural resource with significant benefits in terms of food security, health and income. Alien plant invasion is a major threat to wetlands managed in an unsustainable manner;
- Soil fertility management is of the utmost importance in Africa. Judicious soil fertility management is conducive to increasing soil organic matter essential for a healthy soil;
- The use of fertilizer to correct soil infertility is low or non-existent in many Africa countries despite low soil fertility. This is attributed to the price structure of inorganic fertilizers and their availability;
- During a recent Conference of Parties (COP 11) under the umbrella of the United Nations Framework Convention on Climate Change (UNFCCC) held in Canada in 2005, fertilizer issues relevant to climate change were raised during side events organized by fertilizer companies. These issues were pursued during the Africa Fertilizer Summit held recently in Nigeria.

Current status of risk and disaster management

- The Directorate Agricultural Risk and Disaster Management is tasked with risk and disaster management within all farming communities, with emphasis on the climate change scenario;
- The core team involved in climate change are the DoA Directorates Agricultural Risk and Disaster Management (ARDM); Land Use and Soil Management (LUSM); Water Use and Irrigation Development (WUID); Scientific Research and Development (SRD); and the ARC;
- The DoA promotes and facilitates synergy among the Rio conventions; the Convention to Combat Desertification (CCD); the Convention on Biodiversity (CBD); and the United Nations Framework Convention on Climate Change (UNFCCC) at international level;
- At national level, the Directorate ARDM plays a leading role in the Governmental Committee on Climate Change (GCCC); and the National Committee on Climate Change (NCCC), the advisory body to the Minister of Environmental Affairs and Tourism;
- A DoA mandate is to develop and implement a national climate change response strategy and plans specifically for agriculture;
- DoA is tasked to make the agricultural sector aware of climate change;
- In view of the agricultural climate change strategy and its climate change awareness campaign, the Agricultural Sector Workshop on Climate Change was organized. This Workshop is regarded as most important as it forms part of the foundation for future actions to be taken.

Research and some salient points

In its attempt to ensure goal-directed and outcome-based climate change research, the Directorate ARDM and the Workshop facilitator requested research and related institutions involved in climate change studies, to submit their current initiatives relating to climate change. These are reflected in the appendices of the Discussion Document.

It is unfortunate that some of the institutions concerned did not respond to the request. The appendices, however, provide a fair overview of current research and capabilities in South Africa.

Research projects funded by DoA and, of the utmost importance within the climate change scenario, are the carbon sequestration and atlas being prepared by the ARC and the University of KwaZulu-Natal respectively. Plans to evaluate response to the atlas will be done following the completion of the atlas as well as undertaking the economic analysis. Project output on the economic analysis will be undertaken soon**.**

During the World Summit on Sustainable Development (WSSD) of 2002, DoA was allocated the natural resource management mandate and ARDM's climate change initiative forms a critical part of this mandate.

DoA, as custodian of agriculture, fully realizes the importance of climate change. DoA should be conversant with mitigation techniques and facilitate adaptation to ameliorate vulnerabilities. DoA's concerns regarding climate change research projects entail the following:

- Research institutions should identify research projects and advise government of such essential research;
- Research institutions sourcing research funds under the banner of DoA but not informing DoA in advance. This is of notable importance regarding policy issues;
- Lack of information sharing by researchers with government pertaining climate change-related research progress, hinders the decision-making process;
- Institutions expect government to be proactive regarding climate change research and this should be *vice-versa***;**
- Lack of a multidisciplinary approach towards climate change. An integrated approach is paramount in all research implementation strategies.

Scientist sometimes blame decision-makers for not factoring climate change issues in their short- and long-term planning in terms of climate change mitigation and adaptation even if its unreliable. Scientists should make research findings or outputs available so as to assist decision-makers with their mitigation and adaptation plans.

Weather, climate and for that reason, any other information is *useful* only to the extent that people can use it to improve their outcome beyond what they would otherwise have been.

Challenges

- Efforts to mitigate climate change effectively and to ensure timely adaptation require a value chain and the flow of information to influence production and finally the consumer. The value chain is comprehensive and includes elements such as inputs, infrastructure and packaging prior to reaching its final destination, namely the consumer;
- Climate information, to be used effectively, must reach agricultural management, decision makers, extension services, organized agriculture and all farmers in a timely and interpreted way;
- Informed crop diversification to minimize and wisely manage risk;
- Economic analysis should be a element within the management style of both established and developing farmers;
- Plant and animal diseases are part and parcel of climate change effects. Pest and diseases should receive concerted and proactive attention. It is well known that there is already new cases of malaria in a previously malaria-free zone;
- To be able to better understand climate change and its effects, to facilitate early warnings of and to mitigate climate change effects, inventories of greenhouse gases are inevitable;
- Bio-fuel in particular as well as biogas research and development should be persevered with as the lesser use of fossil fuels and oil is paramount in view of mitigating climate change. Natural resources and environmental impacts as well as food security should, however, underpin these developments.

Conclusions

- A comprehensive climate change programme for the agricultural sector is a high priority. This Workshop, taking cognizance of the experiences of different agricultural sector stakeholders with climate change, is a most important part of developing this long-term programme with far-reaching effects. The Discussion Document: Climate Change and the Agricultural Sector in South Africa, is an important building block of the proposed programme;
- In addition to the programme on climate change, draft plans for the sector should be compiled as a matter of urgency;
- Continued discussions with farming communities are imperative. The farming community is an important part of the value chain. Without their knowledgeable participation in developing and executing the proposed programme, all our efforts could be futile and we will not be able to effectively address the multiple challenges of climate change;
- Consultation with all stakeholders should continue;
- Awareness of climate change and its real and postulated effects are paramount. Knowledge starts with awareness – and adaptation and adoption is possible only when there is knowledge;
- Climate change and relevant related research must continue and be enhanced in a goal-directed way;
- The conservation and resilience of the natural resources are to be maintained by a concerted integrated agro-ecosystems approach. Regardless our plans, programmes and efforts, the challenges of climate change cannot be faced effectively, and sustainable development and economic growth will stay evasive if not founded in a healthy natural resource base.

Summary of the South African National Climate Change Conference October 2005

G.F. Midgley

Global Change Research Group, South African National Biodiversity Institute, P/Bag X7, Claremont 7735
Tel.: 021 799 8708; Fax: 021 797 6903; E-mail: midgley@sanbi.org

Abstract

A summary of the South African National Climate Change Science Conference that took place at Midrand in October 2005, is presented. Major science messages are abstracted from the conference presentations and some key recommendations are presented.

Introduction

Global climate change science has an appreciable history in South Africa and in southern Africa. This field of science is multi-disciplinary, inherently diverse and ranges from the study of physical atmospheric processes through biological and ecological responses and feedbacks, to interactions with human society and economic activities. South African scientists have played an important role in raising awareness of this field of study and its relevance for developing regional, national and local responses to the threat of climate change. In this regard, a series of scientific conferences has been held on this topic, beginning with a national workshop in 1987 (Long term data series relating to South Africa's renewable resources), followed by several national conferences and coordinated research activities. In 1989 the national conference on Geosphere-Biosphere Change in Southern Africa was held at the University of Cape Town and in 1995 the International Geosphere Biosphere Program (IGBP) supported a regional conference, Global environmental change: Implications for southern Africa, at the CSIR in Pretoria. In the late 1990s, many South African scientists contributed to the SA Country Study on Climate Change and in 2003 the conference Global change and regional sustainability was held at Kirstenbosch in Cape Town.

These activities, together with ambitious regional multinational scientific studies, such as the SAFARI and SAFARI 2000 studies on regional atmospheric impacts of natural and human-caused fires in southern Africa, raised awareness of global environmental change. On-going research has also provided information for national negotiating teams involved in deliberations under the United Nations Framework Convention on Climate Change (UNFCCC). These activities informed the drafting of the Initial National Communication – submitted to the UNFCCC in 2003 and the National Climate Change Response Strategy, which was released in September 2004, and which provides a framework for climate change response in South Africa. However, it is increasingly recognized that scientific meetings and activities must engage actively and more broadly with stakeholders and affected parties.

Thus, South Africa's National Climate Change Committee (NCCC), a multi-stakeholder forum set up to guide the Department of Environmental Affairs and Tourism (DEAT) on matters relating to climate change, decided early in 2005 to combine a focused science meeting with a meeting of stakeholders in a parallel consultative programme, encouraging mutual interaction and exchange of information to allow a deeper understanding both of the science and its uncertainties, and the concerns of those potentially affected. For this reason, key scientific inputs were canvassed from scientists from a wide range of disciplines and regions, and merged into an exciting and innovative programme to allow productive interaction with stakeholders in a consultative framework. To this end, many mainstream national and international scientists who have published their work in high impact journals such as *Nature* and *Science,* are included in the science programme. It was not possible to be fully inclusive in this exercise, but rather to provide a window on the developing science of global change and its uncertainties, specifically with reference to Africa, and through this to test this approach for future deliberations. In addition, broad stakeholder involvement in the planning of the Climate Change Conference was ensured through the engagement of a wide range of members of the NCCC. Stakeholders from the NGO and business communities were also invited to attend and to host their own side events and exhibition stands.

The programme of the consultative conference was developed to allow for informal discussion, debate and feedback from the scientific conference. A broad range of issues was slated for discussion, particularly with regard to their impact on South African climate change policy. Stakeholders were invited to contribute to debate and to shape conference outcomes. Therefore, this combination of meetings was a truly creative attempt to bring together scientists, politicians, NGOs and other stakeholders in the same venue to discuss and deliberate on the urgency and

FIGURE 1: Programme of the South African National Climate Change Science Conference, October 2005

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM

Climate Change Science in Africa

Day 1: Monday, 17 October		
07:30-10:00	Arrival, registration and tea / coffee	
Session 1	**Chair: Ms Pam Yako, Director General Department of Environmental Affairs & Tourism**	**Opening session**
10:00	Minister of Environmental Affairs & Tourism, Mr M. van Schalkwyk	Opening Address
10:20	Minister of Science and Technology Mr M. Mangena	Keynote Address
10:45	Dr Rob Adam, Director General, Department of Science and Technology	A climate change R&D strategy for South Africa
11:15	Professor Sir Peter Crane, FRS, Director, Royal Botanic Gardens, Kew, UK	Global change and evolution – how will species stand the tests of time?
11.45	Professor Andrew Watkinson, Tyndall Centre for Climate Research, UK	Translating sound climate science into practical and effective public policy
12:30	Adjourn to luncheon hall	
12:30	Lunch	
Session 2	**Chair: Dr Rob Adam, Director General, Department of Science and Technology**	**The science of climate change**
13:30	Dr Luanne Otter, Climate Research Group, University of the Witwatersrand, S Africa	Global change in Africa: towards a synthesis of the science
13.50	Prof Bruce Hewitson, Climate Systems Analysis Group, University of Cape Town, S. Africa	Regional projections of climate change for Africa
14:10	Dr Richard Betts, Hadley Centre, UK	Synergistic interactions between vegetation and climate systems in Africa
14.30	Dr Myles Allen, Oxford University (telephone conference link from Oxford/Royal Soc)	Climate change attribution and detection in Africa
15:00	Questions and open discussion	
15:30	Tea / coffee	
Session 3	**Chair: Prof Urmila Bob, UKZN**	**Modelling impacts and adaptation to CC**
16:00	Prof Colleen Vogel, Univ. of the Witwatersrand, South Africa & Prof Sue Parnell, University of Cape Town, South Africa	Climate change impacts on African cities and societies
16:20	Mr Graham von Maltitz and Ms Carmel Mbizvo, CSIR, South Africa	Likely impacts of climate change on biodiversity based livelihoods
16:40	Mr Randall Spalding-Fecher, ECON South Africa	Human health and climate change in southern Africa
17:00	Prof Roland Schulze, University of KwaZulu-Natal, South Africa	Climate change and water resources in South Africa: Where from? Where to?
17:20	Questions and open discussion	

18:00	Session adjourns	
19:00	**Gala Dinner for Science and Consultative Conference Delegates. Hosted by Deputy Minister of Science and Technology, Mr D. Hanekom**	

Day 2: Tuesday, 18 October		
Session 4	**Chair: Dr Luanne Otter (Wits University)**	**Ecosystem impacts – I.**
09:00	Prof John Reynolds, University of East Anglia / Simon Fraser University, Canada	Marine ecosystems and fish under climate change
09:20	Dr David Obura, CORDIO, Kenya	Climate change and African tropical coral reefs
9.40	Prof Steven Chown, Stellenbosch University, S Africa	Biodiversity responses in the Southern Ocean African islands
10:00	Questions and open discussion: implications for natural resource management and ecosystem services	
10:30	**Tea / coffee**	
Session 5	**Chair: Mr Saliem Fakir (IUCN-S Africa)**	**Ecosystem impacts – II.**
11.00	Dr Tiba Kabanda, University of Venda	Droughts in South Africa are becoming longer, more intense and more frequent: is it a boost from climate change?
11:20	Dr Pam Berry, Oxford University & Dr Richard Pearson, American Museum of Natural History	Species migration under climate change
11:40	Dr Guy Midgley, Mr Barney Kgope, Dr Nthabiseng Motete* & Mr Brian Mantlana, South African National Biodiversity Institute	Modelling and experimental approaches to quantifying species responses (*Currently at DEAT)
12.00	Ms Wendy Foden, South African National Biodiversity Institute	Detecting and monitoring climate change impacts in arid ecosystems
12:20	Questions and open discussion: implications for natural resource management and ecosystem services	
13:00	**Lunch**	
Session 6	**Chair: Prof Brian Huntley (SANBI)**	**Ecosystem impacts – III.**
14:00	Prof David Thomas, Oxford University, UK	Climate change impacts on southern African landscapes in the 21st Century
14:20	Prof William Bond, University of Cape Town, S Africa, & Mr Barney Kgope, SANBI	CO_2, fire and African ecosystems
14:40	Prof Chris Thomas, University of York, UK	Climate change and extinction risk of African terrestrial biodiversity
15:00	Prof Norman Owen-Smith, Univ. of the Witwatersrand, S Africa	African mammal population responses and extinction risk.
15:20	Dr Jane Olwoch, University of Pretoria	Climate change, ticks, and tick-borne diseases in Africa
15:40	Questions and open discussion: implications for natural resource management and ecosystem services	
16:15	**Tea**	
Session 7	**Chair: Dr James Murombedzi (IUCN-ROSA)**	**Global change professional capacity & networks**
16.45	Mr Graham von Maltitz, CSIR Environmentek, South Africa	Strategic research and professional capacity: AIACC
17.05:	Dr Luanne Otter, University of the Witwatersrand and PACOM/START	Strategic research and professional capacity: the START network
17.25	Profs Paul Desanker & Michael Adewumi, AESEDA, Pennsylvania State University	Strategic research and professional networks: AESEDA
17.45	Mr Martin Hendricks & Prof Mark Gibbons, University of the Western Cape, & Prof John Lambshead, Natural History Museum, London	Professional capacity building through bilateral engagement: the NRF/Royal Society experiences
18.05	Facilitated discussion – Priorities for capacity and research integration on the African continent (L. Otter or C. Vogel and P Barnard)	
18:30	Session adjourns	

19:00	**Evening events Dinner packs will be provided for delegates**	
19:00-21:00	Bruce Hewitson, Roland Schulze, Amadou Gaye (co-facilitators)	Interactive Workshop: Data resources for regional climate change analyses

Day 3: Wednesday, 19 October		
14:00-17:30	**Parallel workshop session 1:** **Interactive workshop:** New Research from Emerging Scientists **Facilitators:** Barney Kgope (SANBI) and team [facilitated open discussion on key themes]	**Parallel workshop session 2:** **Interactive workshop:** Compound Impacts of Invasive Species & Climate Change Project **Facilitators:** Guy Midgley, Greg Masters [planning meeting related to the proposed project]

potential responses to the threat of climate change in southern Africa and Africa as a whole. In this short report, the main outcomes of the science conference are addressed.

Programme and outcomes of the science conference

The Science Conference benefited from substantial support from the Royal Society, United Kingdom, who funded the attendance of key researchers in climate change and ecosystem science. The programme focused, to a large extent but not exclusively, on ecosystem and biodiversity impacts (Figure 1). The key science messages flowing from this programme and subsequent discussion, are summarized:

The influence of human beings on climate change in South Africa, southern Africa and Africa as a whole is real and identifiable. Observed trends are consistent with the best scientific models of climate response.

Observed climatic changes include:

- Widespread, significant increases in air temperature;
- Regionally specific changes in rainfall patterns (including drying trends in western regions of southern Africa associated with rising temperatures over the Indian Ocean region); and
- Increasing rainfall variability in some eastern regions.

Observed climatic changes are implicated in declining populations of some indigenous African species, both on land and in the ocean, and especially in coral species on east African tropical reef systems and in freshwater systems, with locally significant impacts on human livelihoods and nature-based tourism.

Southern Ocean islands show evidence of glacier retreat and ecosystem changes due to warming and drying trends, emphasizing the universality of these changes.

Future global warming of between 0.7 and 1.4°C is projected by the middle of this century with a high degree of consensus, but warming over continents could be even greater. Continued warming and climate change beyond 2050 is very likely, but its rate depends on patterns of global fossil fuel use and poorly understood feedback from the biosphere.

Ongoing climate change may cause a widespread increase in evaporation and further drying over the western regions of southern Africa, including the Western Cape and Northern Cape Province. Greater rainfall variability and increasing rainfall intensity over eastern regions is likely, with positive implications for deep soil water recharge events, but a greater erosivity of rainfall events. These changes all have far-reaching implications for water resource management strategies.

Projected impacts of alleged climate change on natural ecosystems and indigenous species are overwhelmingly negative, including potential destabilization of Kalahari dune systems in the west, but higher rates of bush encroachment projected in eastern regions. Potential species extinctions are projected throughout southern Africa, notably in the western regions of southern Africa, which is a particular threat to the Succulent Karoo and Fynbos Biomes. These impacts on species will negatively affect human livelihoods, especially those of the rural poor.

Key sectors such as health and agriculture urgently require updated assessments of their vulnerability to climate change. Early indications suggest significant impacts on rural livelihoods and food security, but in-depth assessments are lacking and represent a major vulnerability and the unknown.

Overall, the projected biophysical and socio-economic impacts of ongoing and projected climate change in Africa, southern Africa and South Africa are overwhelmingly negative, indicating a strong need both for developing adaptive responses and a focus on facilitating global reductions in greenhouse gas emissions.

Significant scientific uncertainties remain, but in no way undermine the key messages above. Coordinated multi-disciplinary research is needed to address these, focusing at least on regional projections of changes and their biophysical and socio-economic impacts, feedbacks to the climate system from the biosphere and marine system, interactions with other disturbances such as fire and invasive species, and the development of adaptive strategies.

Conclusions

South African and international scientists made a compelling case that climate change is occurring, is detectible, and could result in a range of impacts on the African continent. Impacts on South Africa could include increases in the distribution and intensity of drought e.g. in the Limpopo Province (although there are contradictions between broad scale GCM projections and projections that are mechanistically downscaled); potential impacts on agricultural crop yields with some negative implications for food security; heightened growth rates of invasive species under warmer conditions; catastrophic marine coral bleaching that could take place every 5 years in East Africa by 2015; an increase in endemic species at greater risk of extinction as climatically suitable areas may be progressively reduced in extent; and increased areas may be affected by vector-borne diseases, including malaria.

Scientists recommended several actions, including a focus on small-scale livelihoods for marine fisheries; clustering nature reserves to allow for wild species migration and dispersal; an advance in understanding vulnerability, integrated assessment modelling, food security, capacity building and increasing post-graduate student training to provide a strong growth of professionals for future needs in addressing these trends; and a strong relationship with stakeholders in promoting awareness of climate change and adaptation. It was also proposed that an African Network on Global Environmental Change could contribute to integrating different scientific perspectives and allowing African scientists to present regionally coherent views to policy makers.

Climate change and agriculture: Water sector relationships in South Africa [1]

R. Schulze

School of Bioresources Engineering & Environmental Hydrology,
University of KwaZulu-Natal, Private Bag X01, Scottsville 3209
Tel.: 033 2605 489, Fax: 033 2605 818; E-mail: schulzer@ukzn.ac.za

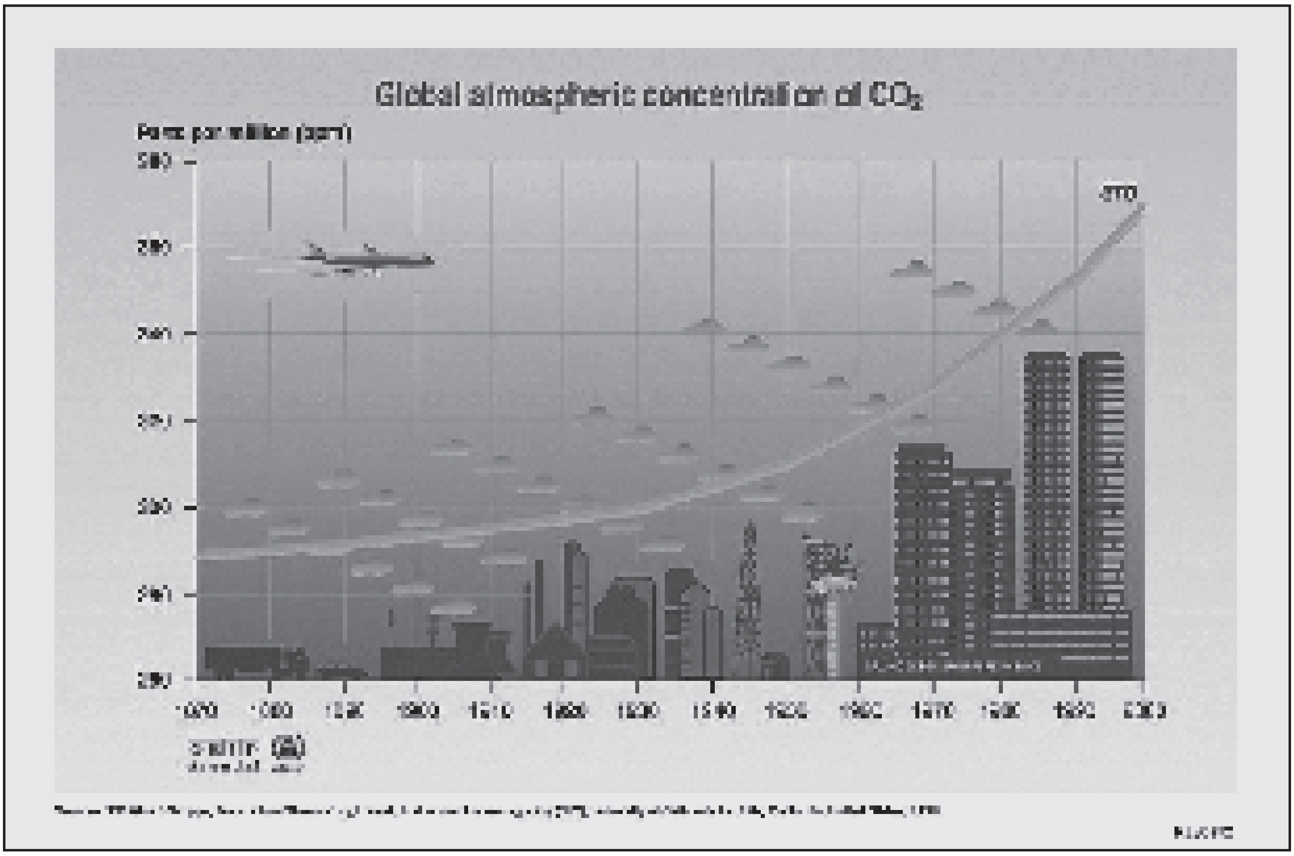
Introduction

Concepts, some results from case studies and thoughts towards a way forward are being discussed in view of the realities and direct and indirect consequences of climate change on the agricultural sector. Uncertainties prevailing in the climate change debate are mentioned as these should be taken cognizance of when compiling feasible plans of action to conserve natural resources, to minimize environmental impact and to ensure sustainable rural livelihoods.

Climate change observations

Observations are portrayed in the increase in global atmospheric CO_2 concentrations over 130 years (Fig. 1); temperature anomaly (Fig. 2); annual means of daily minimum temperatures between 1950 and 1998 at Cedara in the KwaZulu-Natal Province (Fig.3); trends in last frost date (Fig.4); 50-year trends in the number of rain days in April for South Africa (Fig. 5); a comparison of annual median reference potential evaporation (1950 – 1969 *versus* 1980 – 1999) (Fig. 6); a comparison of the range in lowest and highest flows in

Fig 1



1 As the author was unable to submit the manuscript to be published as agreed, the Organising Committee took the liberty to compile this paper from the author's oral paper presented during the Workshop. The Organising Committee takes no responsibility for the correctness of the contents of the paper.

10 years of accumulated summer stream-flows (1950 – 1969 *versus* 1980 – 1999) (Fig. 7); and shifts in the timing of three summer months with the highest accumulated stream-flows (1950 – 1969 *versus* 1980 – 1999) (Fig. 8).

Fig 2

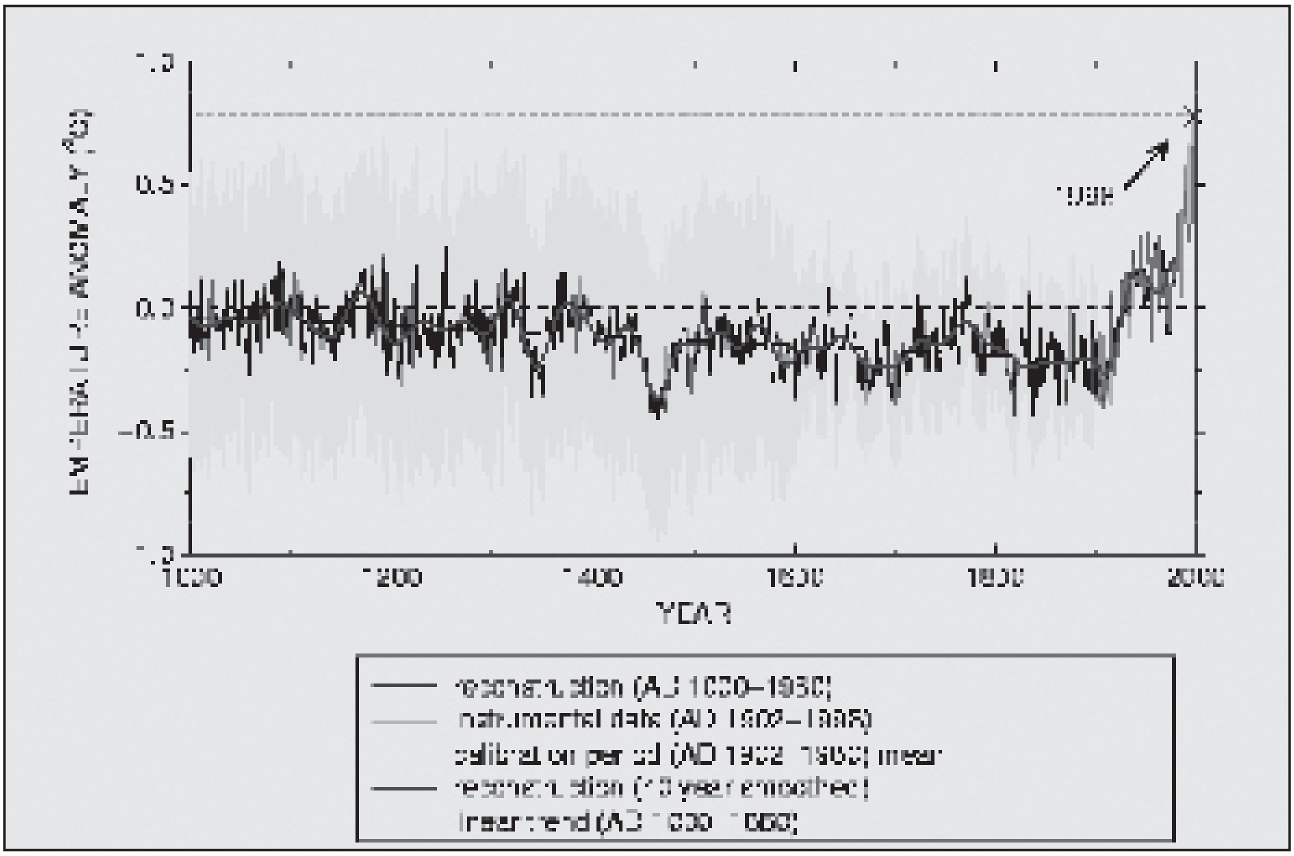


Fig 3

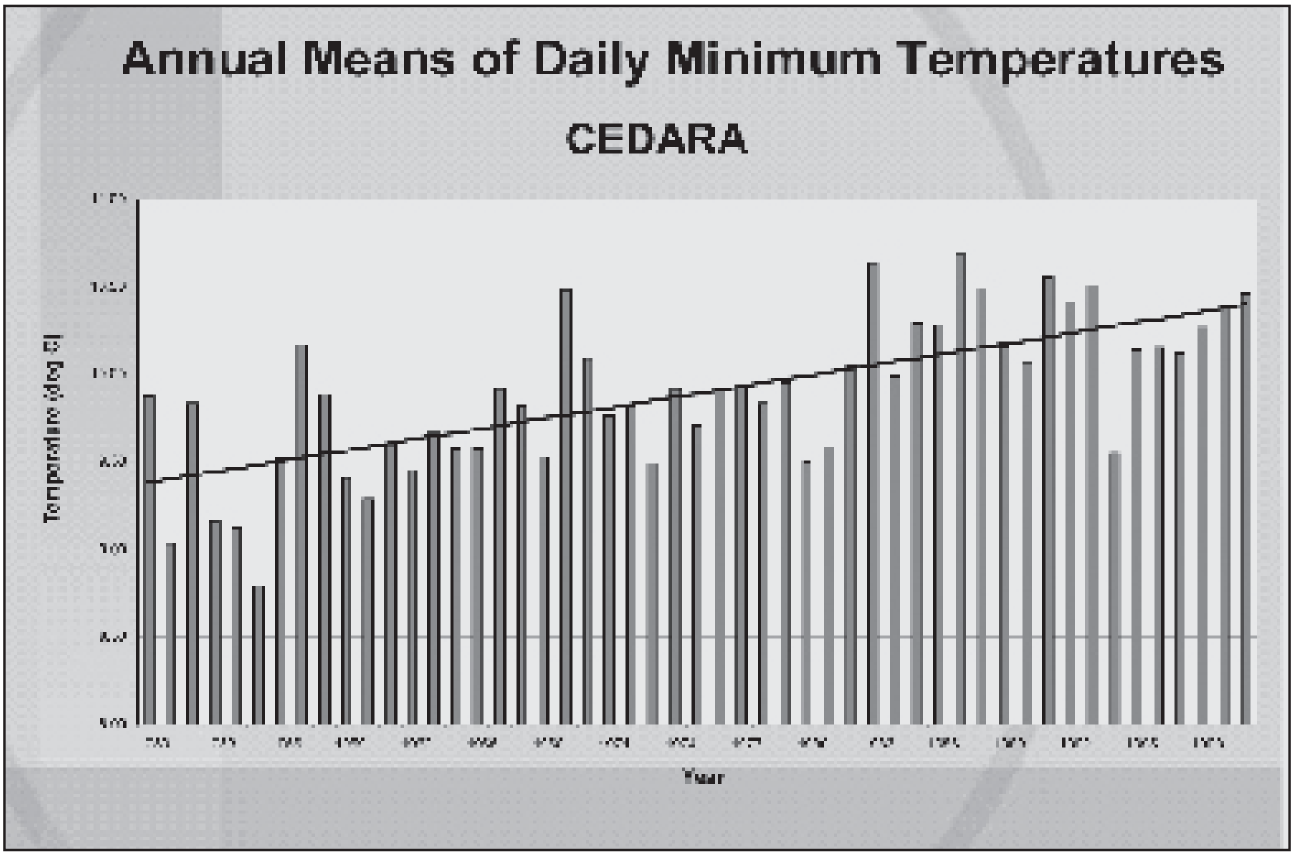


Fig 4

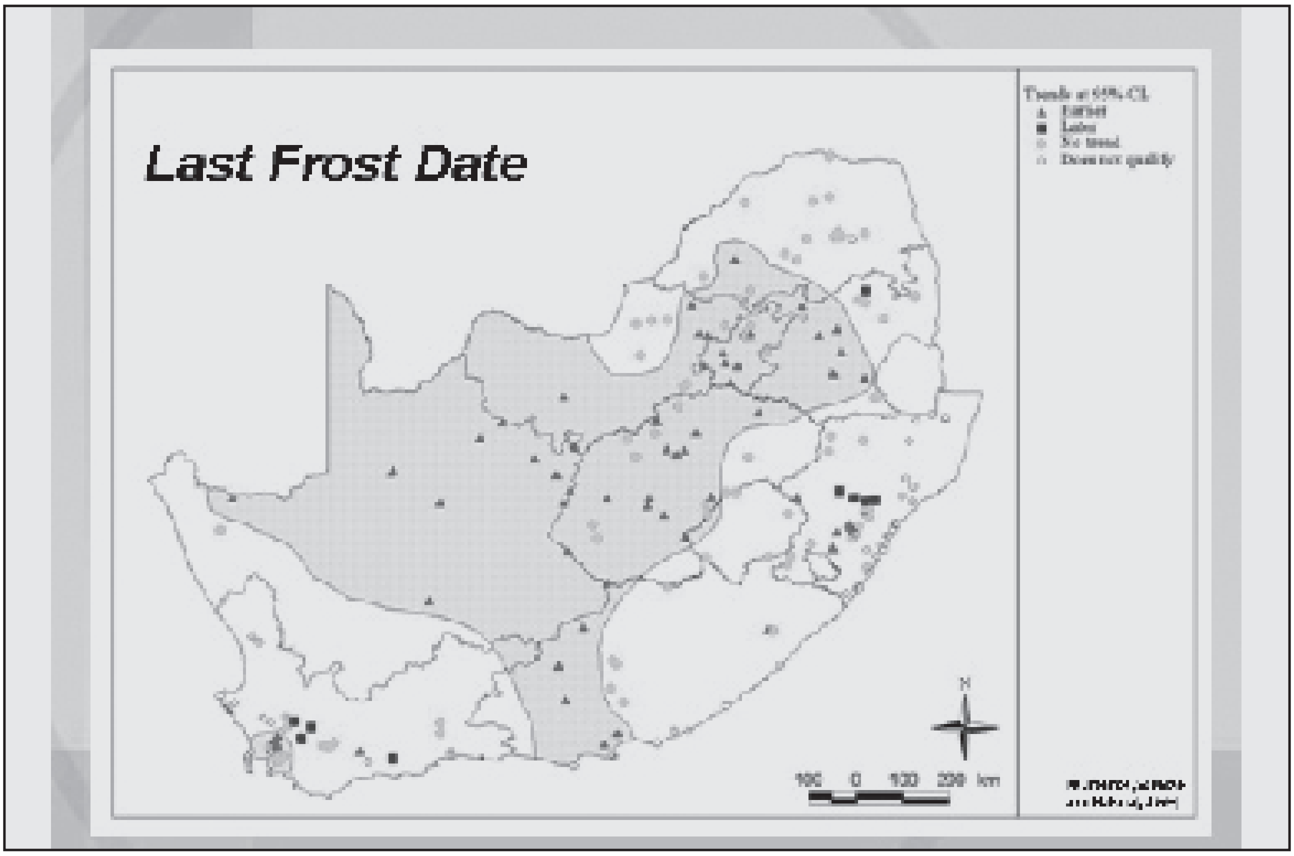

Last Frost Date
N
100 0 100 200 km

Fig 5

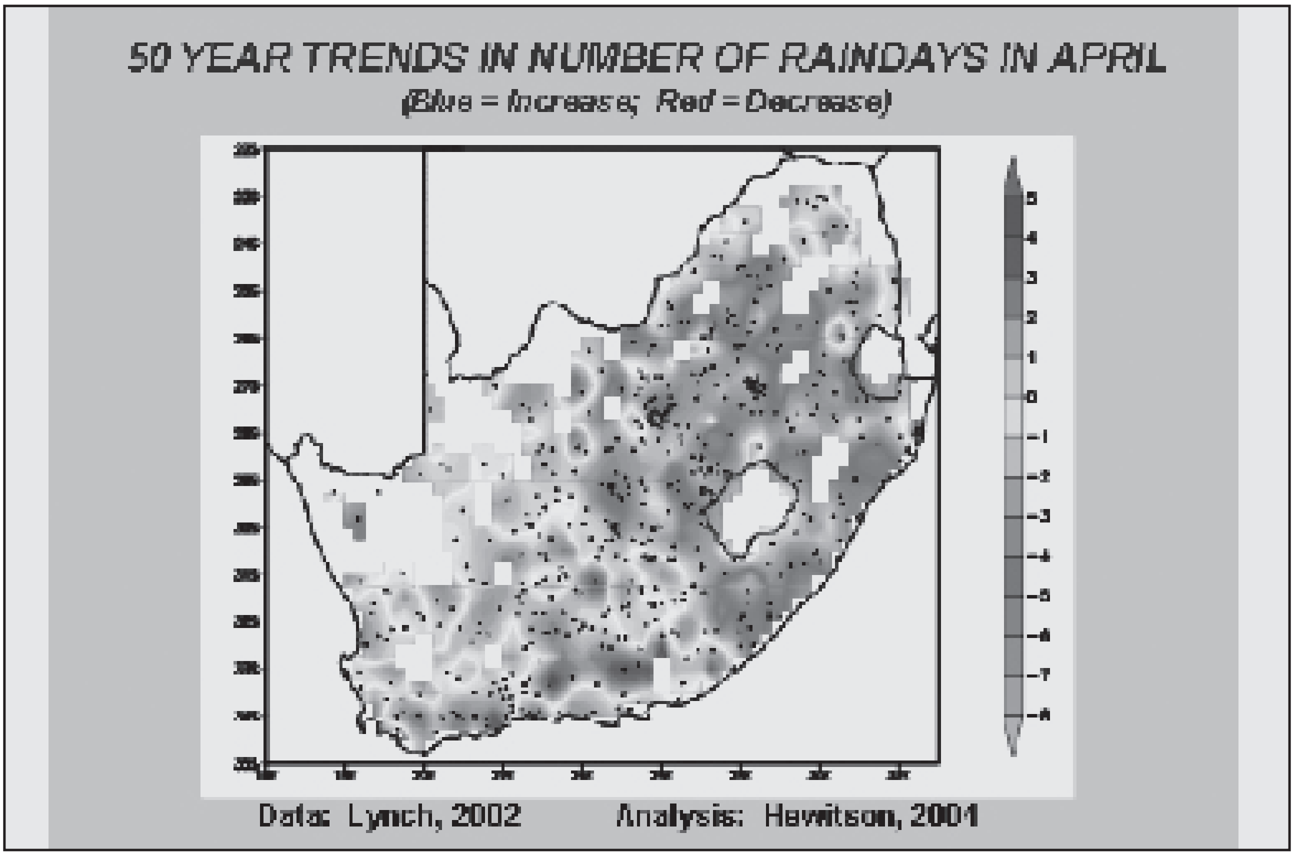

50 YEAR TRENDS IN NUMBER OF RAINDAYS IN APRIL
(Blue = Increase; Red = Decrease)
Data: Lynch, 2002
Analysis: Hewitson, 2001

Fig 6

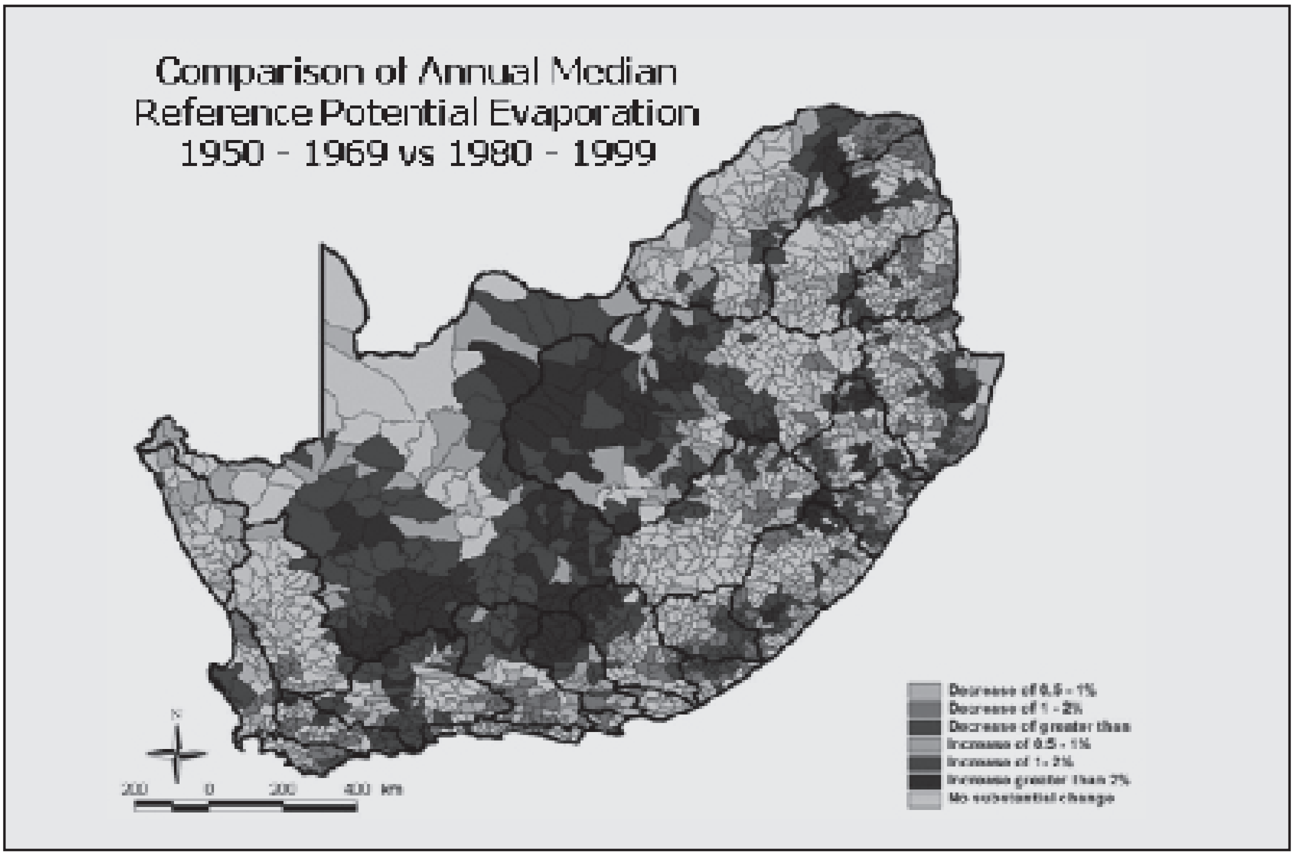

Comparison of Annual Median
Reference Potential Evaporation
1950 - 1969 vs 1980 - 1999
Decrease of 0.5 - 1%
Decrease of 1 - 2%
Decrease of greater than
Increase of 0.5 - 1%
Increase of 1 - 2%
Increase greater than 2%
No substantial change
N
200 0 200 400 km

Fig 7

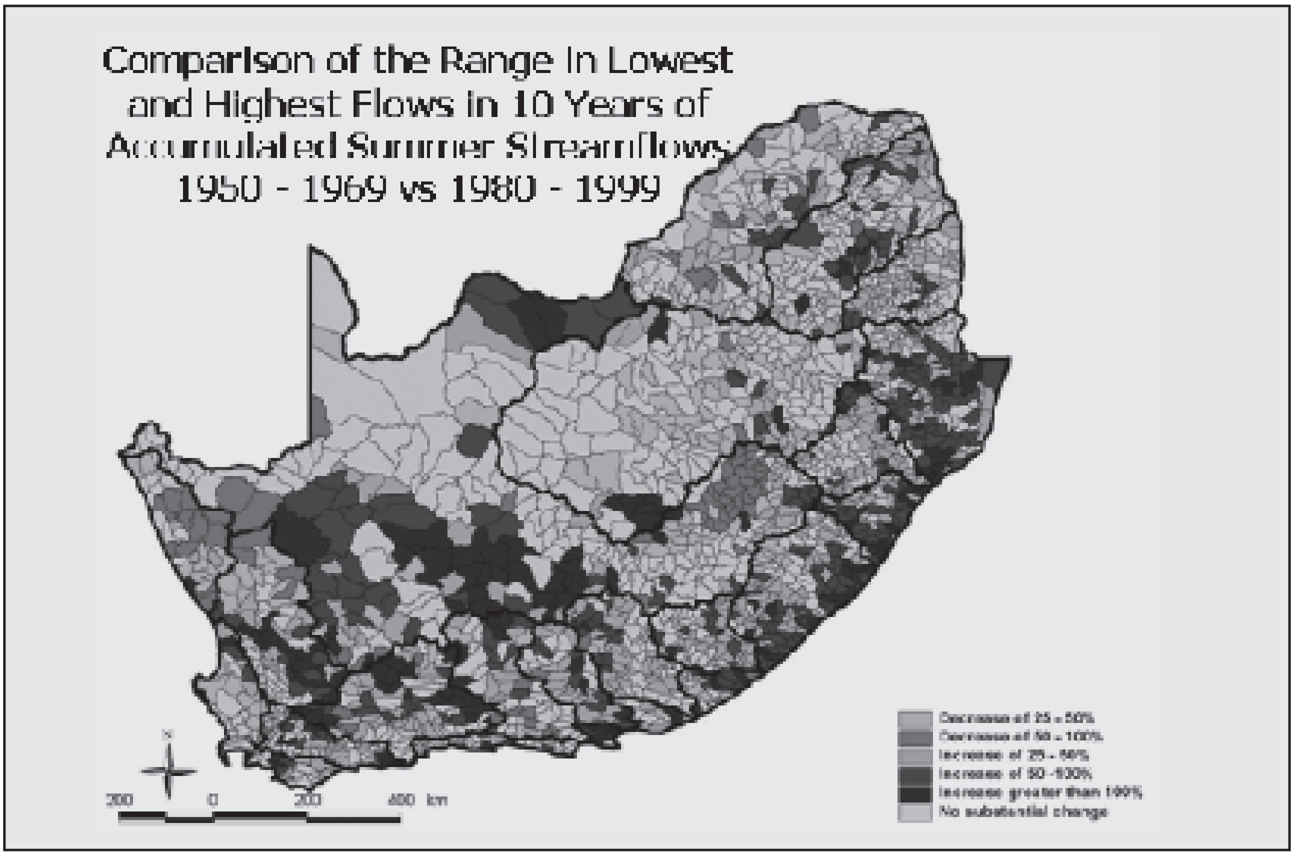
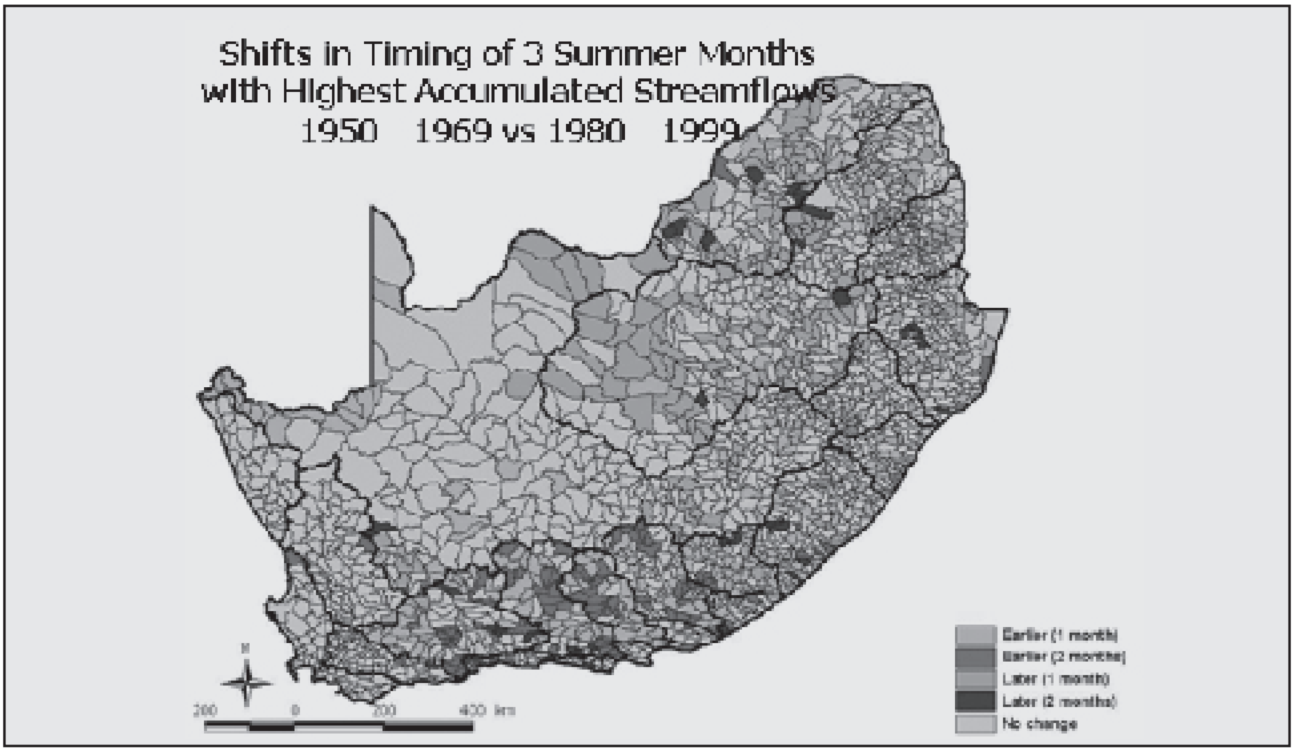

Comparison of the Range in Lowest
and Highest Flows in 10 Years of
Accumulated Summer Streamflows
1950 - 1969 vs 1980 - 1999
Decrease of 25 - 50%
Decrease of 50 - 100%
Increase of 25 - 50%
Increase of 50 -100%
Increase greater than 100%
No substantial change
N
200 0 200 400 km

Fig 8



Plant response to climate change

As pictured in Fig. 9, the plant forms an interactive part of the natural resources continuum and plant processes (Fig. 10) as well as physiological phases. Cycles (Fig. 11), consequently, affect the sustainability of the continuum. A change in atmospheric CO_2 concentrations can have important repercussions in the plant:water relationships and plant processes, particularly so on photosynthetic responses (Fig. 12) and transpiration rate (Fig. 13). The photosynthetic response and transpiration rate were estimated using the Ceres 3.0 and the C_3 pathway of DSSAT models respectively.

Fig 9

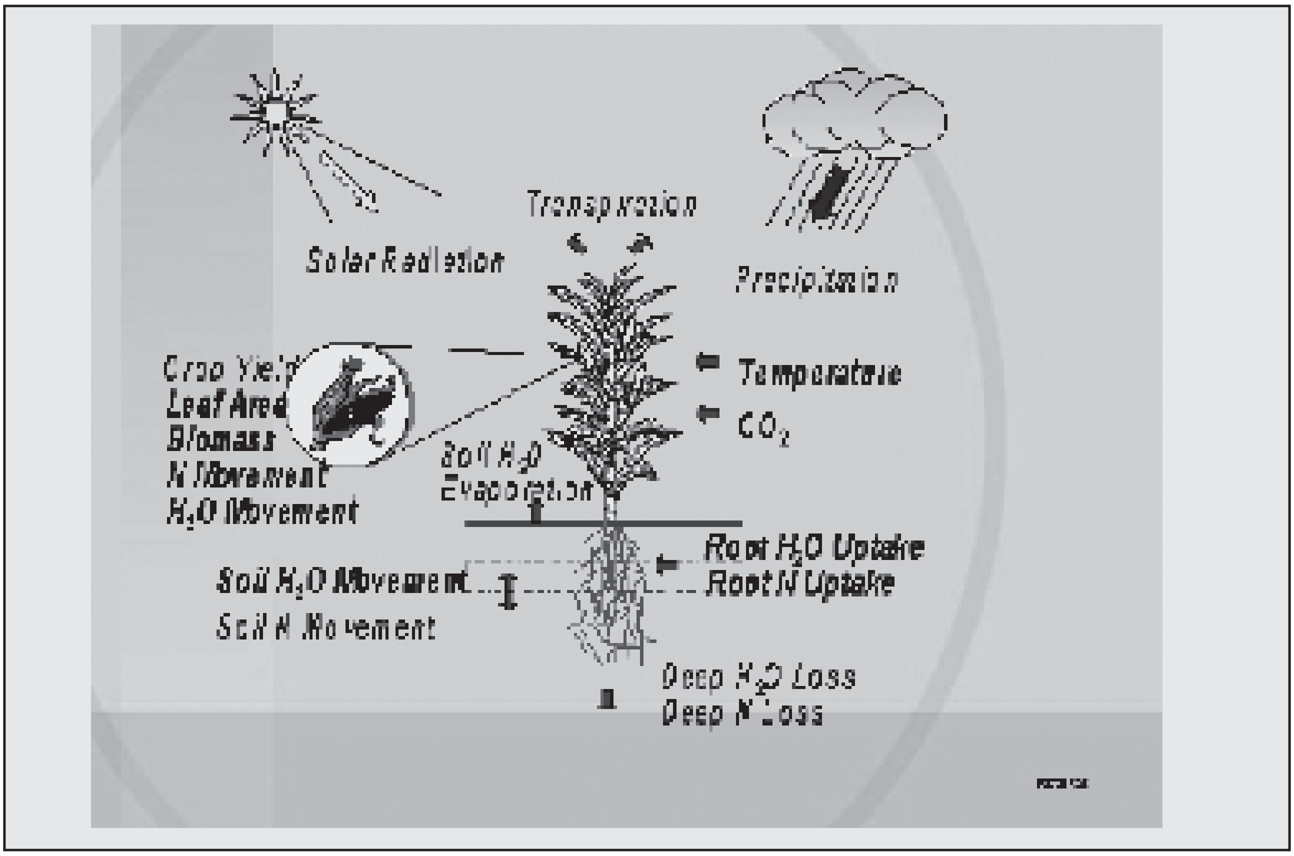


Fig 10

PROCESS	SOLAR RADIATION	TEMPERATURE	RAINFALL MOISTURE STRESS	ΔCO_2
Photosynthesis	√	√	√	√
Leaf area development	√	√	√	
Transpiration : potential	√	√		√
Transpiration : actual			√	
Vegetative development		√	√	
Reproductive development		√	√	
Root growth		√	√	
Grain # ear # head : addition		√	√	
Grain # ear # head : growth		√	√	
Yield, ie biomass accumulation	√	√	√	√

Fig 11

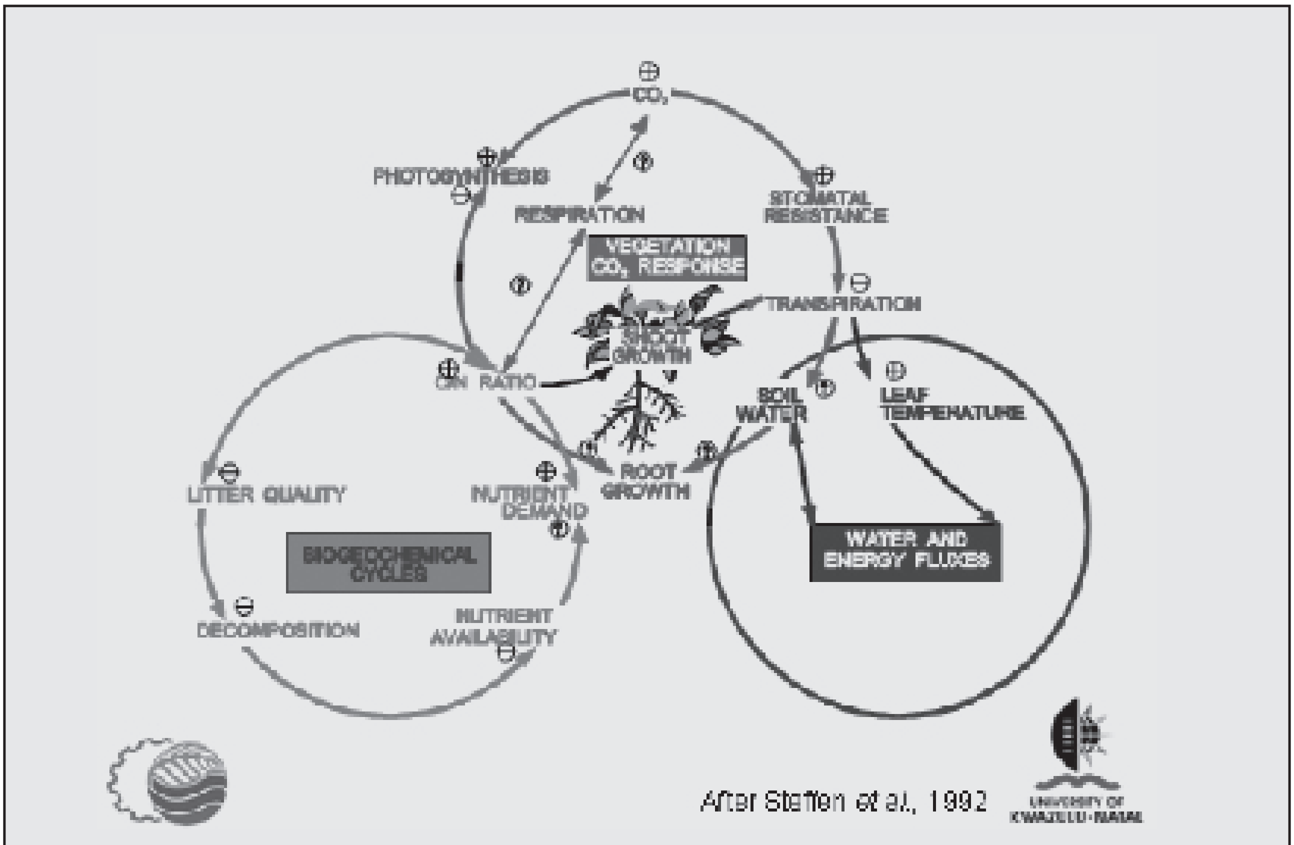
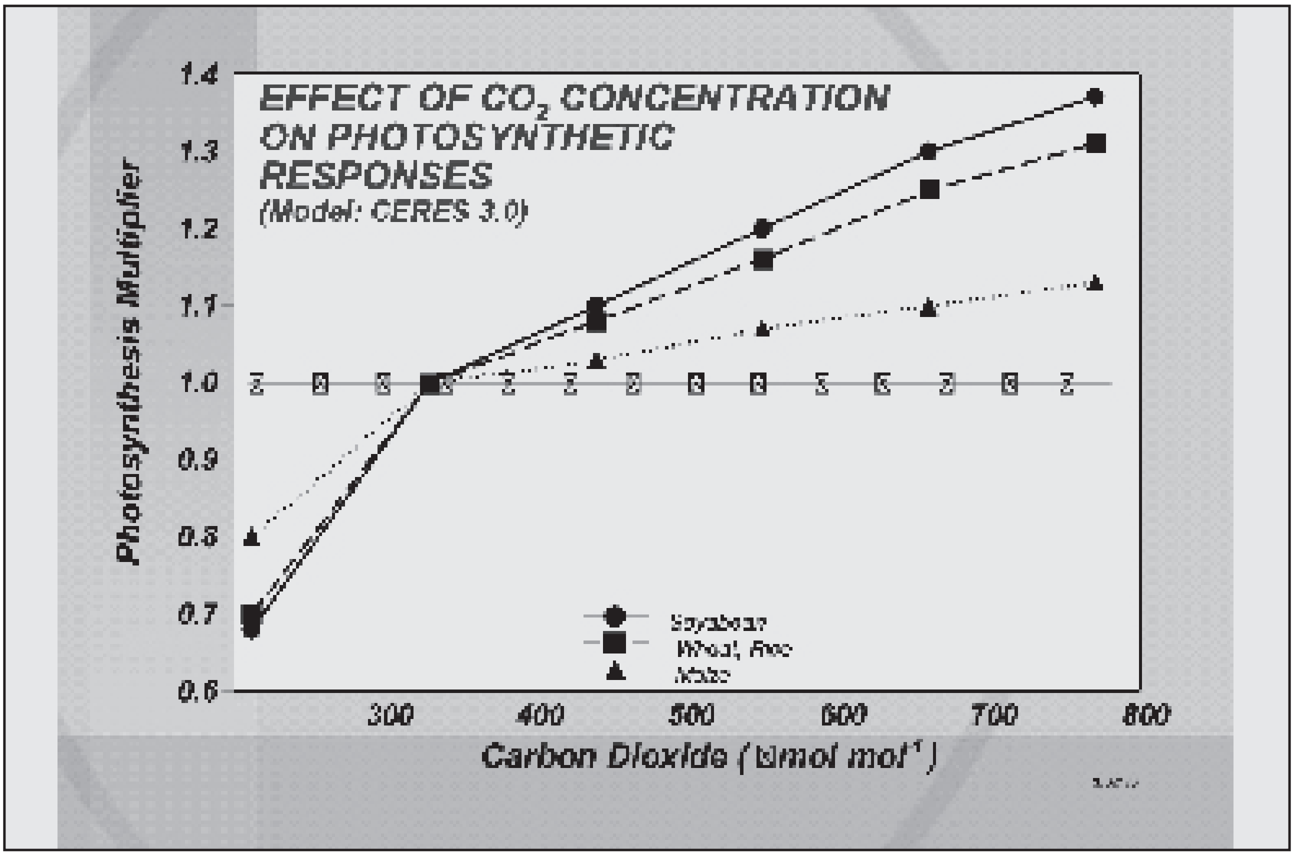
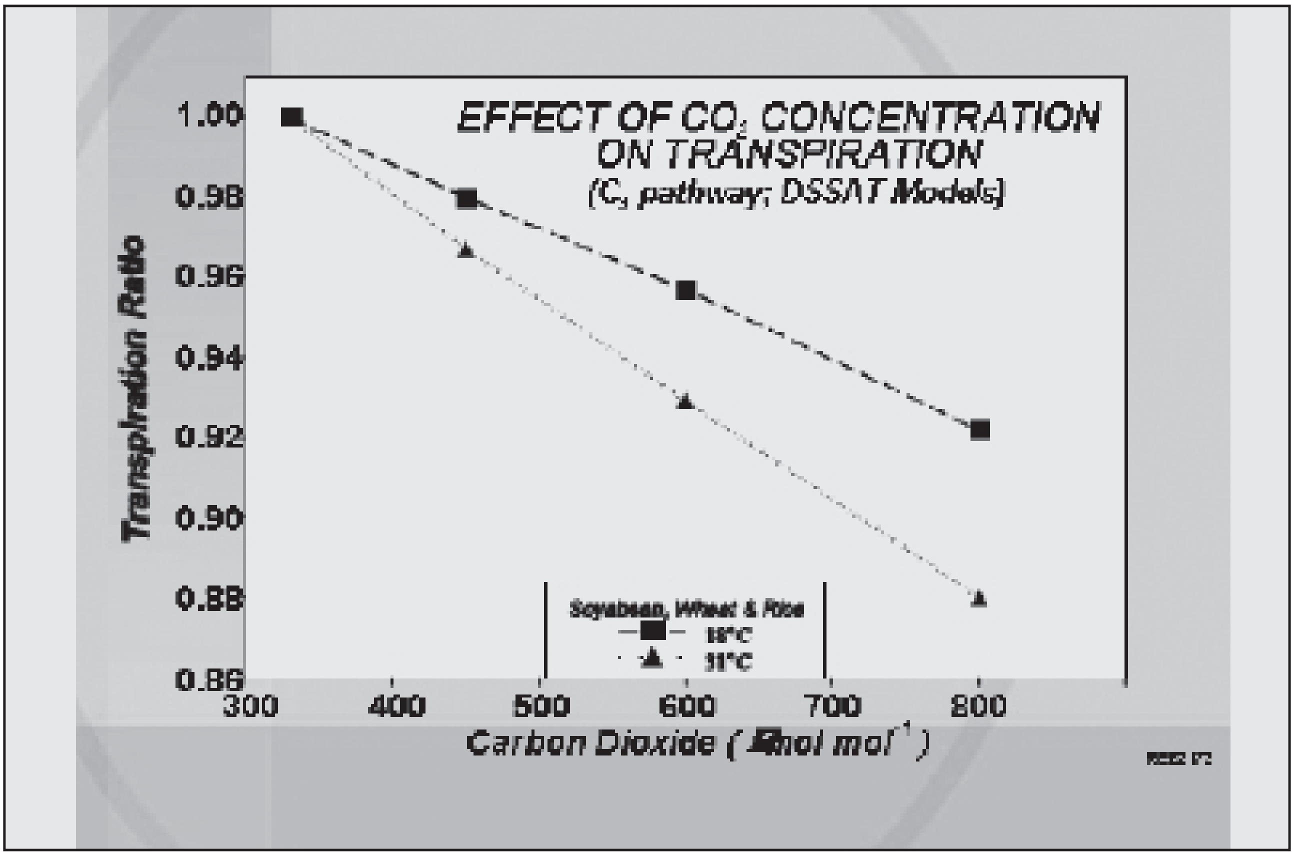


Fig 12



EFFECT OF CO_2 CONCENTRATION
ON PHOTOSYNTHETIC
RESPONSES
(Model: CERES 3.0)
Photosynthesis Multiplier
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
300
400
500
600
700
800
Carbon Dioxide

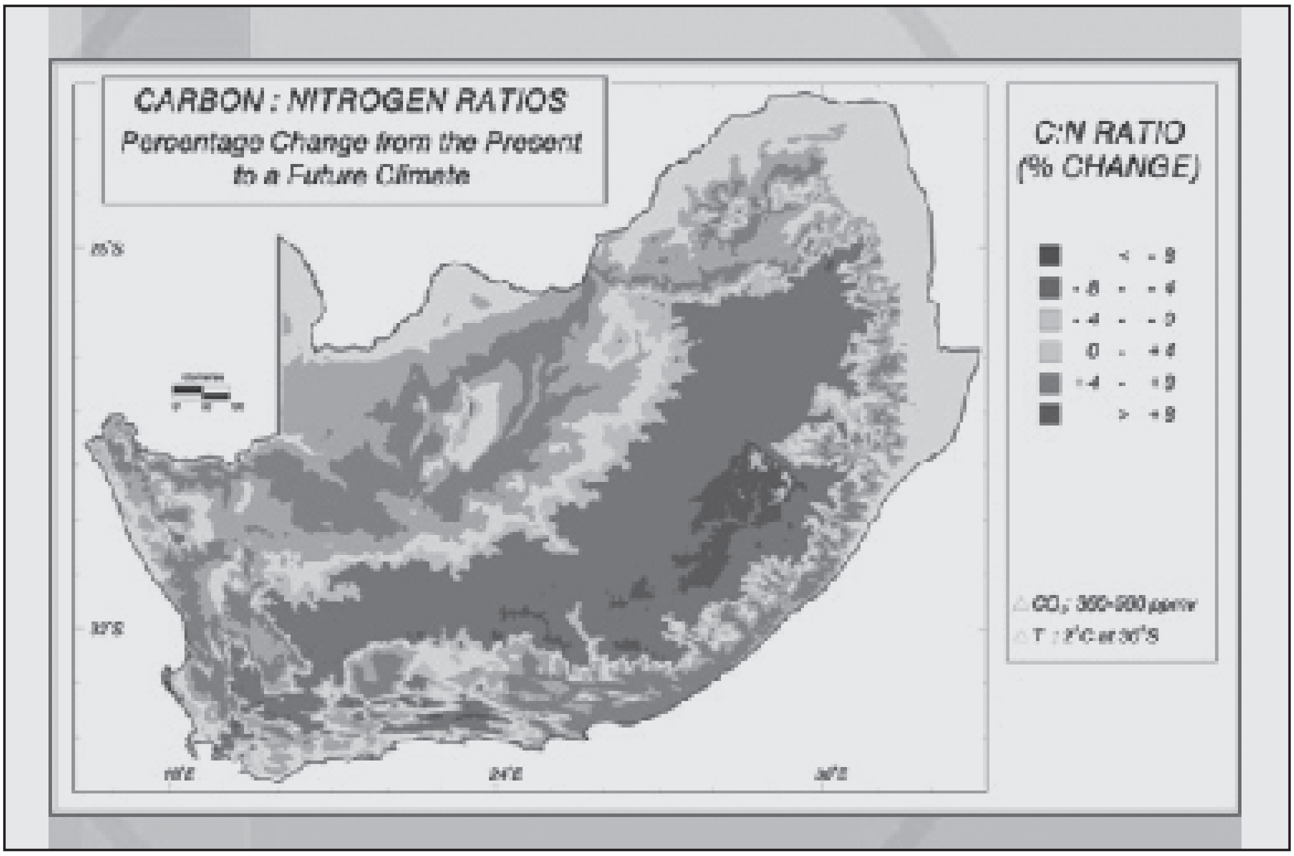
Fig 13



EFFECT OF CO_2 CONCENTRATION
ON TRANSPIRATION
DSSAT Models
Transpiration Ratio
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
300
400
500
600
700
800
Carbon Dioxide

Another most important element within the stability of the continuum, is the carbon:nitrogen (C:N) ratio. Fig. 14 displays the percentage C:N ratio change to be expected from the present to a future climate.

Fig 14



Temperature and rainfall regimes changes

Temperature

By itself, a change in temperature regime can have important repercussions in agriculture. These include the following:

- An increase in potential evaporation from dams and as an atmospheric demand from the soil and crops;
- An increased demand for soil water by vegetation, the onset of plant stress and a higher runoff potential;
- Actual evaporation will increase directly affecting crop yield;
- Concerning agricultural practices, the beginning and end of growing periods will be affected; there will be a shift in the production areas of crops; and tillage practices will have to be revisited;
- Irrigation practices will have to be adjusted in view of crop water demand. This will affect the mode of irrigation scheduling; and
- The frequency, severity and duration of droughts will increase.

The effect of temperature on the vegetative and reproductive development of soyabeans as modeled by SOYGRO, is reflected in Fig. 15, while Fig. 16 portrays the effect of a 2°C increase in the monthly mean daily minimum temperature with regard to water use coefficient, interception loss and the fraction of the roots in the topsoil.

Fig 15

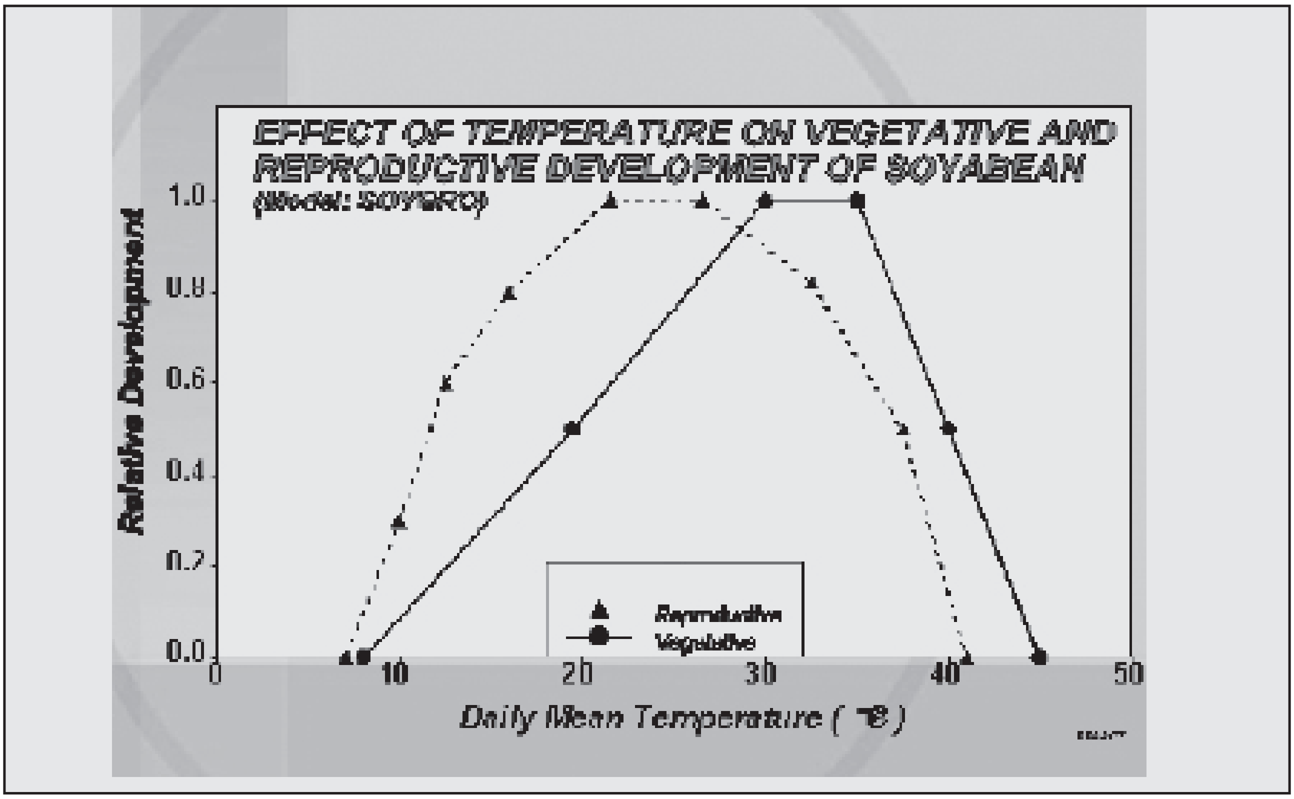
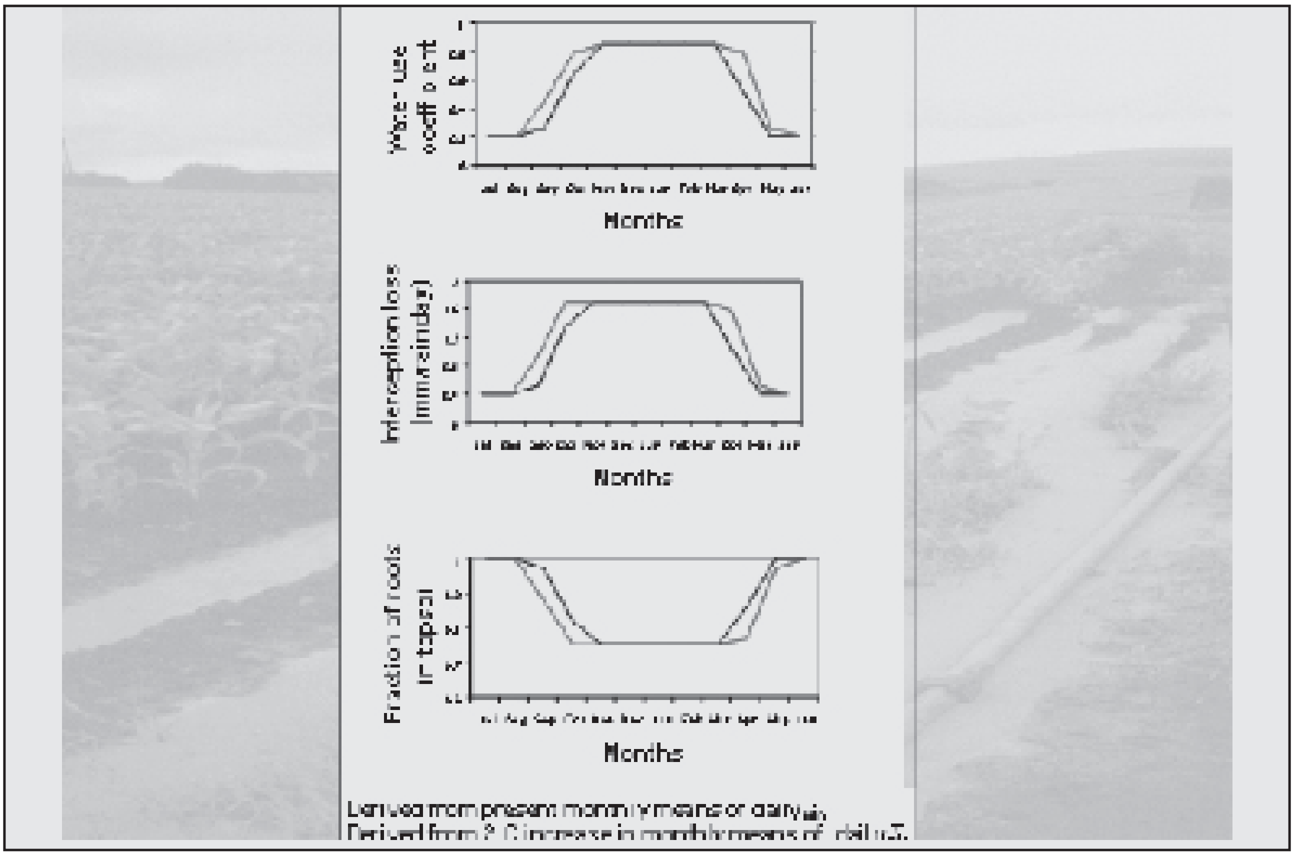

EFFECT OF TEMPERATURE ON VEGETATIVE AND
REPRODUCTIVE DEVELOPMENT OF SOYABEAN
(Model: SOYGRO)
Relative Development
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
Reproductive
Vegetative
Daily Mean Temperature (°C)

Fig 16


Months
Interception loss (mm/rainday)
Months
Fraction of roots in topsoil
Months

Rainfall patterns
Changes in rainfall patterns will have wide ranging repercussions in agriculture such as:

- Changes in global patterns: Frequencies of El Niño and La Niña could increase as well as the frequency of tropical cyclones and their zones of impact;
- Changes in regional patterns (means and seasonal rainfall), affecting both planting date and yield;
- Changes in local event characteristics associated with convectivity, the number of rain days and the amount per rainfall event. These will affect contour spacing, sediment yield, antecedent soil water conditions, in-field traffic, irrigation scheduling and groundwater recharge;
- Changes in extreme events such as more floods and droughts, which will necessitate changes in water security strategies; and in shift in flood frequencies, which will necessitate changes in the hydrological design.

Climate change and water resources
The first results from a project on climate change and water resources in South Africa, funded by the Water Research Commission, deliberated conceptual issues such as the management of catchments, quaternary catchments as well as sub-catchments and cell configurations, including proposed dams (Fig. 17). Fig. 18 explains water resources management and an organizational perspective concerning the supply/demand and the river basin perspectives.

Fig 17

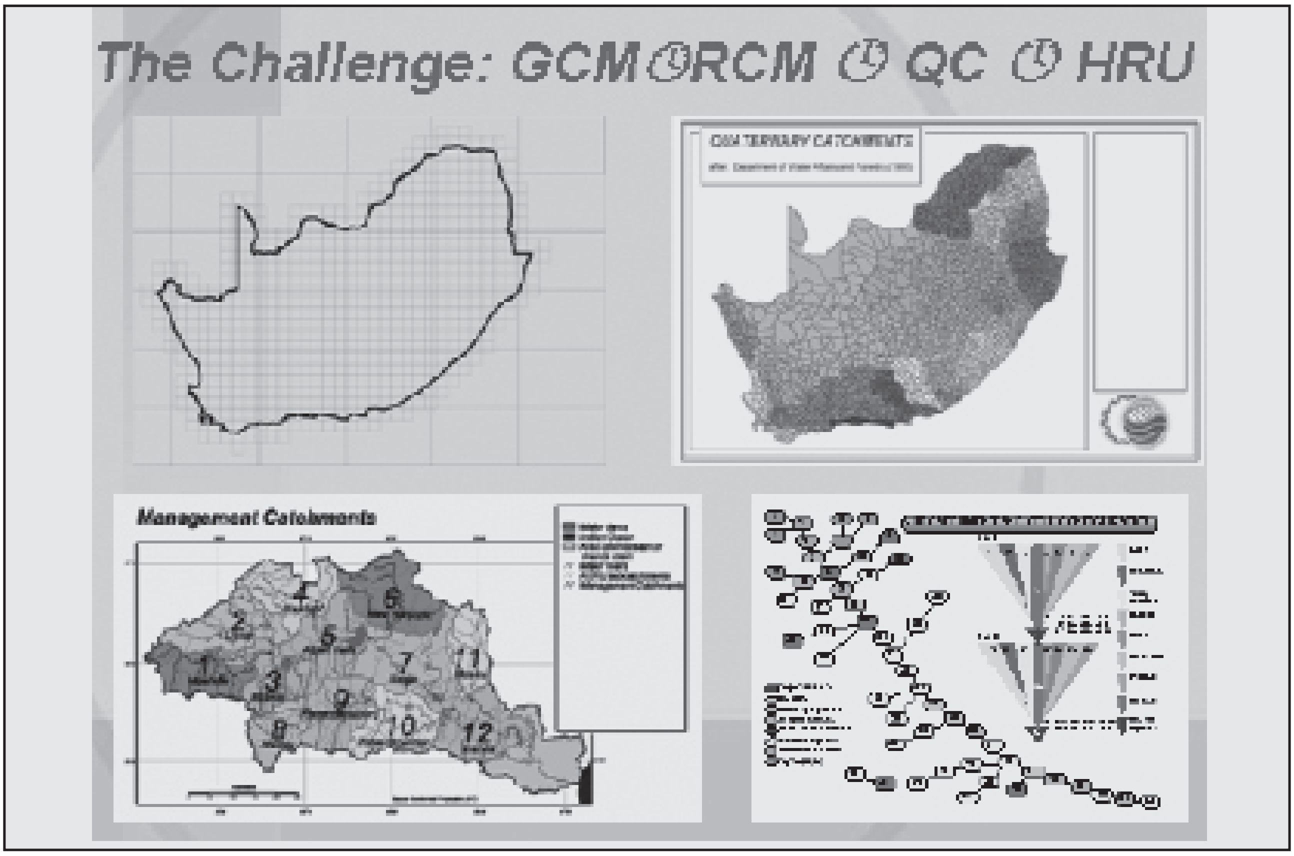


Fig 18

The complex and far-reaching impact of land use and climate change on hydrological responses and water resources was modeled and impacts are illustrated in Fig. 19. The ACRU model was used, simultaneously, to simulate specific objectives and components (Fig. 20). ACRU was, furthermore, used to model total evaporation and runoff (Fig. 21). Fig. 22 is a schematic illustration of irrigation water demand and irrigation scheduling options available in ACRU.

Fig 19

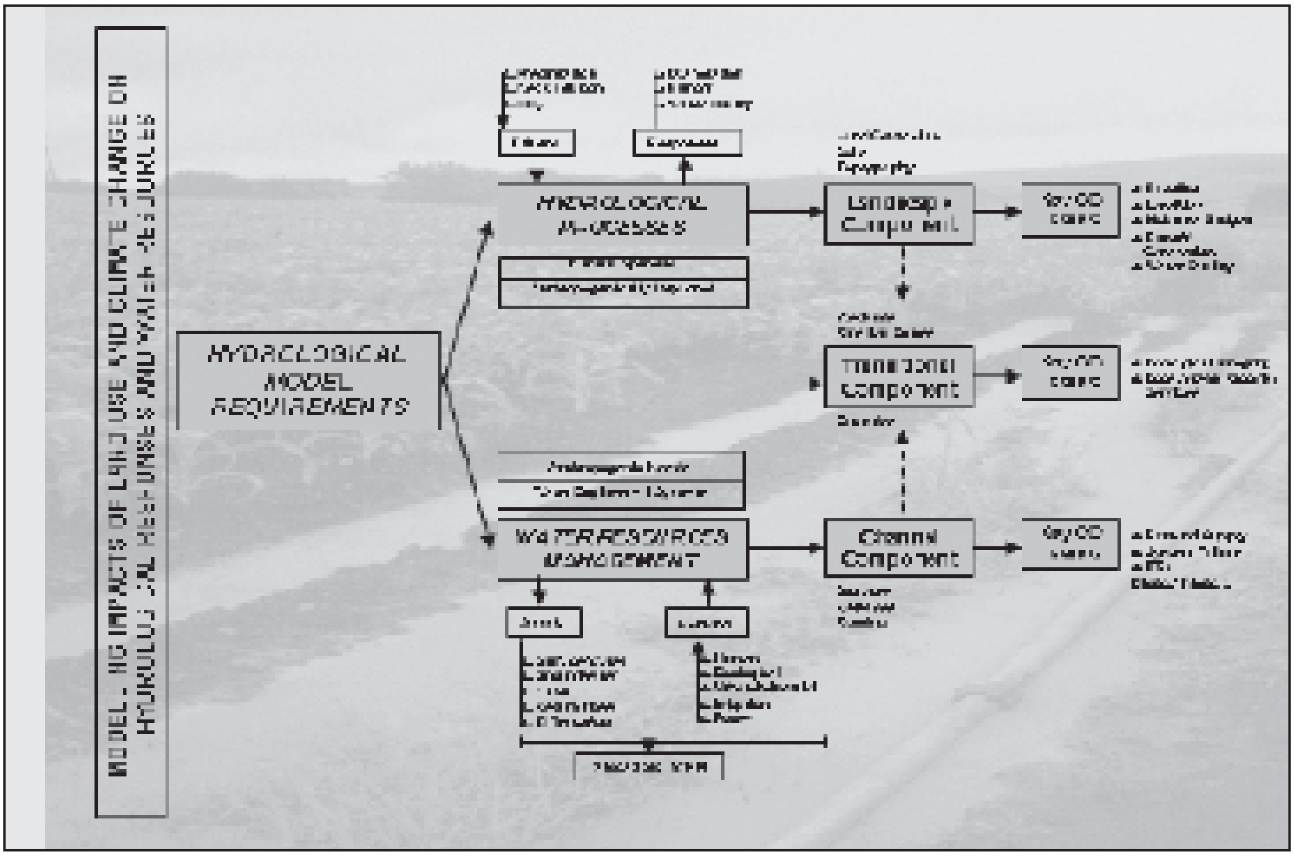


Fig 20

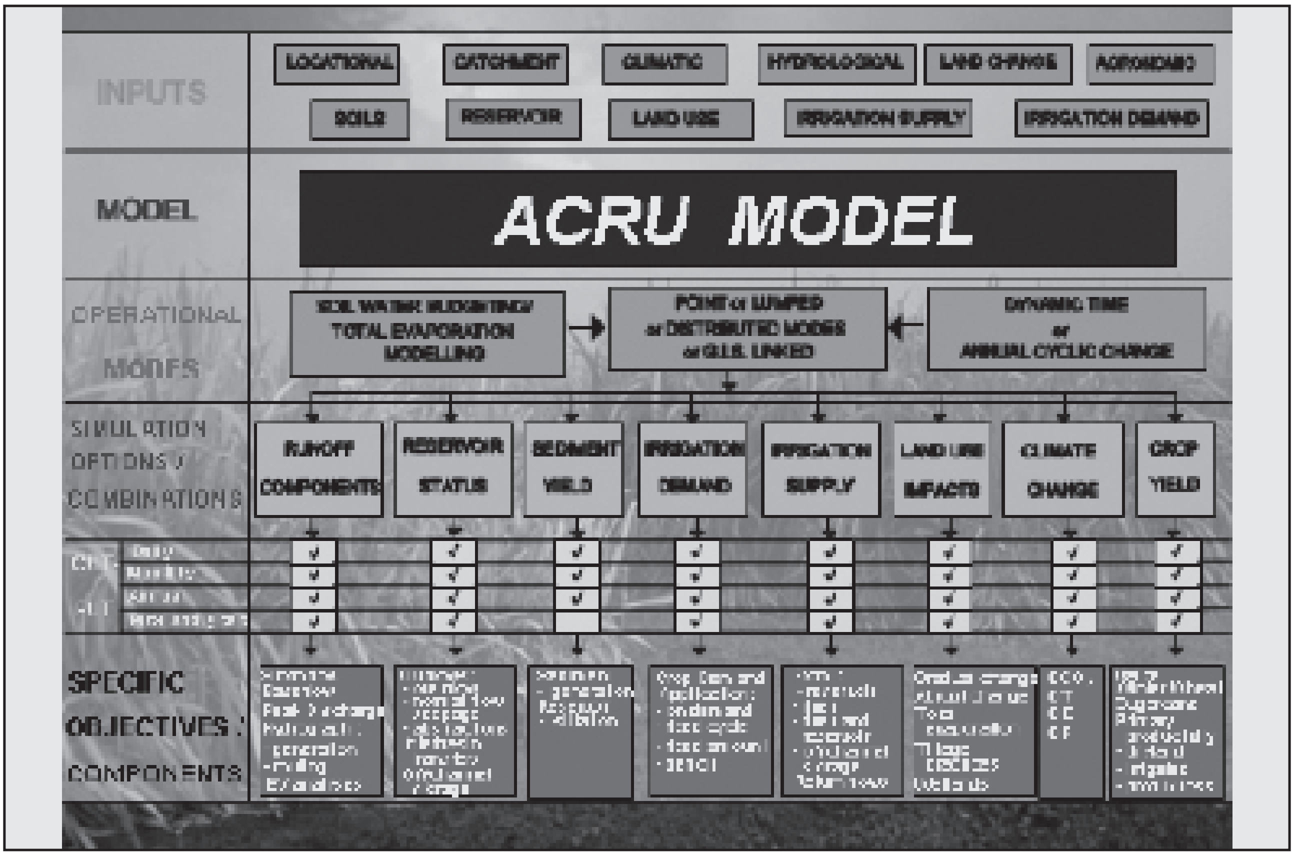

INPUTS
LOCATIONAL
CATCHMENT
CLIMATIC
HYDROLOGICAL
LAND CHANGE
SOILS
RESERVOIR
LAND USE
IRRIGATION SUPPLY
IRRIGATION DEMAND
MODEL
ACRU MODEL
OPERATIONAL MODES
SOIL WATER BUDGETING/ TOTAL EVAPORATION MODELLING
POINT or LUMPED or DISTRIBUTED MODES or G.I.S. LINKED
DYNAMIC TIME or ANNUAL CYCLIC CHANGE
SIMULATION OPTIONS / COMBINATIONS
RUNOFF COMPONENTS
RESERVOIR STATUS
SEDIMENT YIELD
IRRIGATION DEMAND
IRRIGATION SUPPLY
LAND USE IMPACTS
CLIMATE CHANGE
CROP YIELD
SPECIFIC OBJECTIVES / COMPONENTS

Fig 21

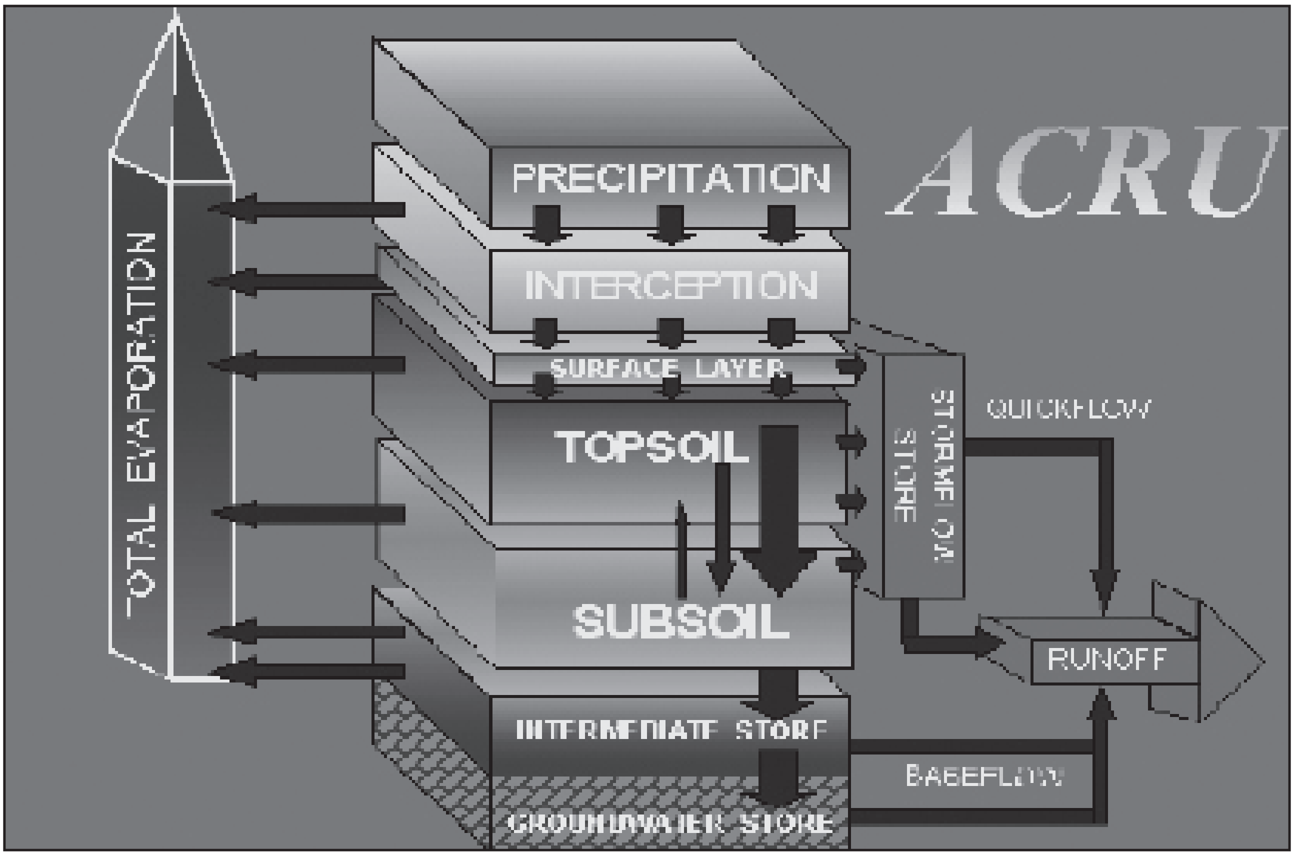
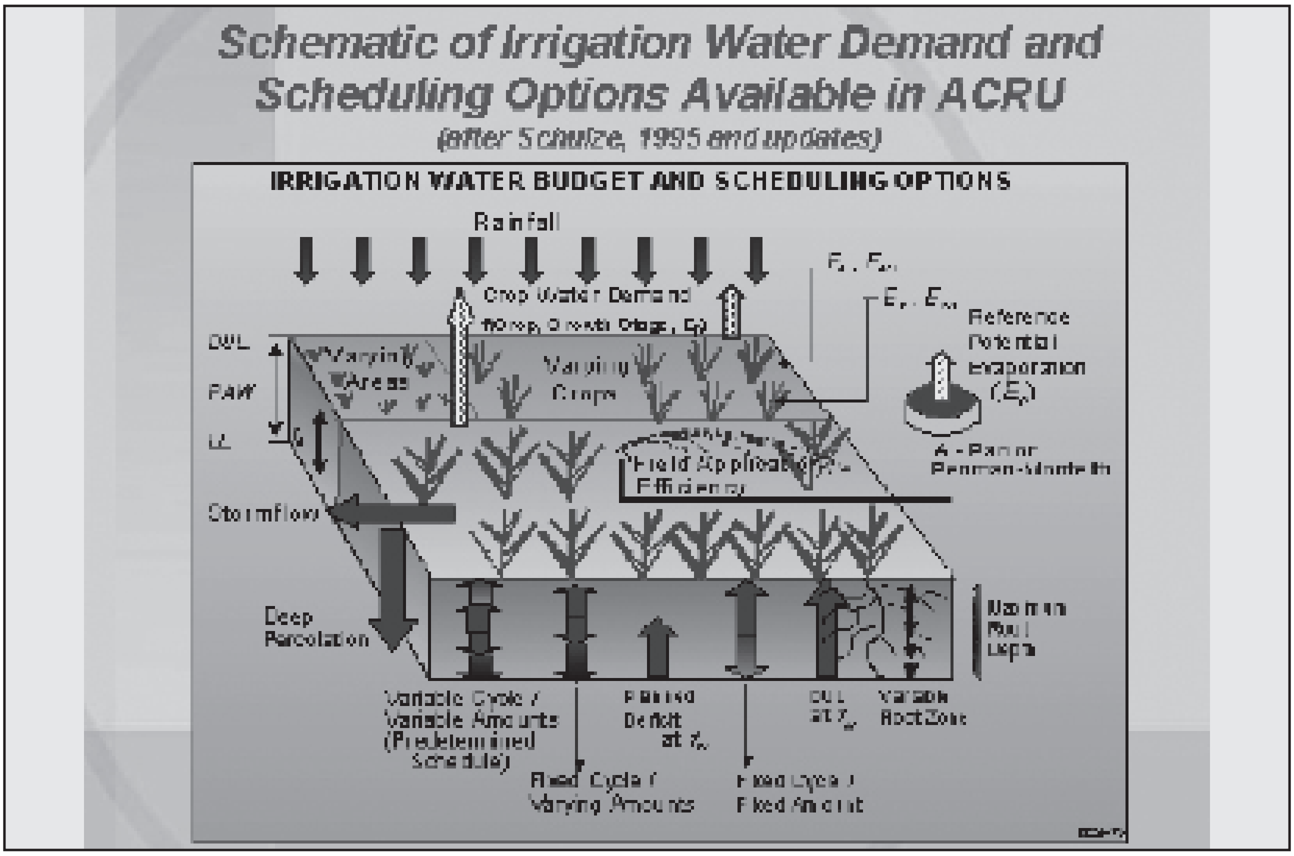

TOTAL EVAPORATION
PRECIPITATION
ACRU
INTERCEPTION
SURFACE LAYER
TOPSOIL
STORMFLOW STORE
QUICKFLOW
SUBSOIL
RUNOFF
INTERMEDIATE STORE
BASEFLOW
GROUNDWATER STORE

Fig 22



General findings of the project concerns temperature and rainfall. These findings are illustrated in Figures 23 and 24.

Fig 23

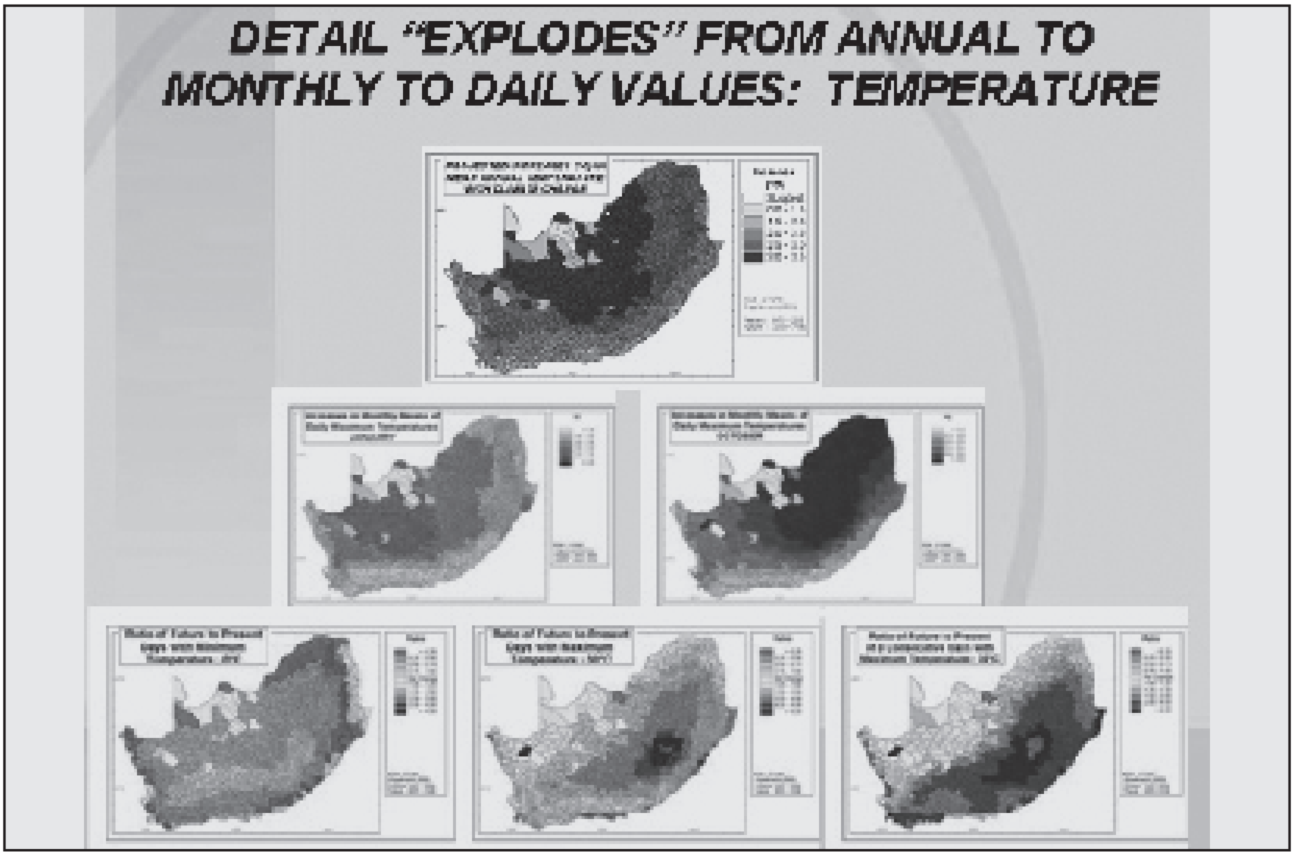
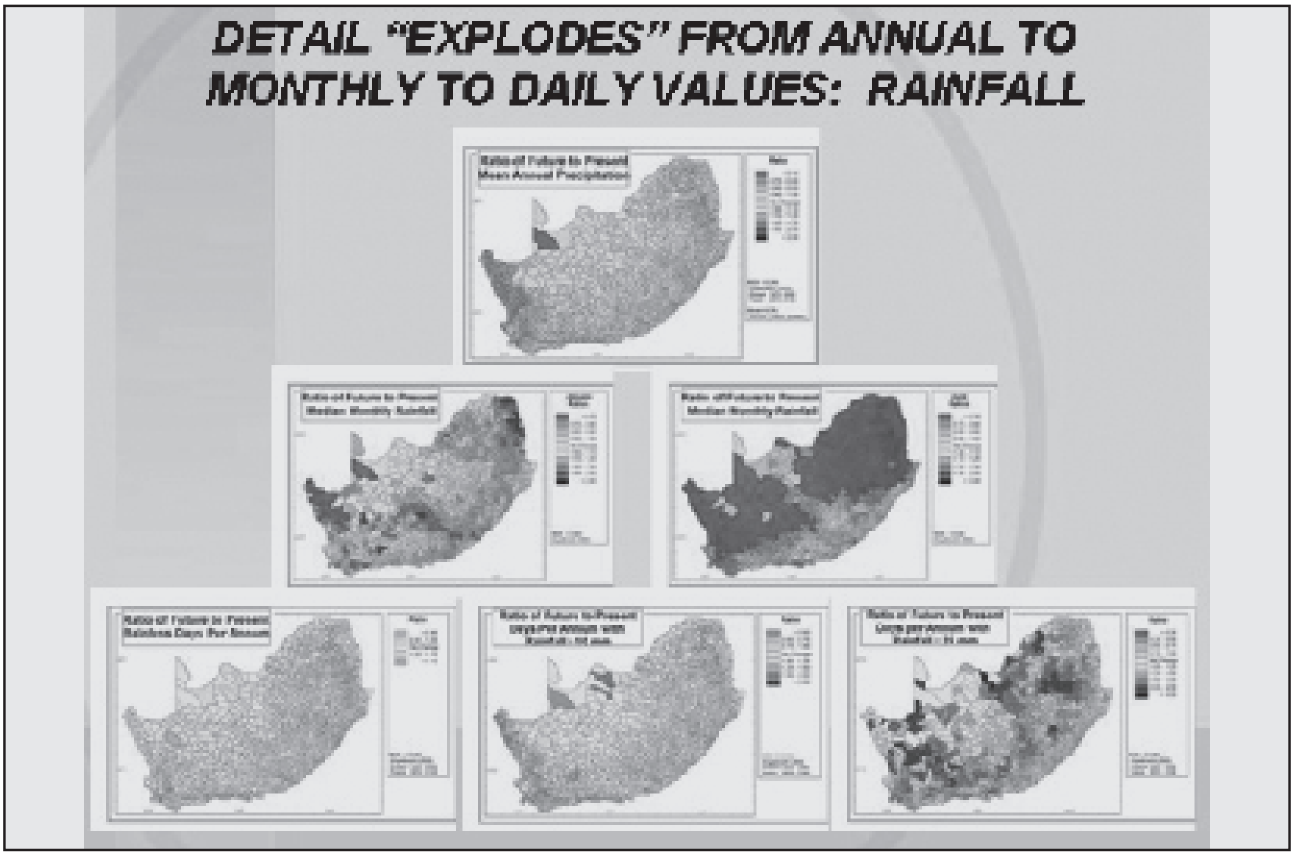


Fig 24



Climate change realities and uncertainties

It is reiterated that climate change is surrounded by both certainties and uncertainties such as:

- A higher concentration of CO_2 (green house gases) in the atmosphere is a certainty. The effect of this higher CO_2 concentration on plant processes such as photosynthesis, transpiration and acclimation, however, needs to be elucidated;
- It is as good as certain that temperature is on the rise. Uncertainties are higher local temperatures and seasonal/diurnal variations;
- There is less certainty about precipitation within the arena of climate change.

Direct consequences of climate change on the agricultural sector

General consequences

- Potential evaporation is projected to increase by 10 – 20%. The implications are enhanced dam evaporation losses and increased irrigation demands (Fig. 25);
- Soils are projected to become increasingly dry more often. The implications are reduced runoff per mm rainfall; land use changes; reduced crop yields; and higher irrigation demands (Fig. 26);
- There is likely to be an increase in heat units (Fig. 27) dictating a shift in climatically suitable and climatically optimum areas (Fig. 28-30);
- Maize yield (t ha^{-1}), simulated by the CERES 3.0 model, could change significantly. Comparing Figures 31 and 32, it is evident that current high producing areas will harvest sub-optimum to poor yields;
- The implications to irrigation are likely to be highly significant in view of irrigation requirements (Fig. 33); percolation and storm flow losses (Fig. 34); irrigation demand by different modes of scheduling (Fig. 35); percolation losses by different modes of irrigation (Fig. 36); and biomass increment (Fig. 37);
- Ratios of annual reference potential evaporation (Fig. 38);
- Mean annual accumulated stream flows and mean annual base flows (Fig. 39);
- Pest and disease life cycles e.g. that of the codling moth displayed in Fig. 40.

Fig 25

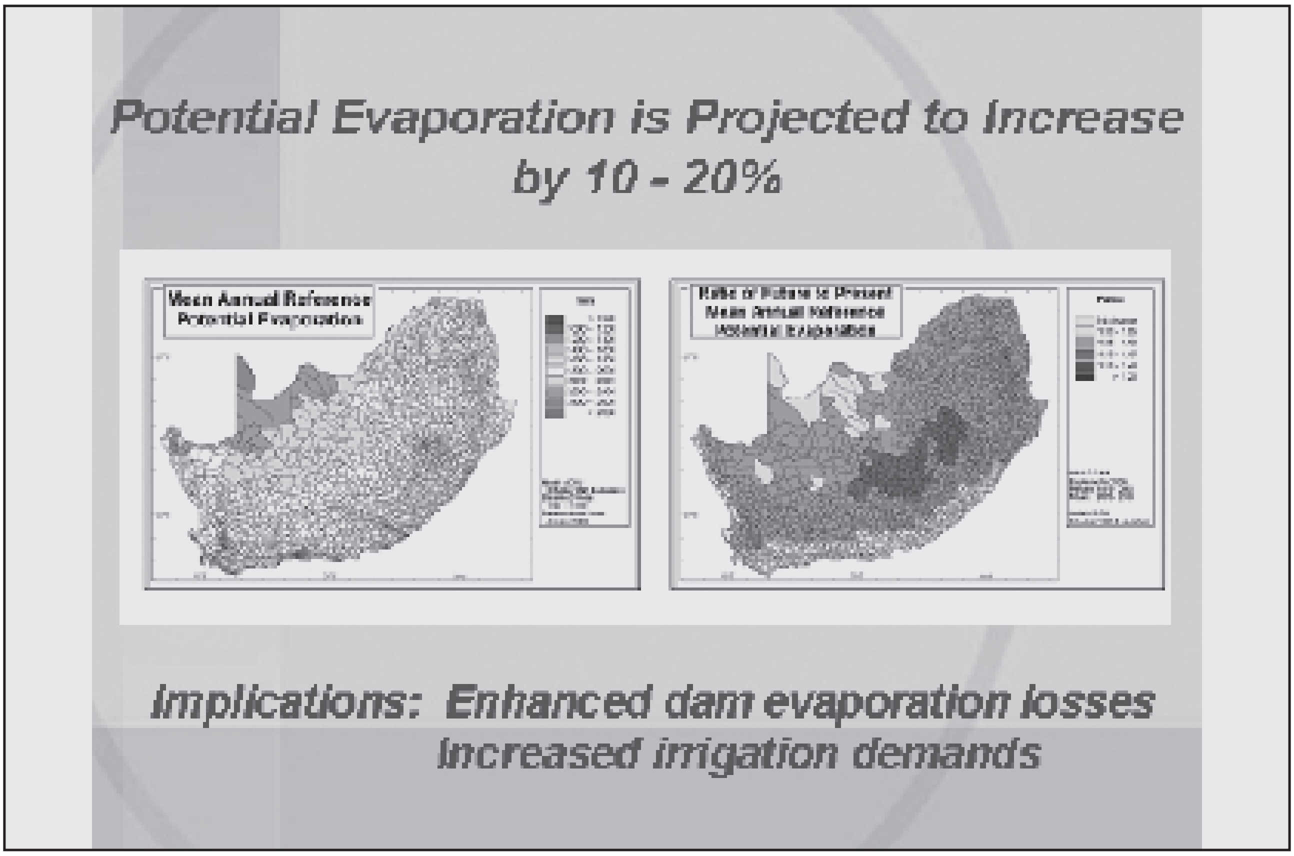

Potential Evaporation is Projected to Increase by 10 - 20%
Mean Annual Reference Potential Evaporation
Ratio of Future to Present Mean Annual Reference Potential Evaporation
Implications: Enhanced dam evaporation losses
Increased irrigation demands

Fig 26

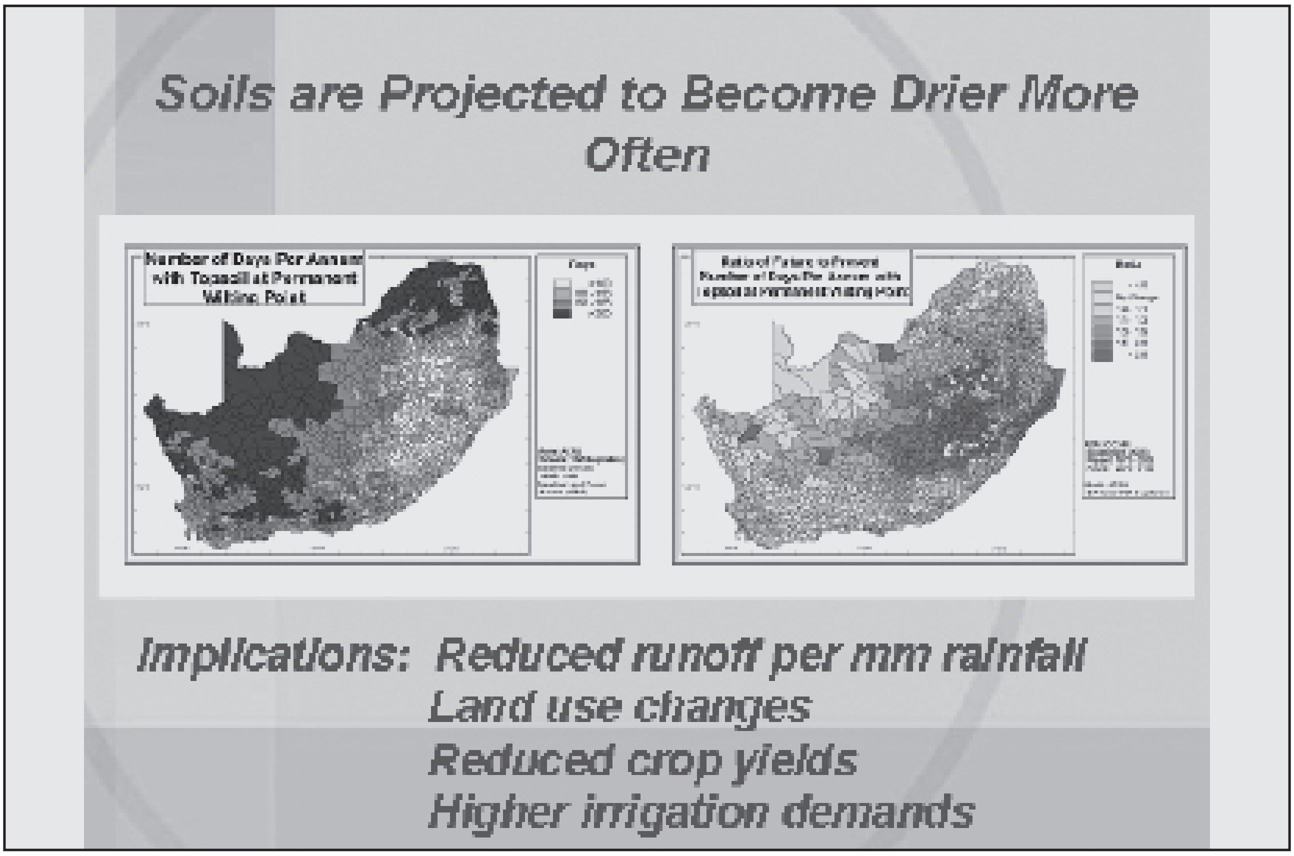
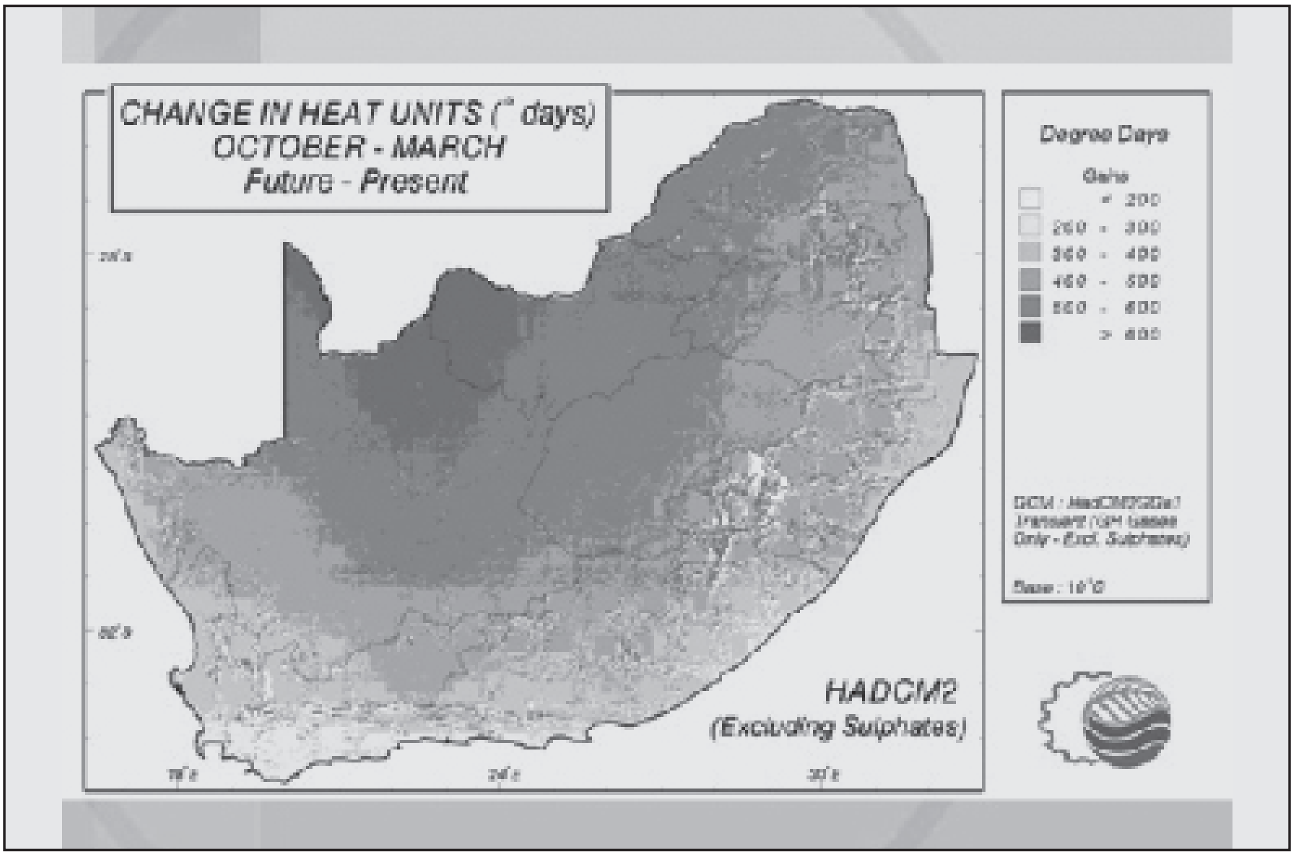
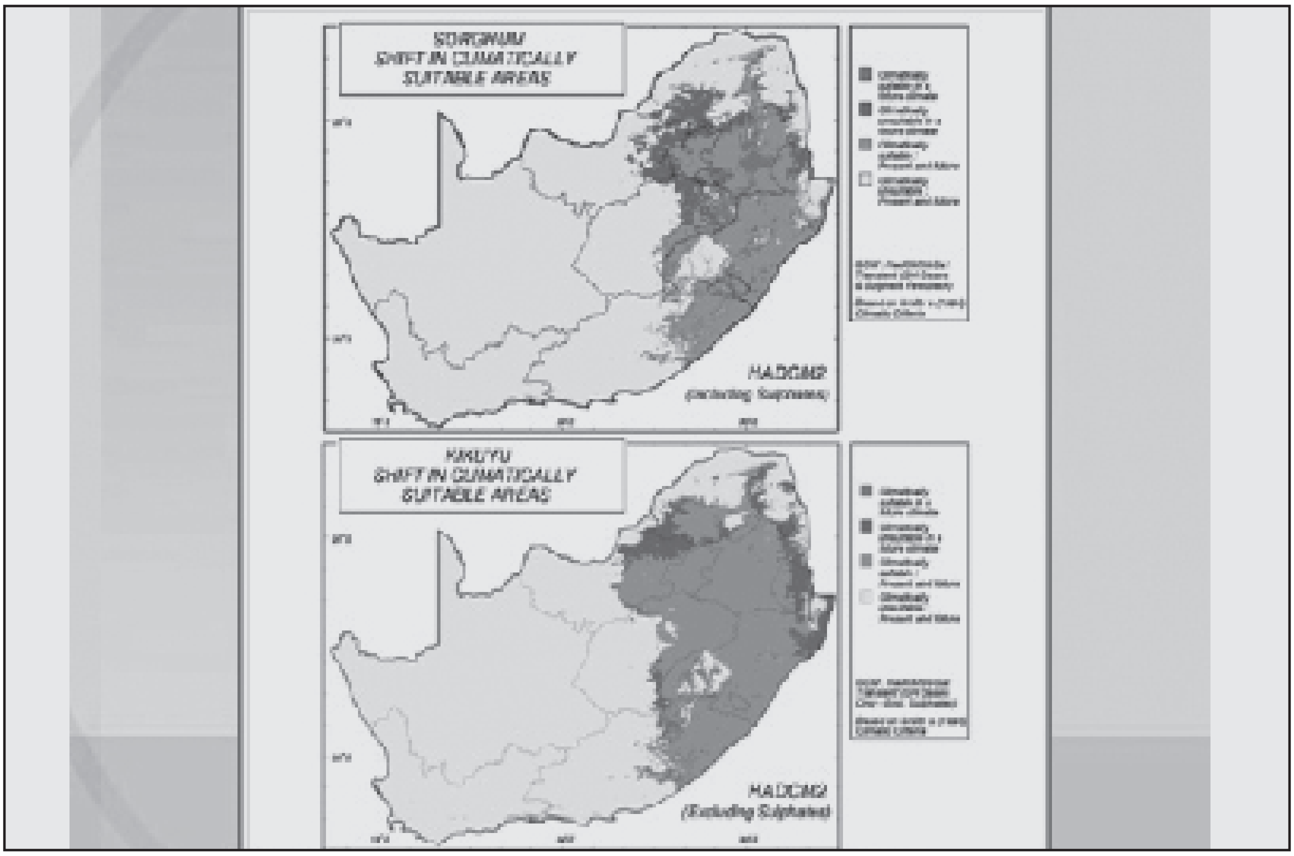

Soils are Projected to Become Drier More Often
Number of Days Per Annum with Topsoil at Permanent Wilting Point
Ratio of Future to Present Number of Days Per Annum with
Implications: Reduced runoff per mm rainfall
Land use changes
Reduced crop yields
Higher irrigation demands

Fig 27



CHANGE IN HEAT UNITS (° days)
OCTOBER - MARCH
Future - Present
Degree Days
HADCM2
(Excluding Sulphates)

Fig 28



SORGHUM
SHIFT IN CLIMATICALLY
SUITABLE AREAS
HADCM2
(Excluding Sulphates)
KIKUYU
SHIFT IN CLIMATICALLY
SUITABLE AREAS
HADCM2
(Excluding Sulphates)

Fig 29

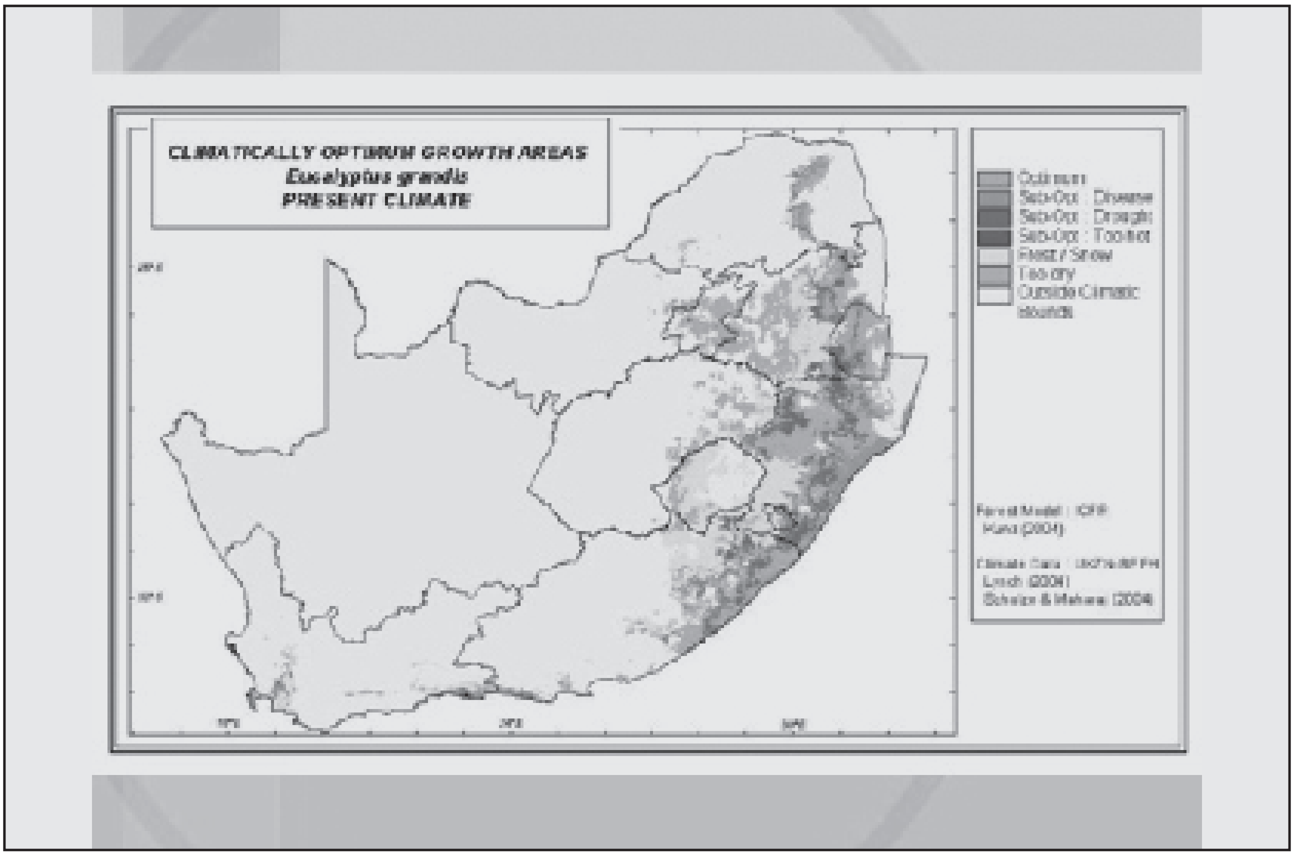

CLIMATICALLY OPTIMUM GROWTH AREAS
Eucalyptus grandis
PRESENT CLIMATE
Optimum
Sub-Opt : Disease
Sub-Opt : Drought
Sub-Opt : Too Hot
Frost / Snow
Too dry
Outside Climatic Bounds

Fig 30

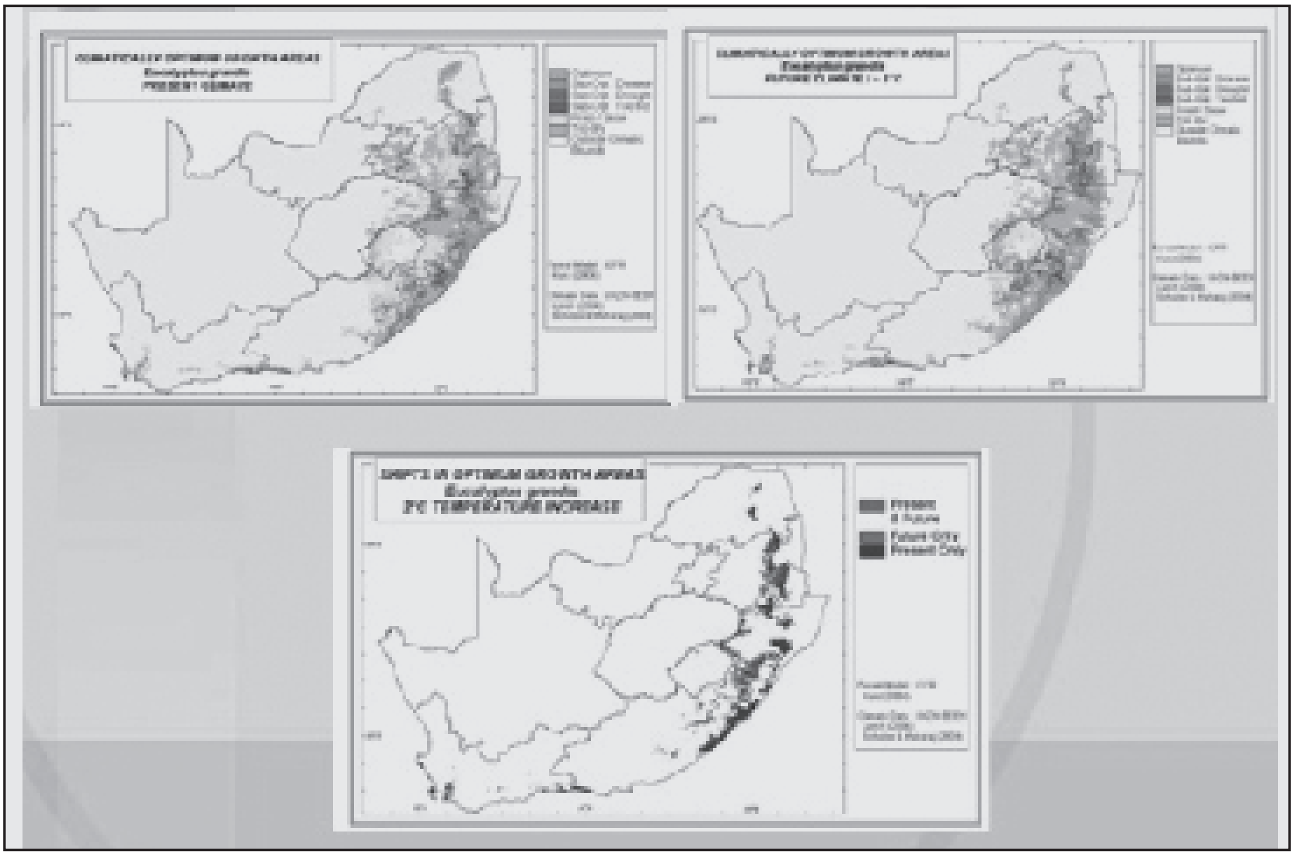

SHIFTS IN OPTIMUM GROWTH AREAS
Eucalyptus grandis
2°C TEMPERATURE INCREASE
Present & Future
Future Only
Present Only

Fig 31

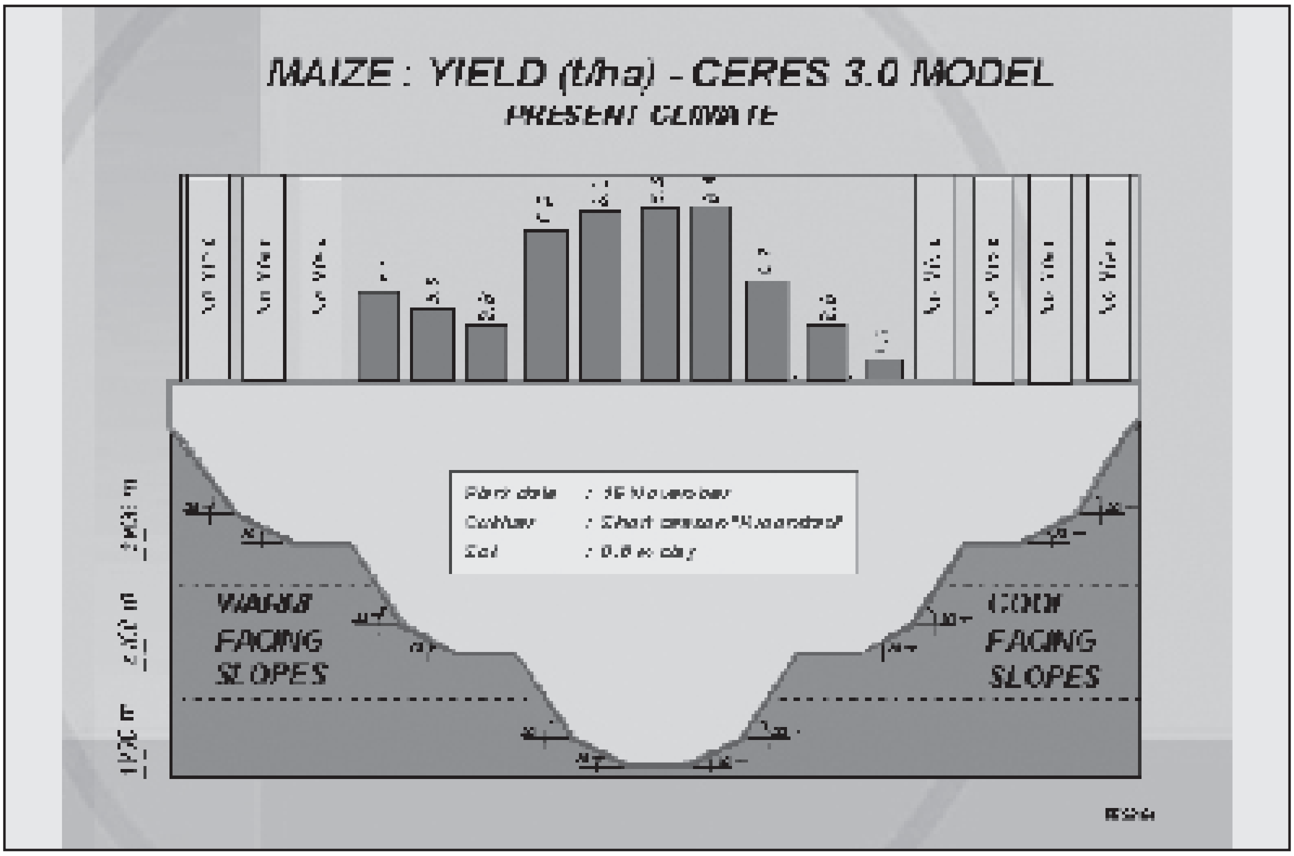

MAIZE : YIELD (t/ha) - CERES 3.0 MODEL
PRESENT CLIMATE
WARM FACING SLOPES
COOL FACING SLOPES

Fig 32

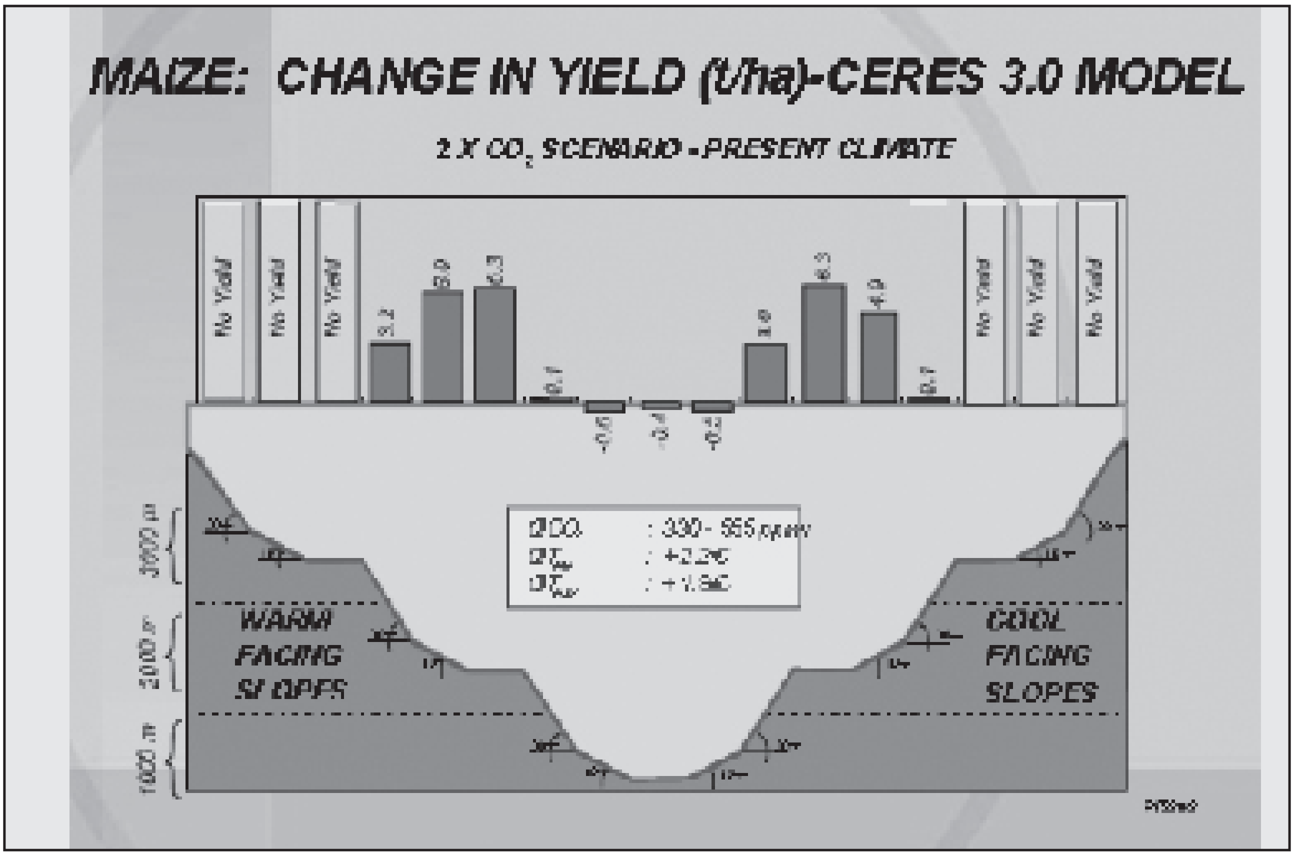

MAIZE: CHANGE IN YIELD (t/ha)-CERES 3.0 MODEL
2 X CO2 SCENARIO - PRESENT CLIMATE
No Yield
No Yield
No Yield
3.2
5.9
6.3
No Yield
No Yield
No Yield
WARM FACING SLOPES
COOL FACING SLOPES
3000 m
2000 m
1000 m

Fig 33

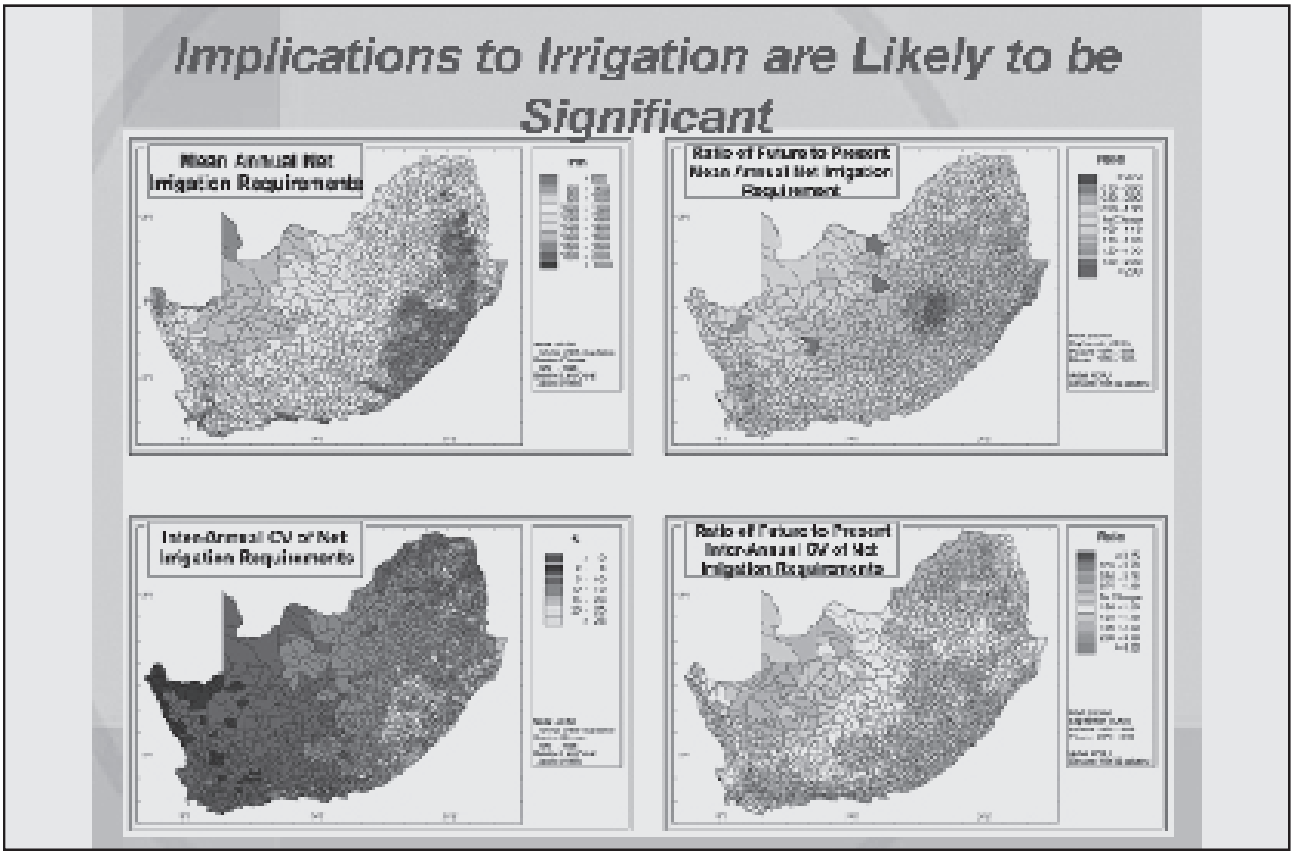

Implications to Irrigation are Likely to be Significant
Mean Annual Net Irrigation Requirements
Ratio of Future to Present Mean Annual Net Irrigation Requirement
Inter-Annual CV of Net Irrigation Requirements
Ratio of Future to Present Inter-Annual CV of Net Irrigation Requirements

Fig 34

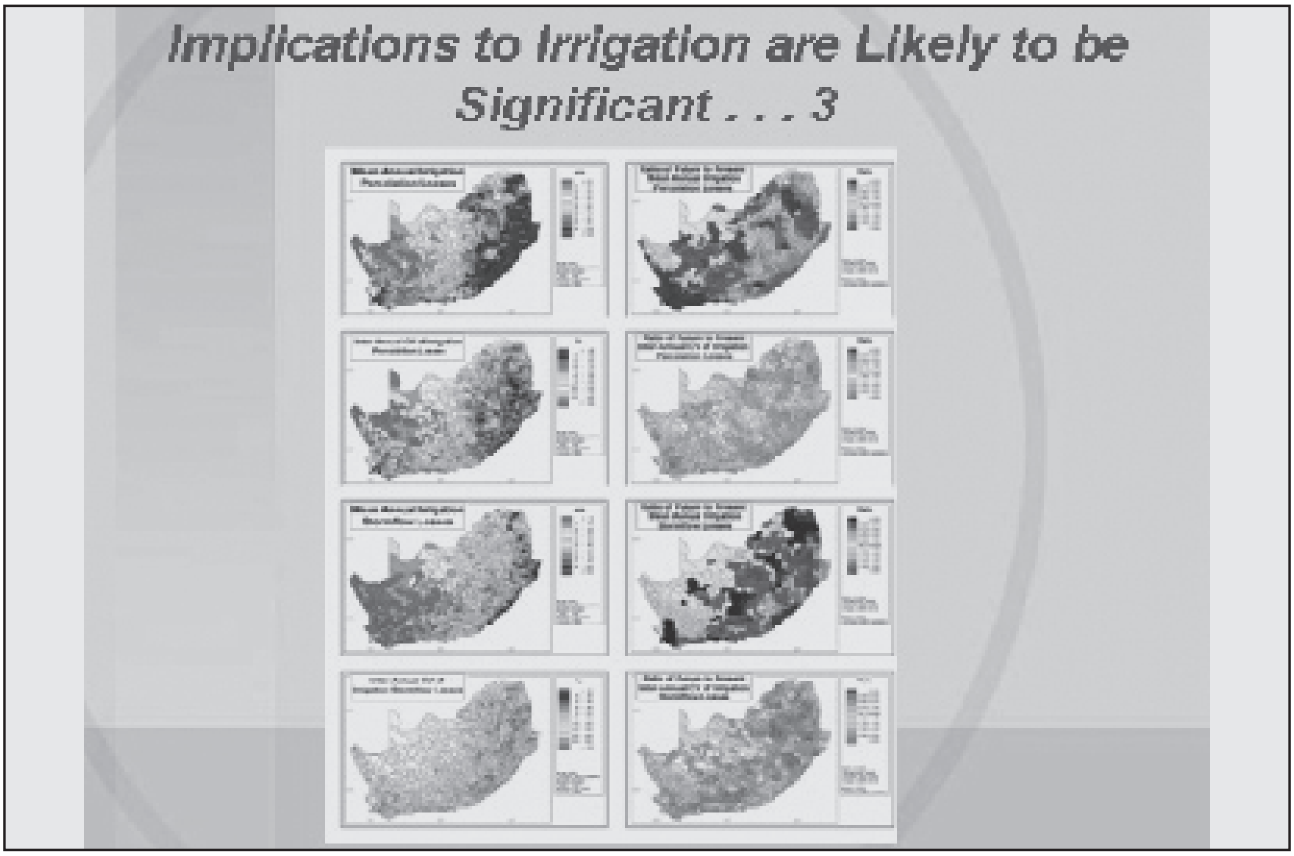

Implications to Irrigation are Likely to be Significant . . . 3

Fig 35

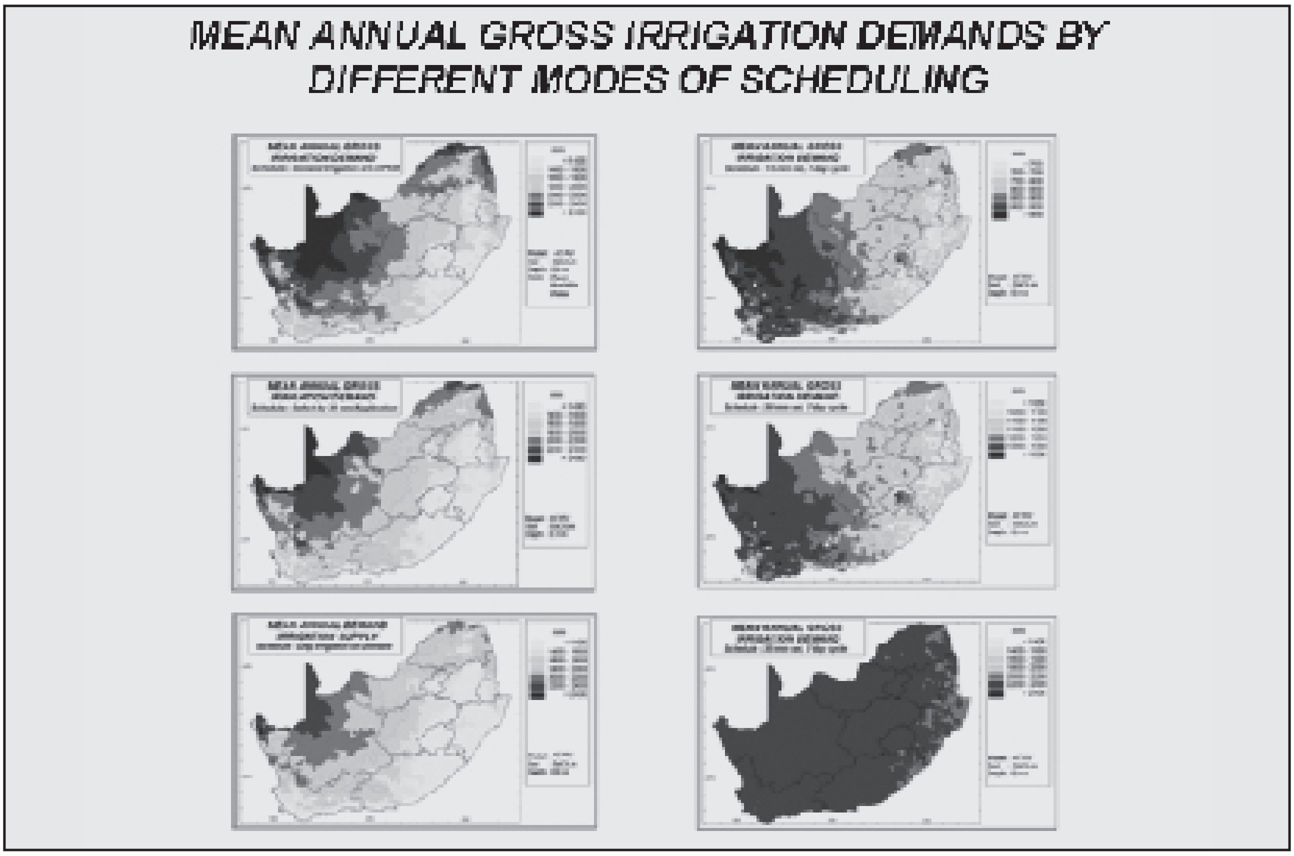

MEAN ANNUAL GROSS IRRIGATION DEMANDS BY
DIFFERENT MODES OF SCHEDULING

Fig 36

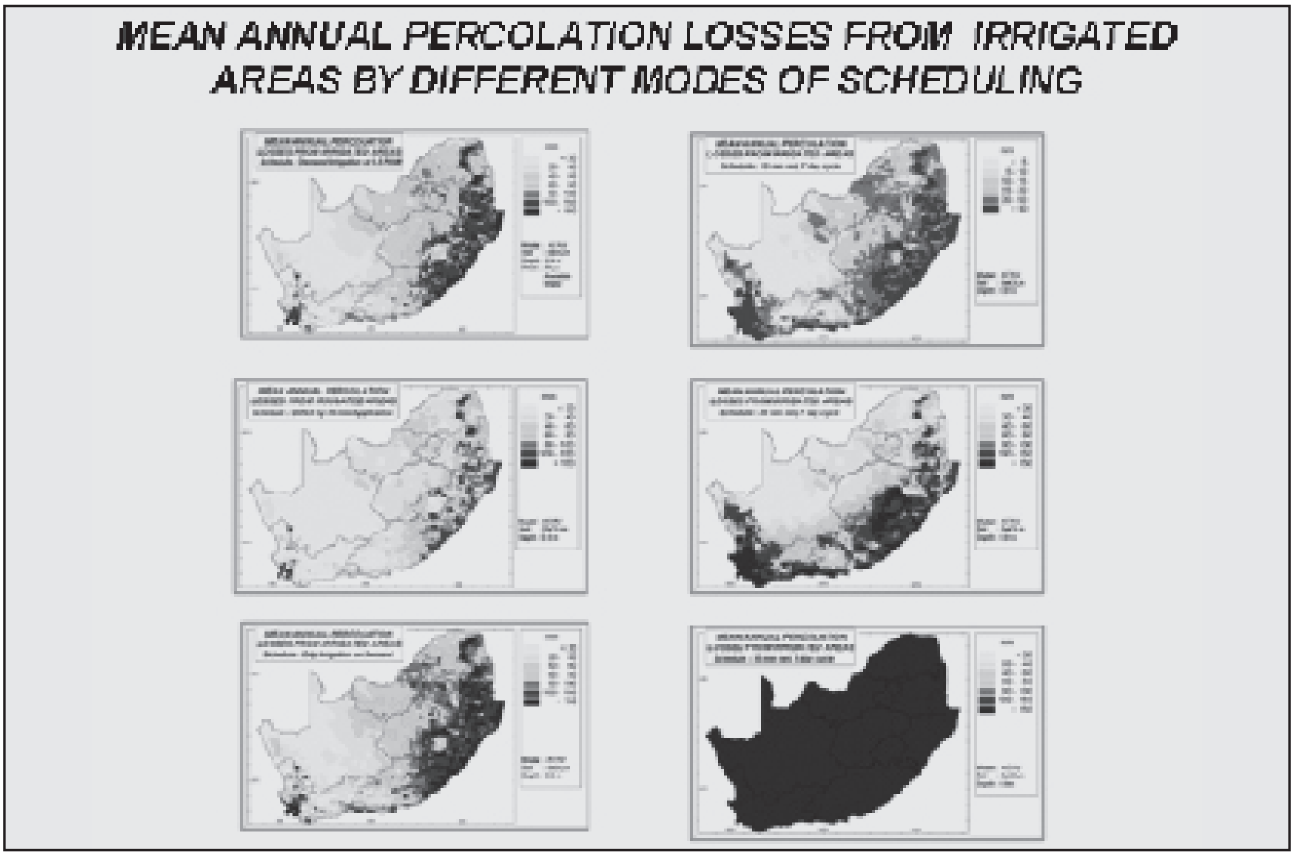

MEAN ANNUAL PERCOLATION LOSSES FROM IRRIGATED
AREAS BY DIFFERENT MODES OF SCHEDULING

Fig 37

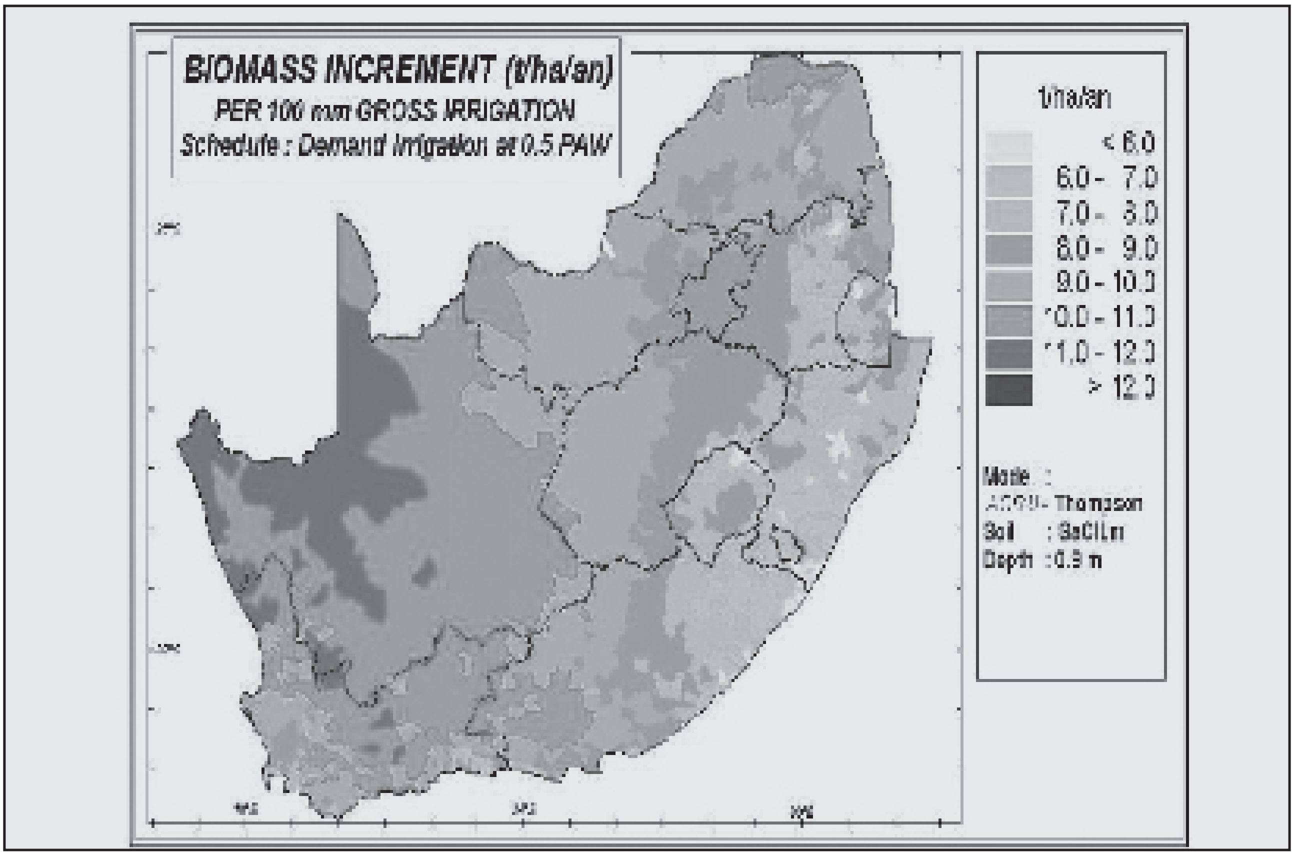

BIOMASS INCREMENT (t/ha/an)
PER 100 mm GROSS IRRIGATION
Schedule : Demand Irrigation at 0.5 PAW
t/ha/an
< 6.0
6.0 - 7.0
7.0 - 8.0
8.0 - 9.0
9.0 - 10.0
10.0 - 11.0
11.0 - 12.0
> 12.0

Fig 38

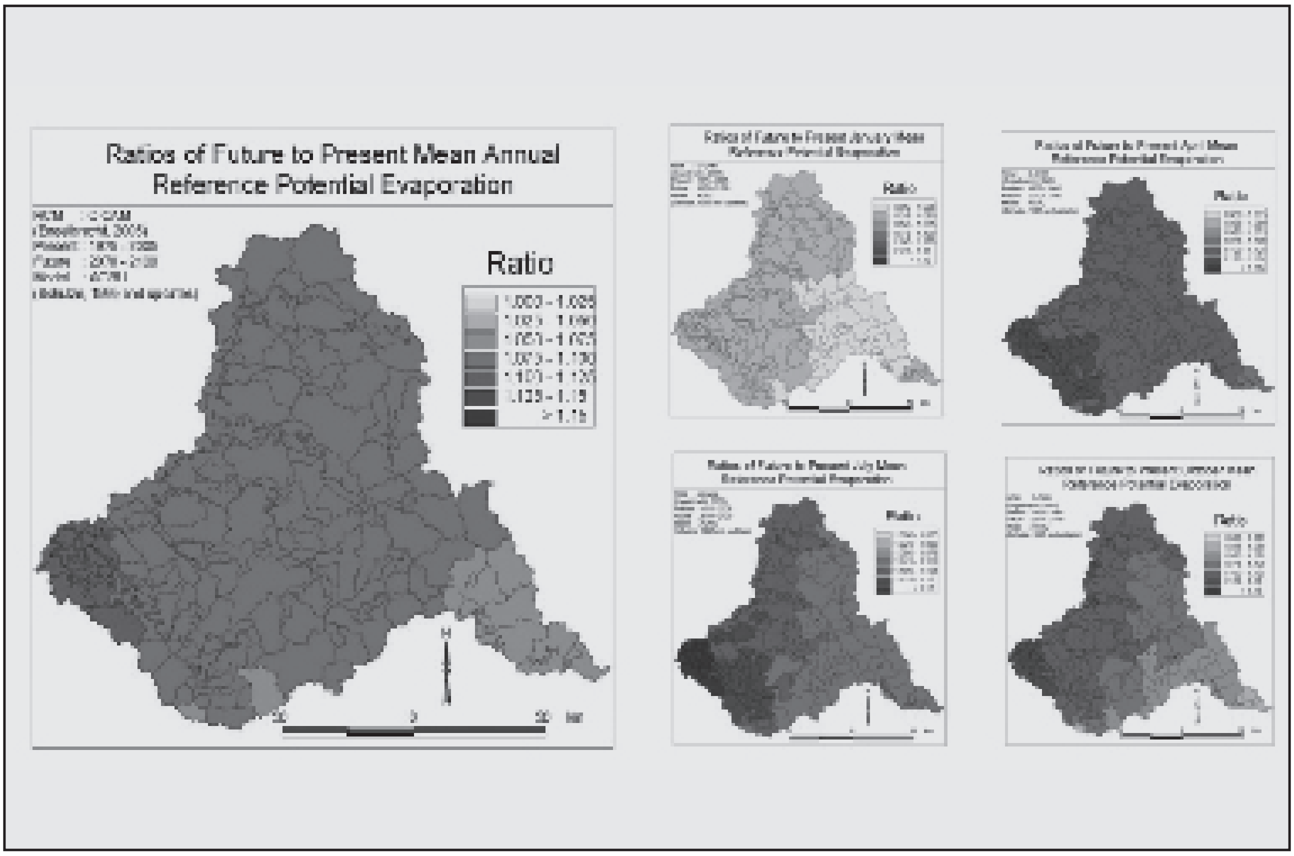

Ratios of Future to Present Mean Annual
Reference Potential Evaporation
Ratio

Fig 39

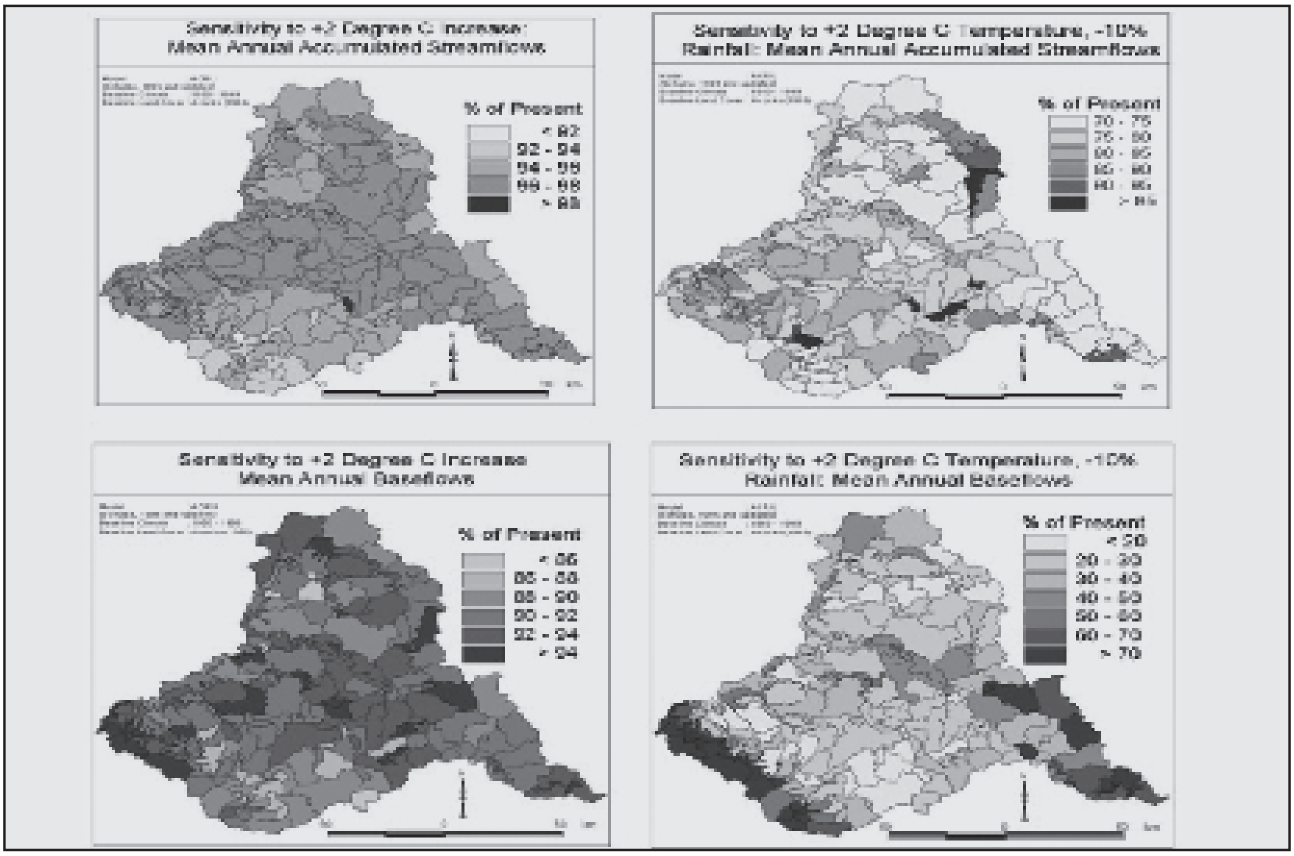

Sensitivity to +2 Degree C Increase: Mean Annual Accumulated Streamflows
% of Present
< 92
92 - 94
94 - 96
96 - 98
> 98
Sensitivity to +2 Degree C Temperature, -10% Rainfall: Mean Annual Accumulated Streamflows
% of Present
Sensitivity to +2 Degree C Increase Mean Annual Baseflows
% of Present
< 86
86 - 88
88 - 90
90 - 92
92 - 94
> 94
Sensitivity to +2 Degree C Temperature, -10% Rainfall: Mean Annual Baseflows
% of Present
< 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
> 70

Fig 40

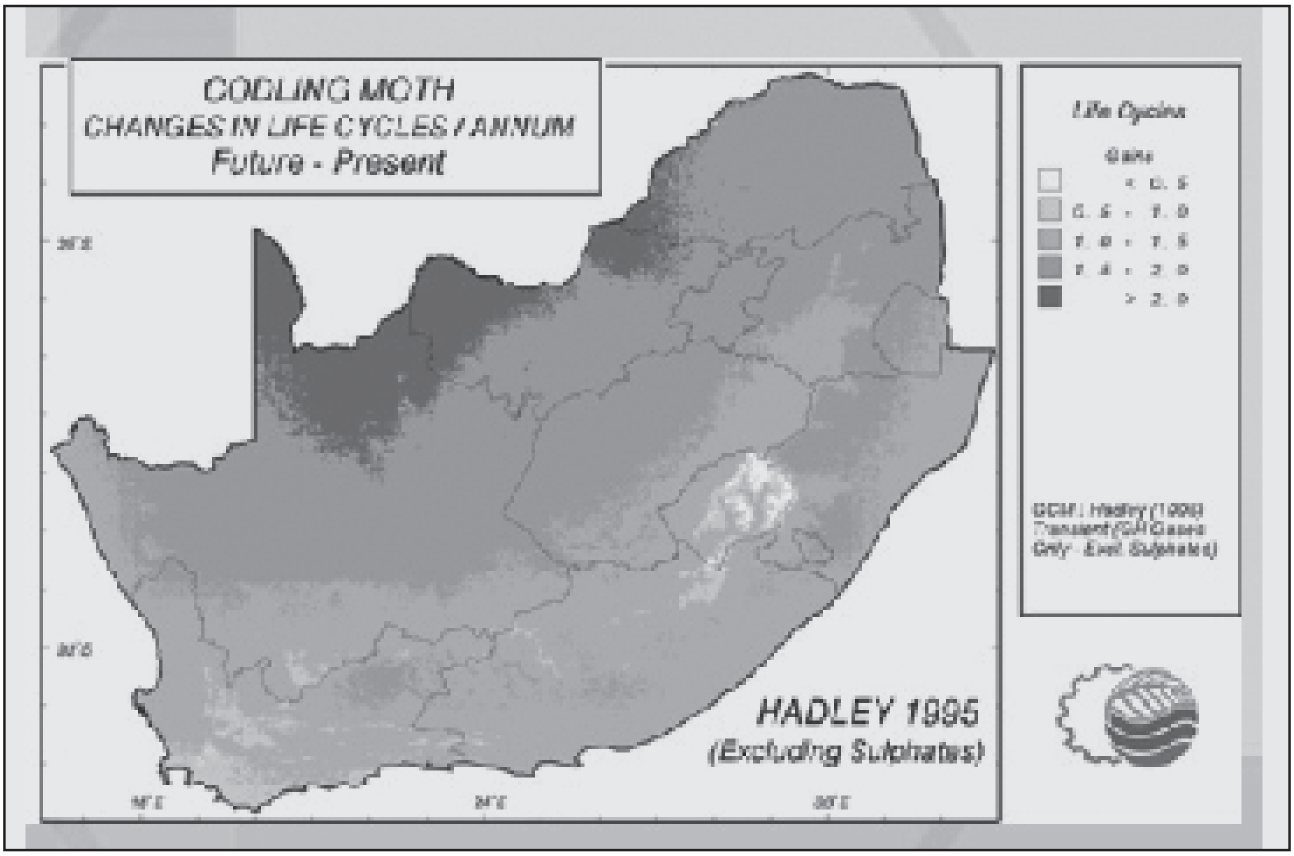
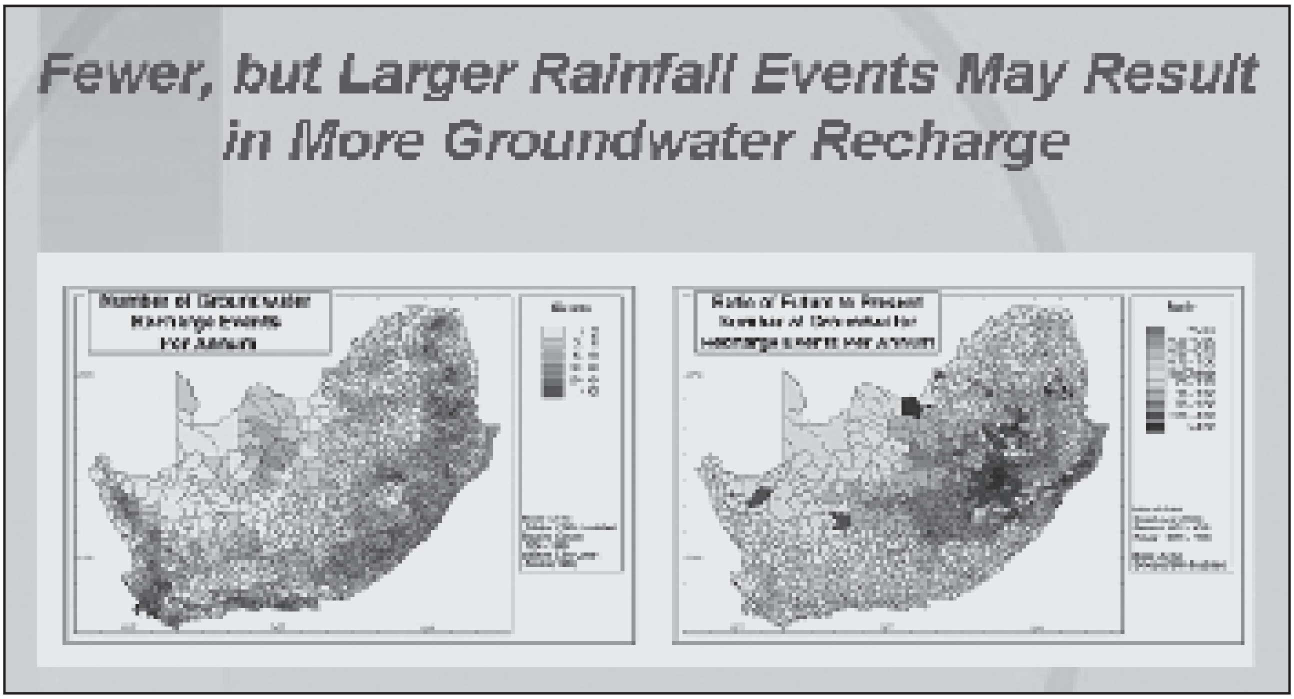

CODLING MOTH
CHANGES IN LIFE CYCLES / ANNUM
Future - Present
Life Cycles
Gains
GCM: Hadley (1995)
Transient (GH Gases Only - Excl. Sulphates)
HADLEY 1995
(Excluding Sulphates)

Fig 41



More direct consequences

- Fewer but higher rainfall events may result in better groundwater recharge (Fig. 41);
- Shifts in the distribution of runoff, implying a change in reservoir operating rules and in ecological reserve (IFRs) (Fig. 42);
- Changes in hill slope and riparian zones affecting, for example, commercial forests and grassland (Fig. 43); and
- Changes in wetlands (Fig. 44).

Fig 42

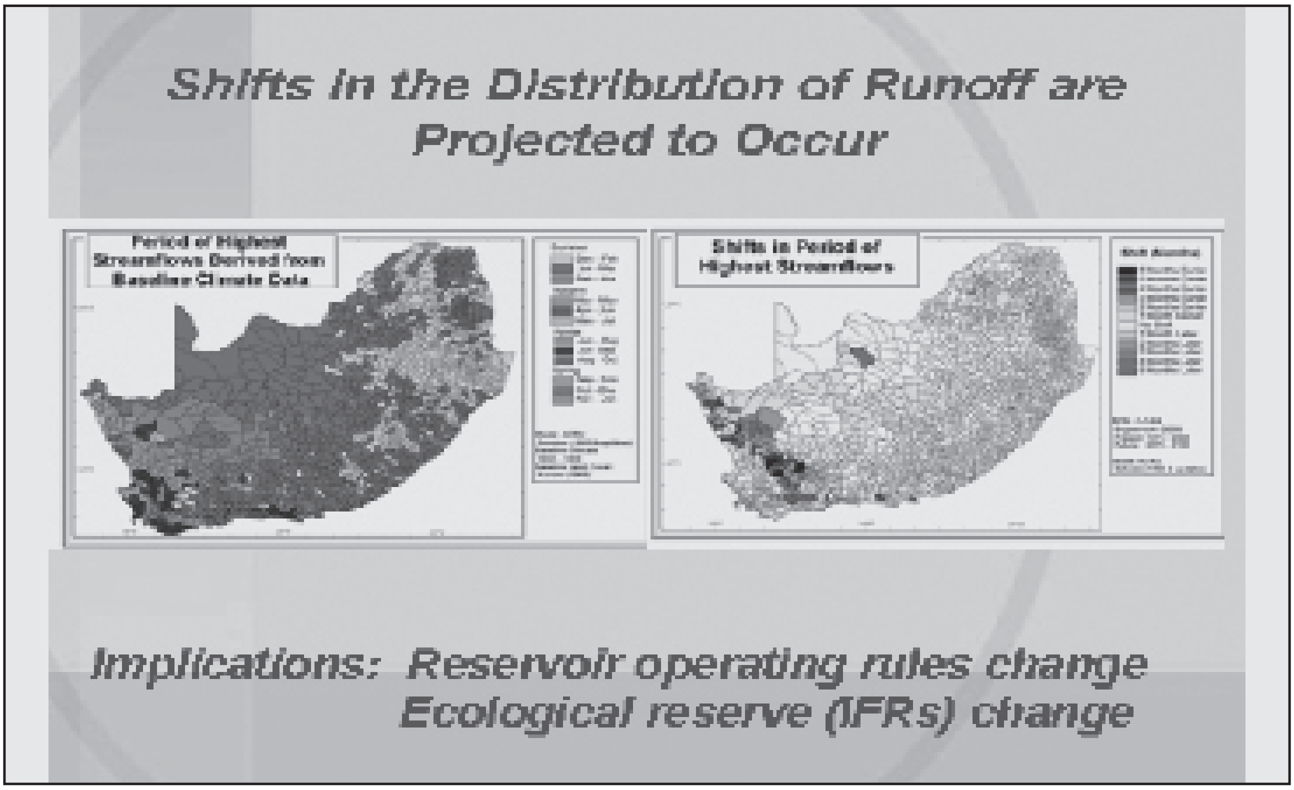


Fig 43

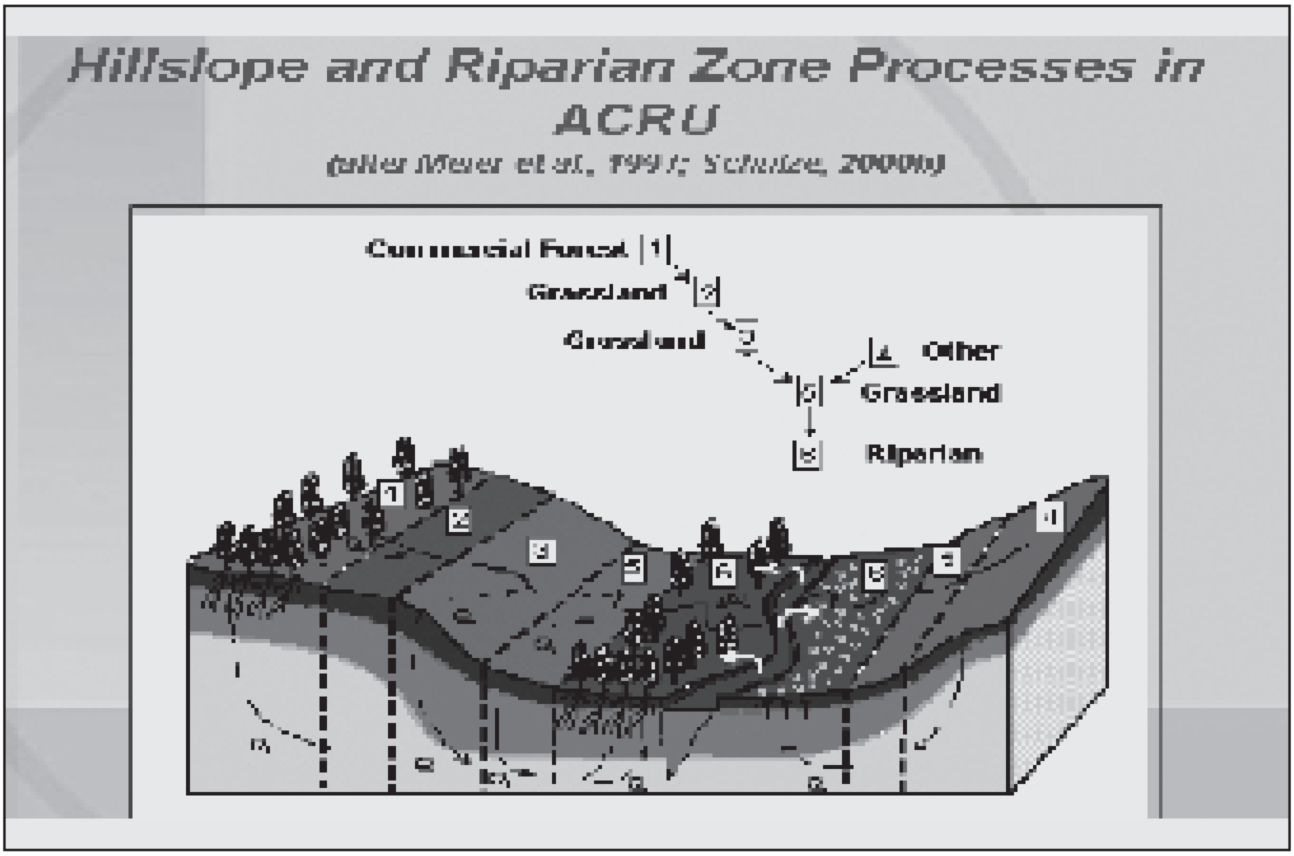
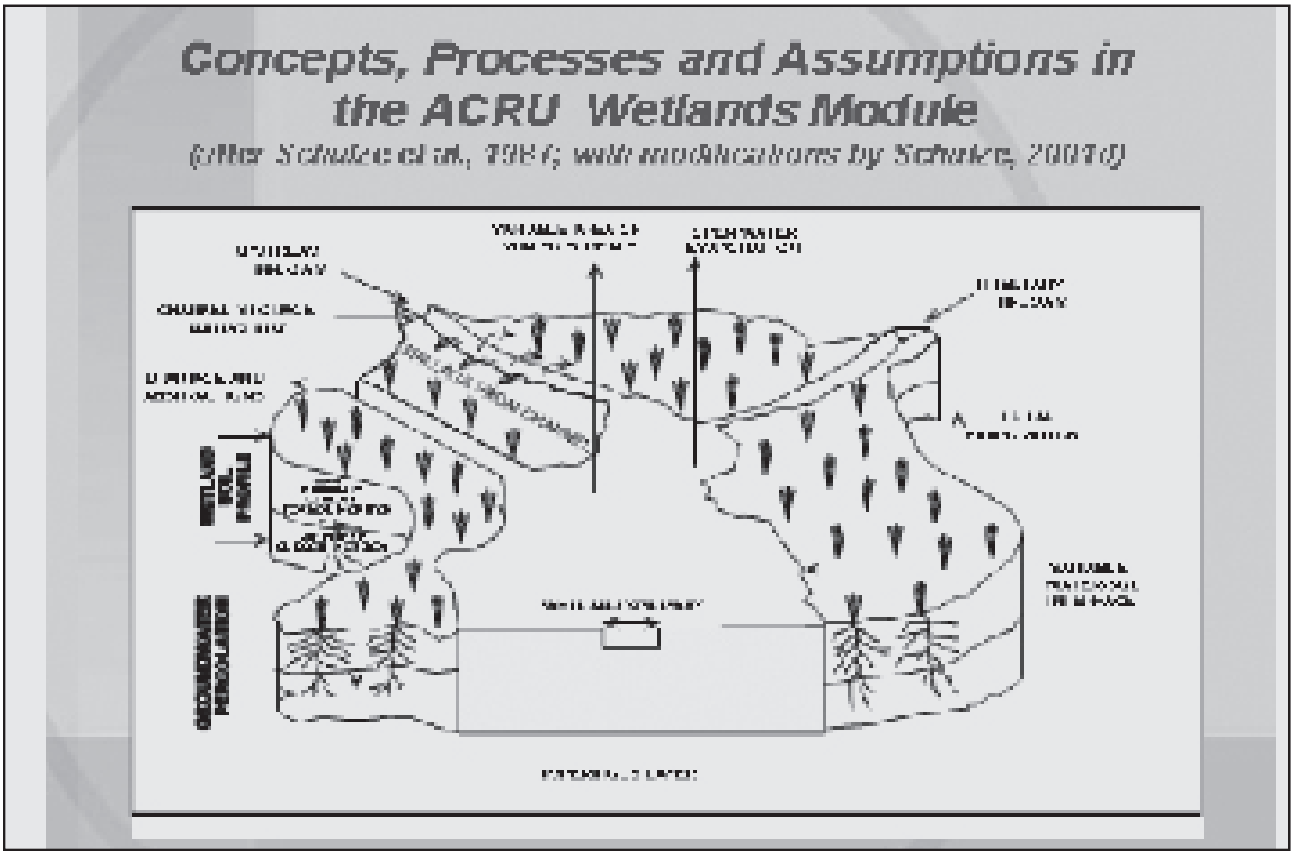
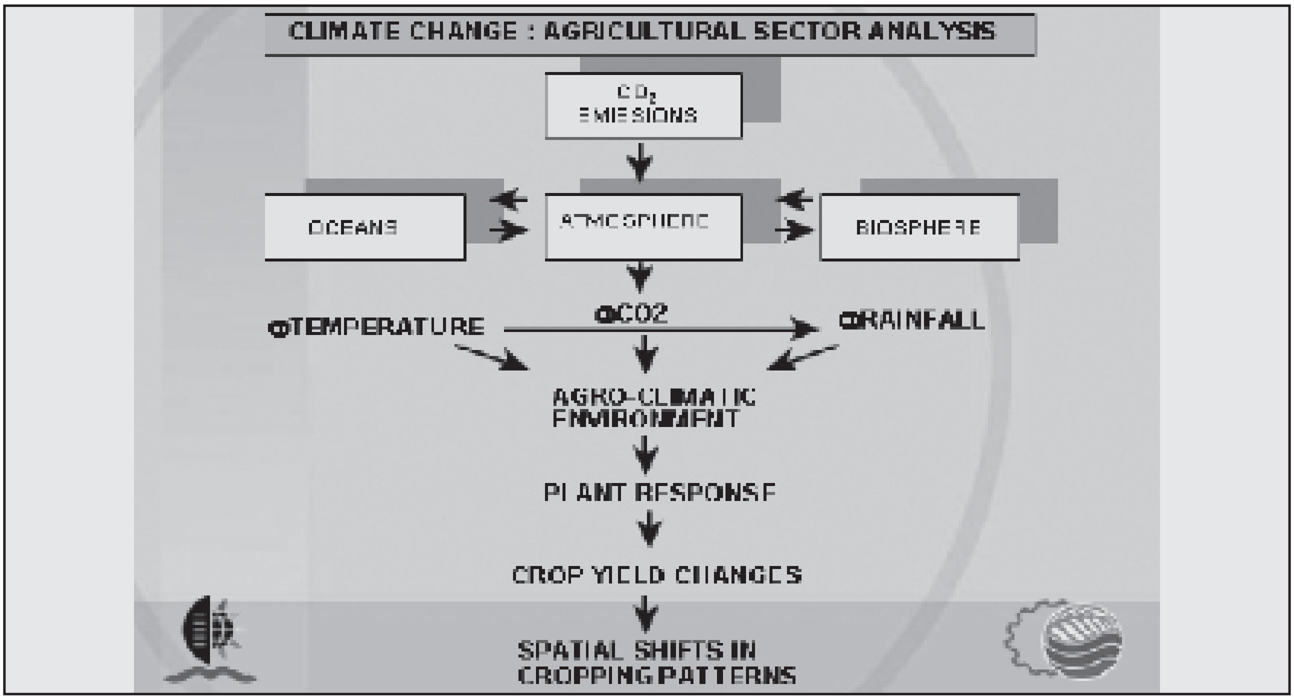

Hillslope and Riparian Zone Processes in ACRU
(after Meier et al., 1997; Schulze, 2000b)
Commercial Forest
Grassland
Grassland
Other
Grassland
Riparian

Fig 44


Concepts, Processes and Assumptions in the ACRU Wetlands Module
(after Schulze et al., 1987; with modifications by Schulze, 2001d)

Effects of climate change on agriculture
The effects of climate change on agriculture are all-embracing as indicated in an analysis of the agricultural sector (Fig. 45).

Fig 45



Agriculture in South Africa is a high-risk enterprise as the success of rainfed agricultural production is directly related to the vagaries of climate and notably of rainfall and temperature – the cornerstones of climate change. Fig. 46, depicting maize yields in the country's highveld maize growing area over 44 seasons, clearly indicates the difference in yield during wettest and driest seasons. The data was used to estimate changes in economic return under different climate change regimes (Fig. 47). The combined effect of higher atmospheric CO_2 levels, higher temperature and less precipitation on economic return is alarming.

Fig 46

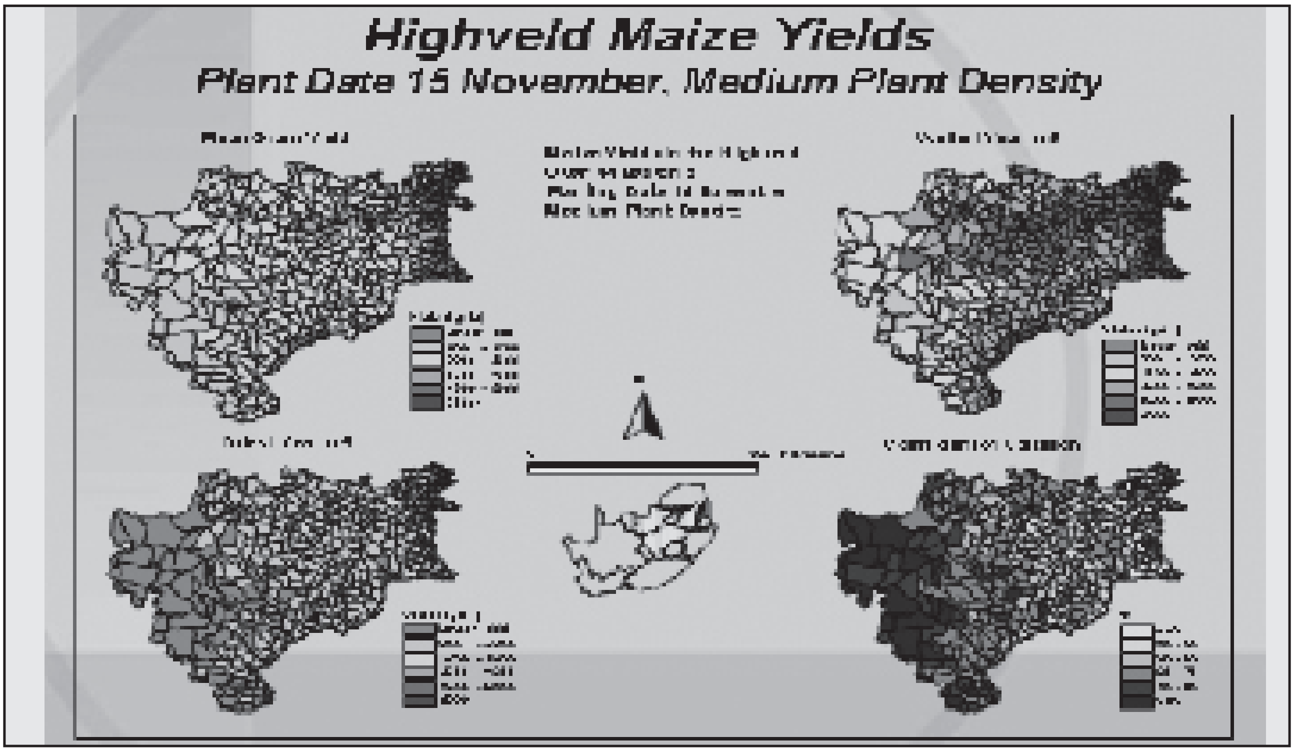
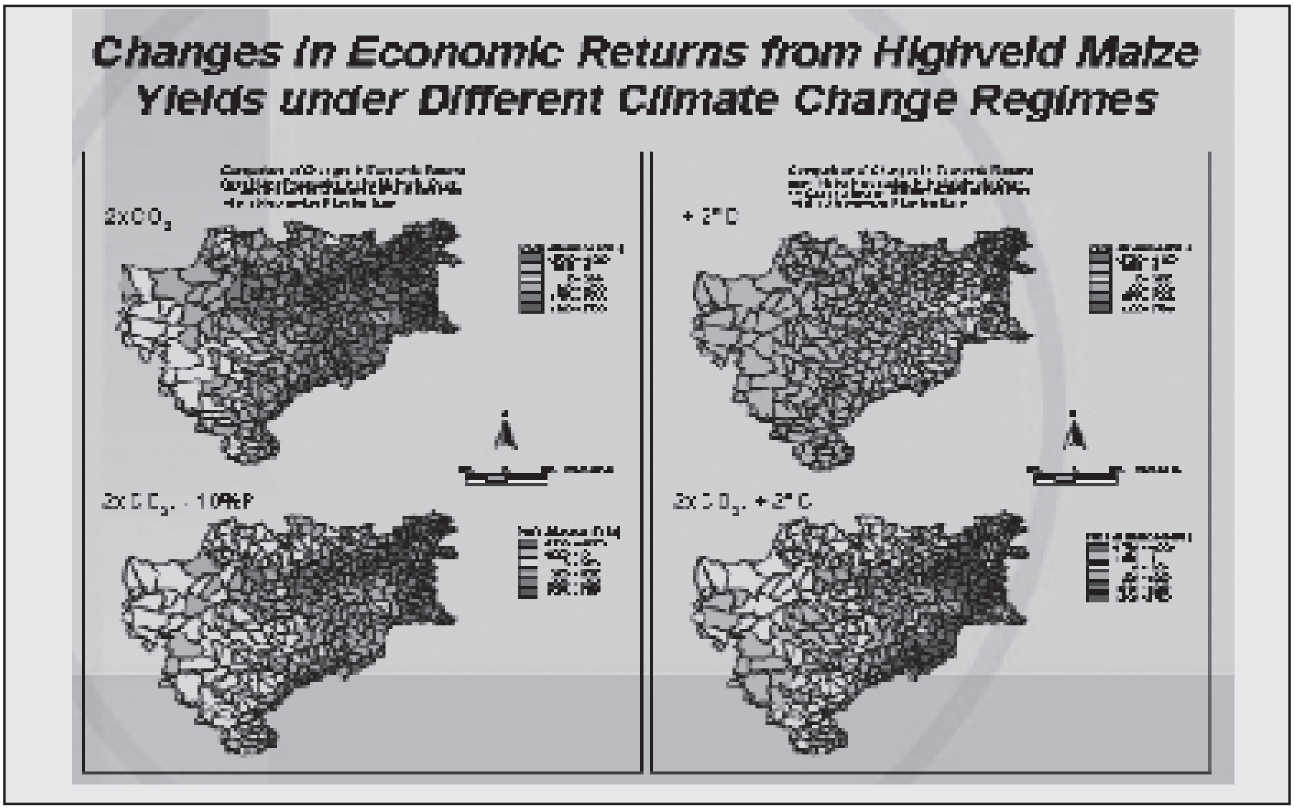


Fig 47



The sustainability of an agro-ecosystem, including the optimum utilization of plant nutrients, is as important as economic return. Fig. 48, the result of simulated nitrogen (N) recovery under increased CO_2 regimes, points out the inhibition of N recovery while Fig. 49 shows the influence of climate change elements on yield when manure and inorganic fertilizer have been used. Fig. 50, depicting decreases in simulated soil organic N levels in a dry and wet area for selected climate regimes, is a serious warning on the effects of climate change on soil organic matter, the cradle of a sustainable agro-ecosystem.

Fig 48

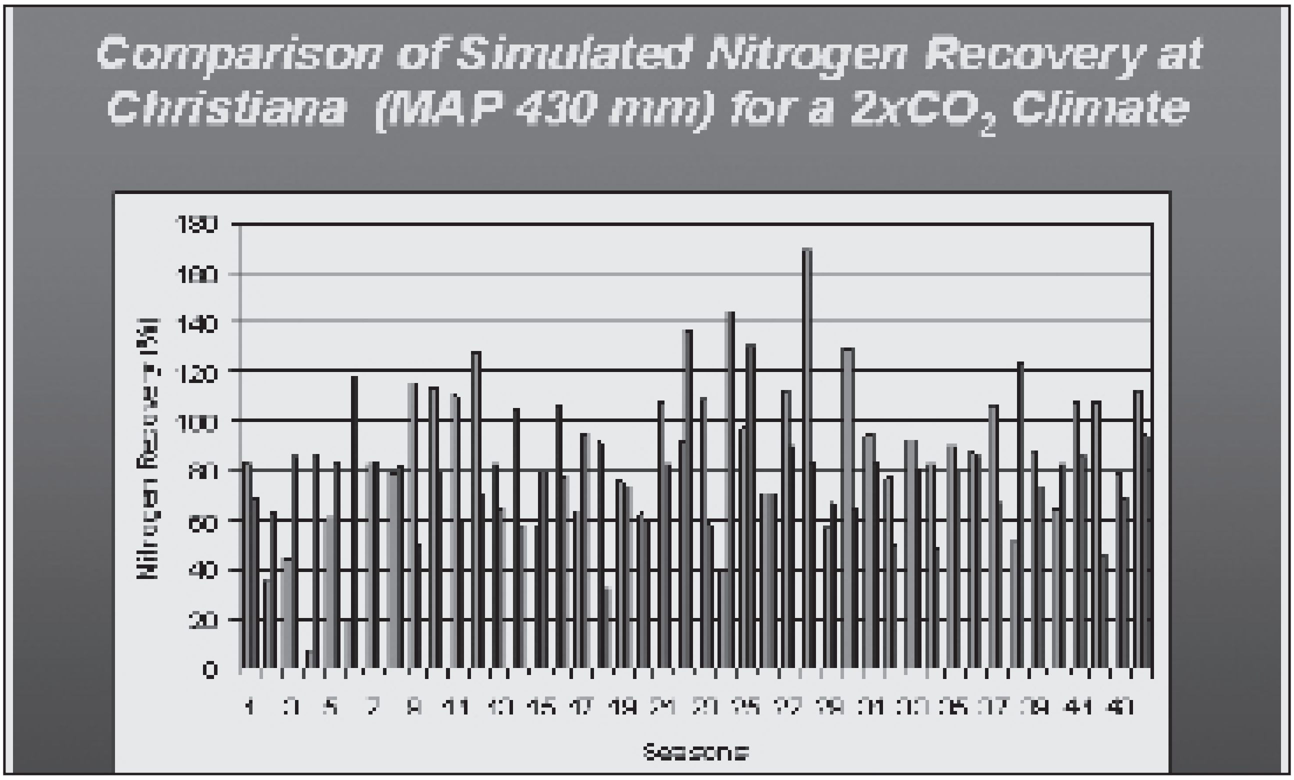


Fig 49

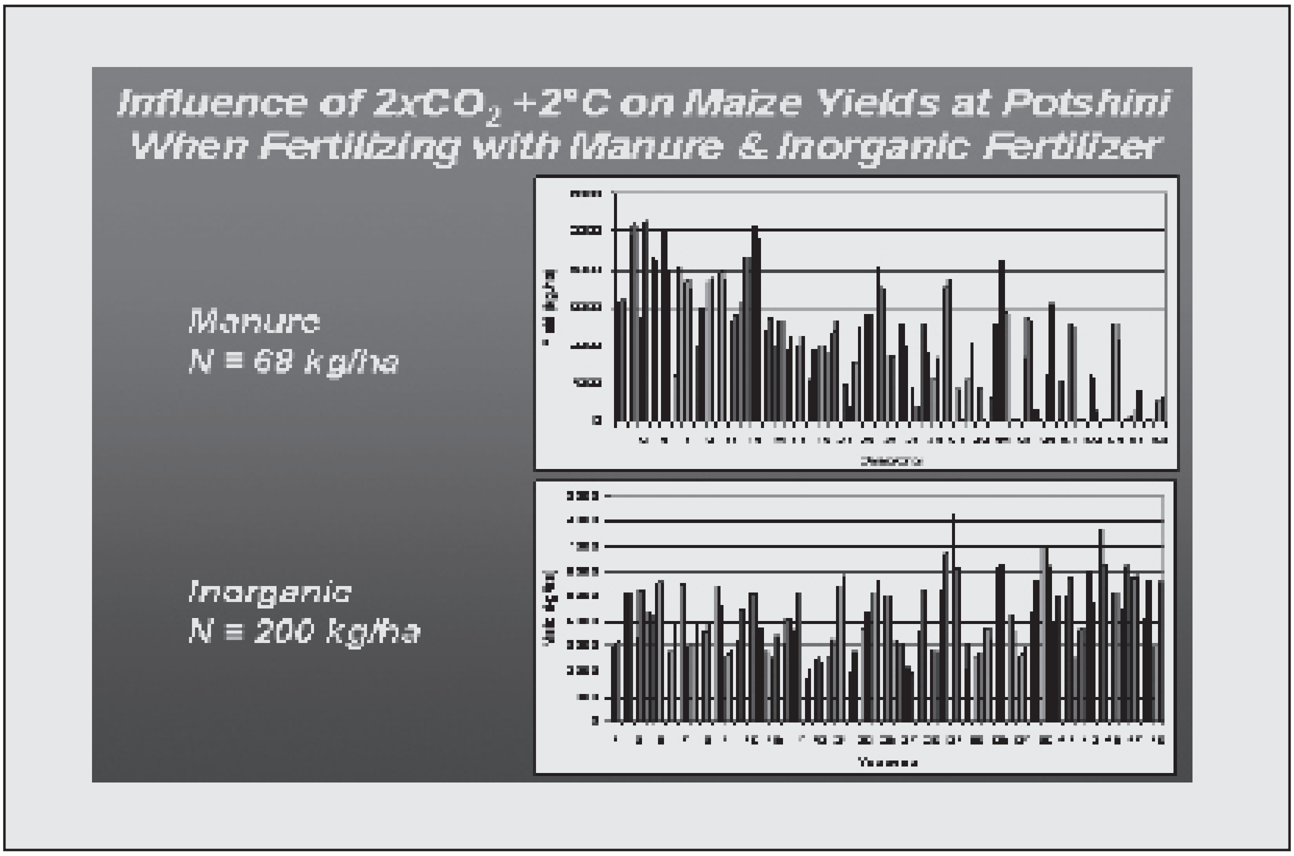
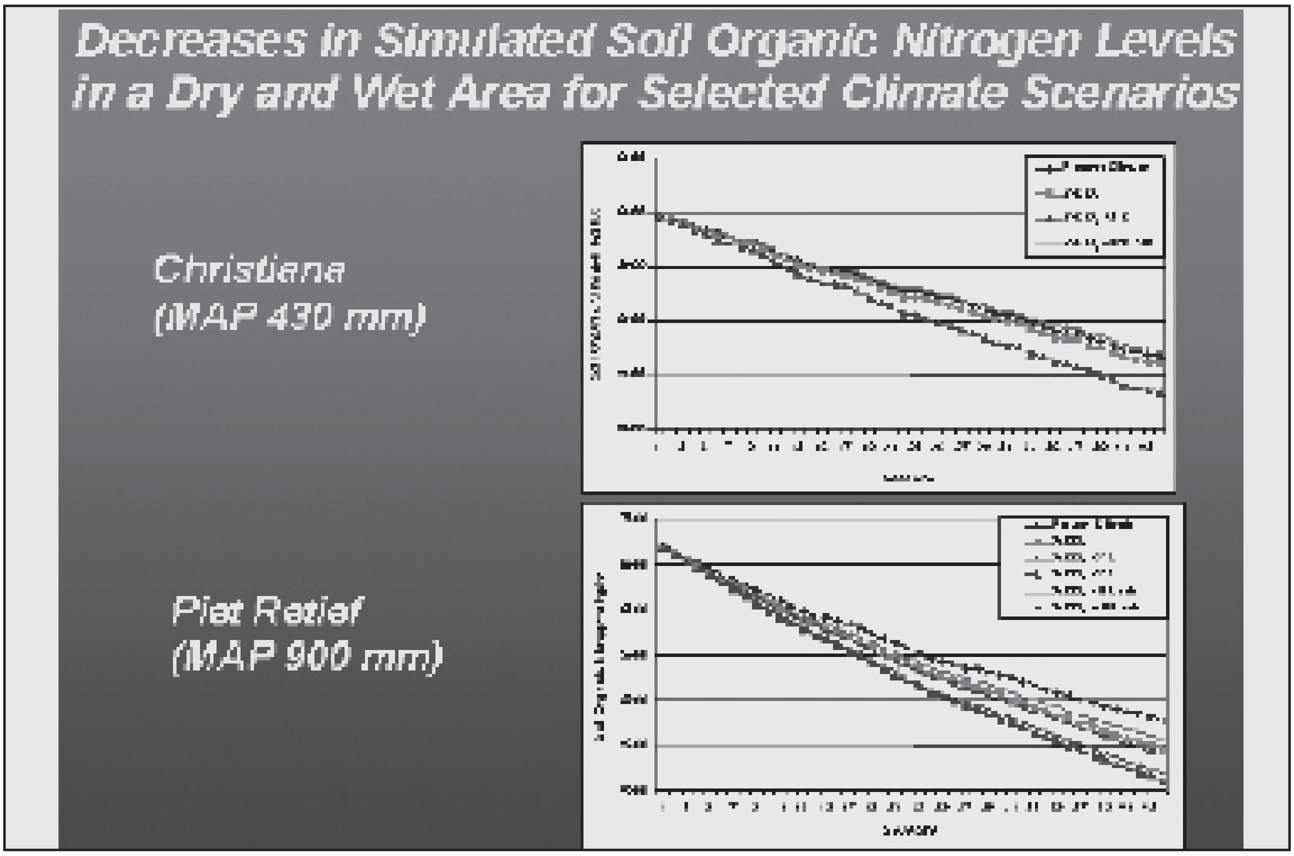

Influence of 2xCO2 +2°C on Maize Yields at Potshini
When Fertilizing with Manure & Inorganic Fertilizer
Manure
N = 68 kg/ha
Inorganic
N = 200 kg/ha

Fig 50


Decreases in Simulated Soil Organic Nitrogen Levels
in a Dry and Wet Area for Selected Climate Scenarios
Christiana
(MAP 430 mm)
Piet Retief
(MAP 900 mm)

Irrigation is a stabilising factor in food production for most countries in Africa and water use efficiency of the utmost importance. To illustrate the possible effects of climate change on the irrigation sector, the Mbuluzi catchment in Swaziland (Fig. 51) and its configuration (Fig. 52) has been selected. Swaziland is renowned for the large-scale irrigation of surgarcane and irrigated sugarcane per sub-catchment is illustrated in Fig. 53.

Fig 51

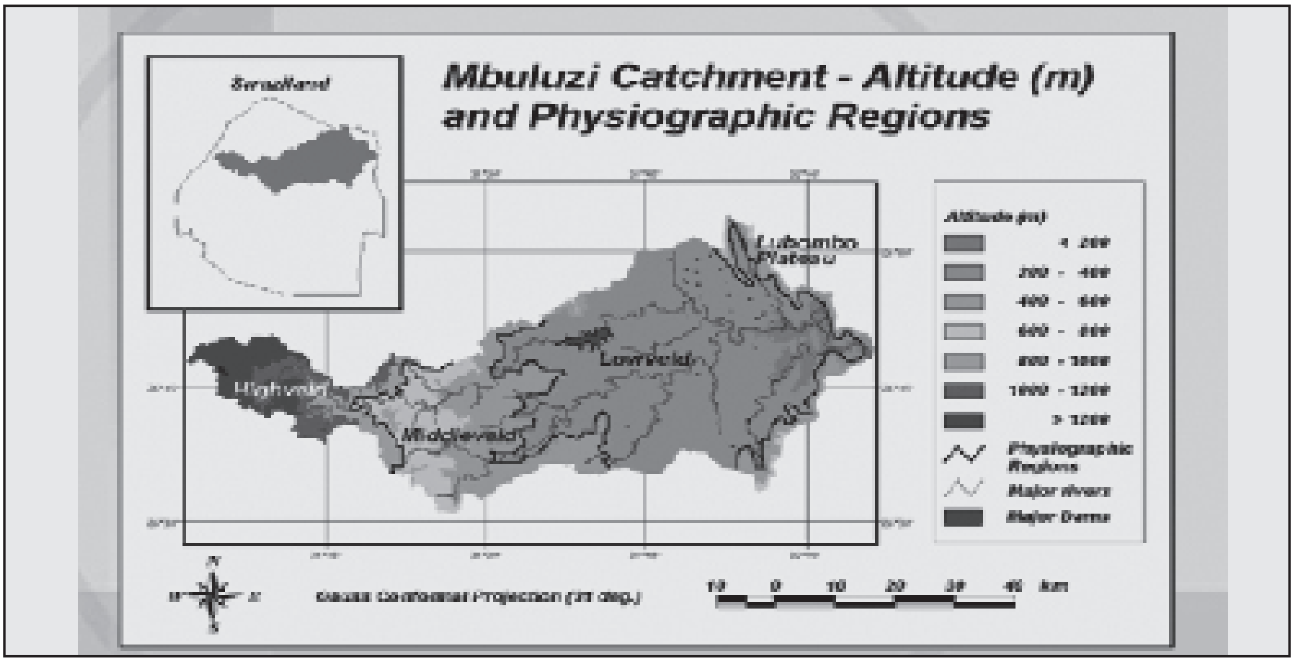


Fig 52

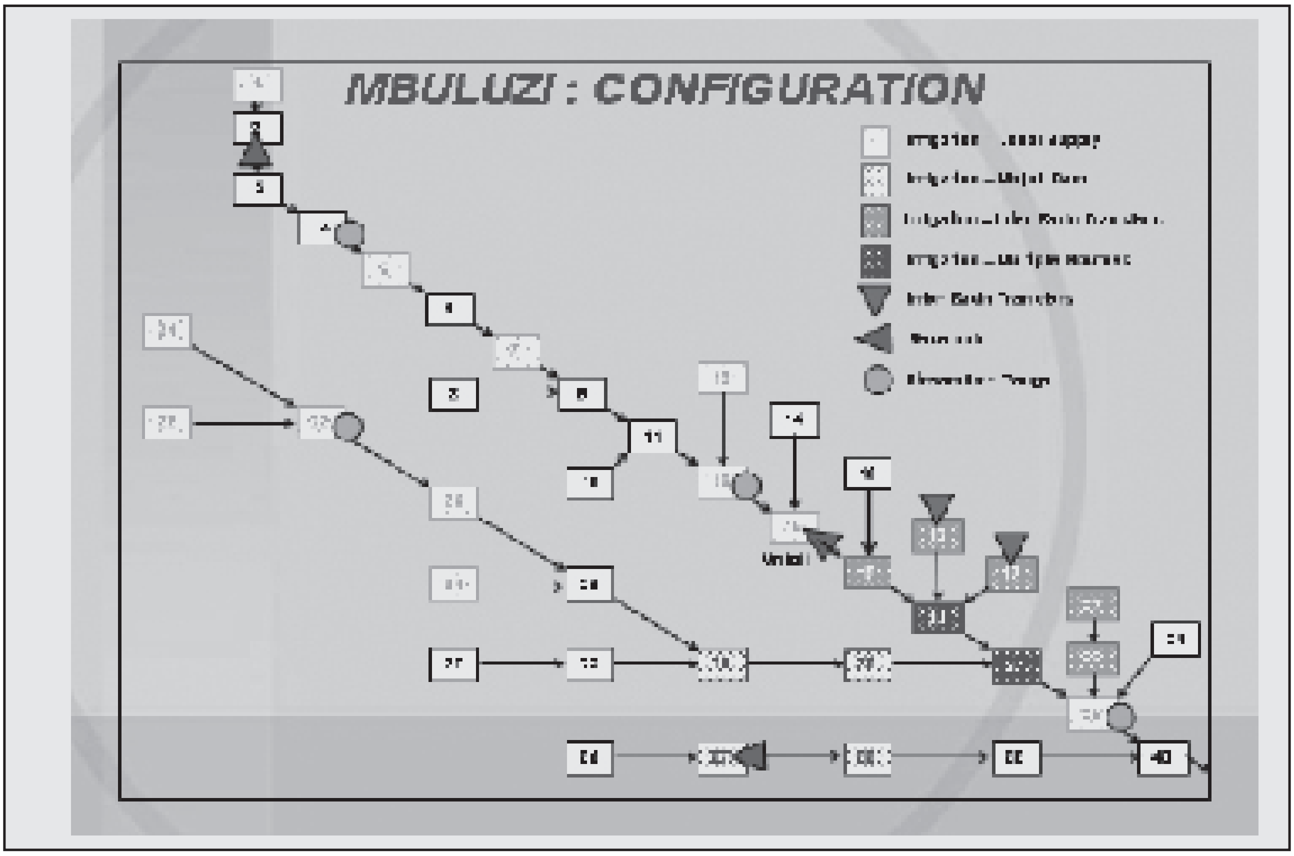


Fig 53

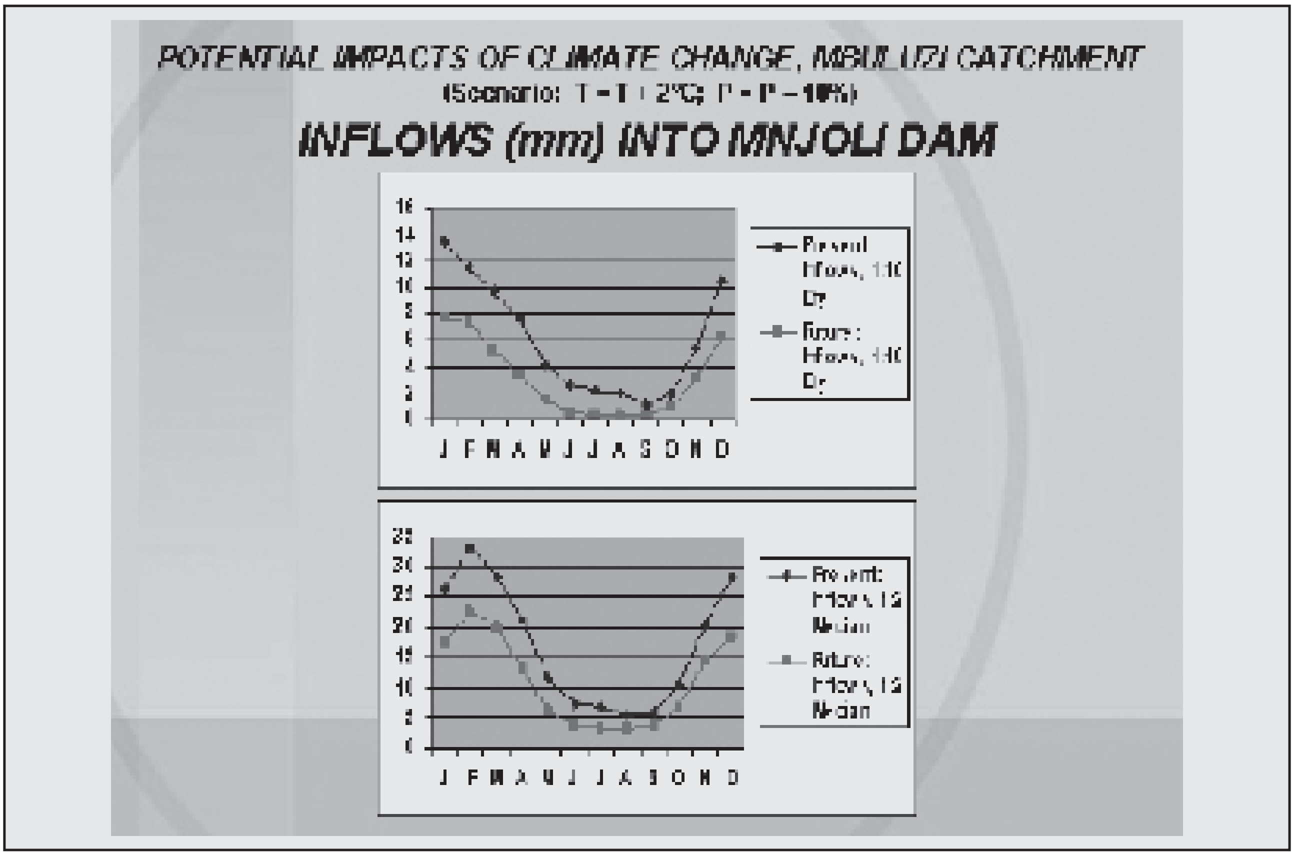


Fig. 54 portrays the potential impacts of climate change on inflows (mm) into the Mnjoli Dam in the Mbuluzi catchment according to a scenario where temperature inclines 2°C and precipitation decreases by 10%, while Fig. 55 displays the potential impacts of the same scenario as percentage of full supply capacity. The effect of these climate change scenarios on sugarcane yield is pictured in Fig. 56.

Fig 54

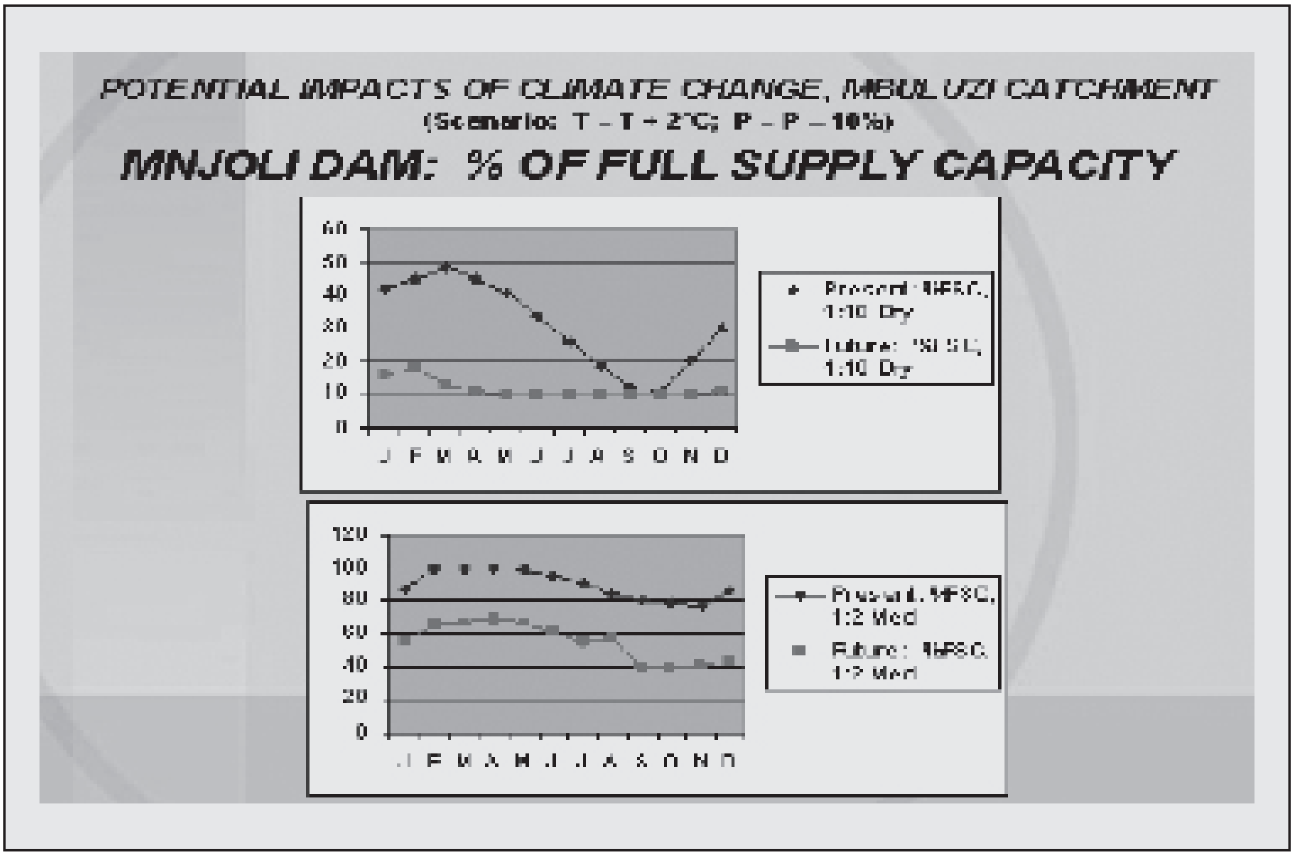
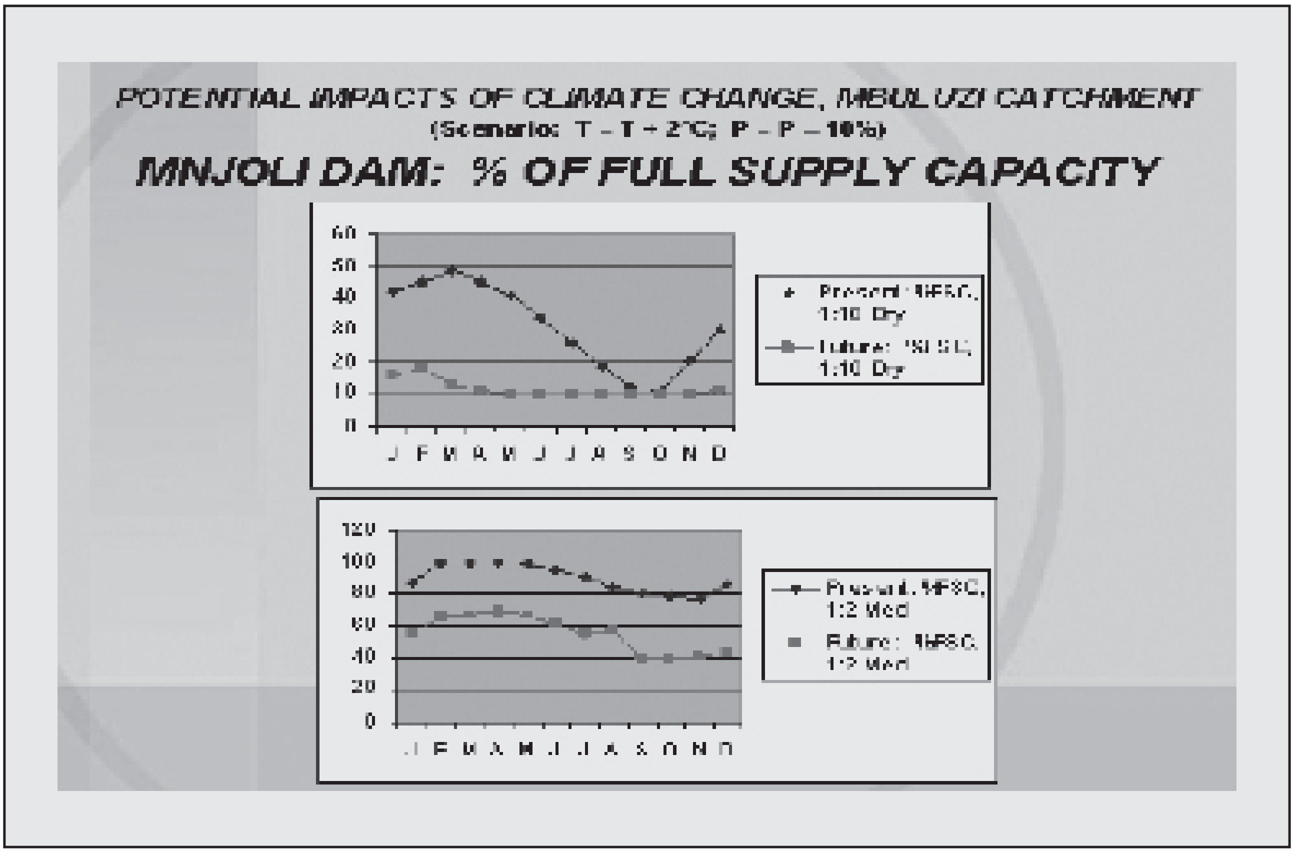


Fig 55



Catchments are trans-boundary and the effects of climate change on the Mbuluzi catchment will directly affect other countries. Fig. 57 is an estimation of the Mbuluzi outflows to Mozambique. It is evident that international water agreements with neighbouring countries may have to be re-negotiated.

Fig 56

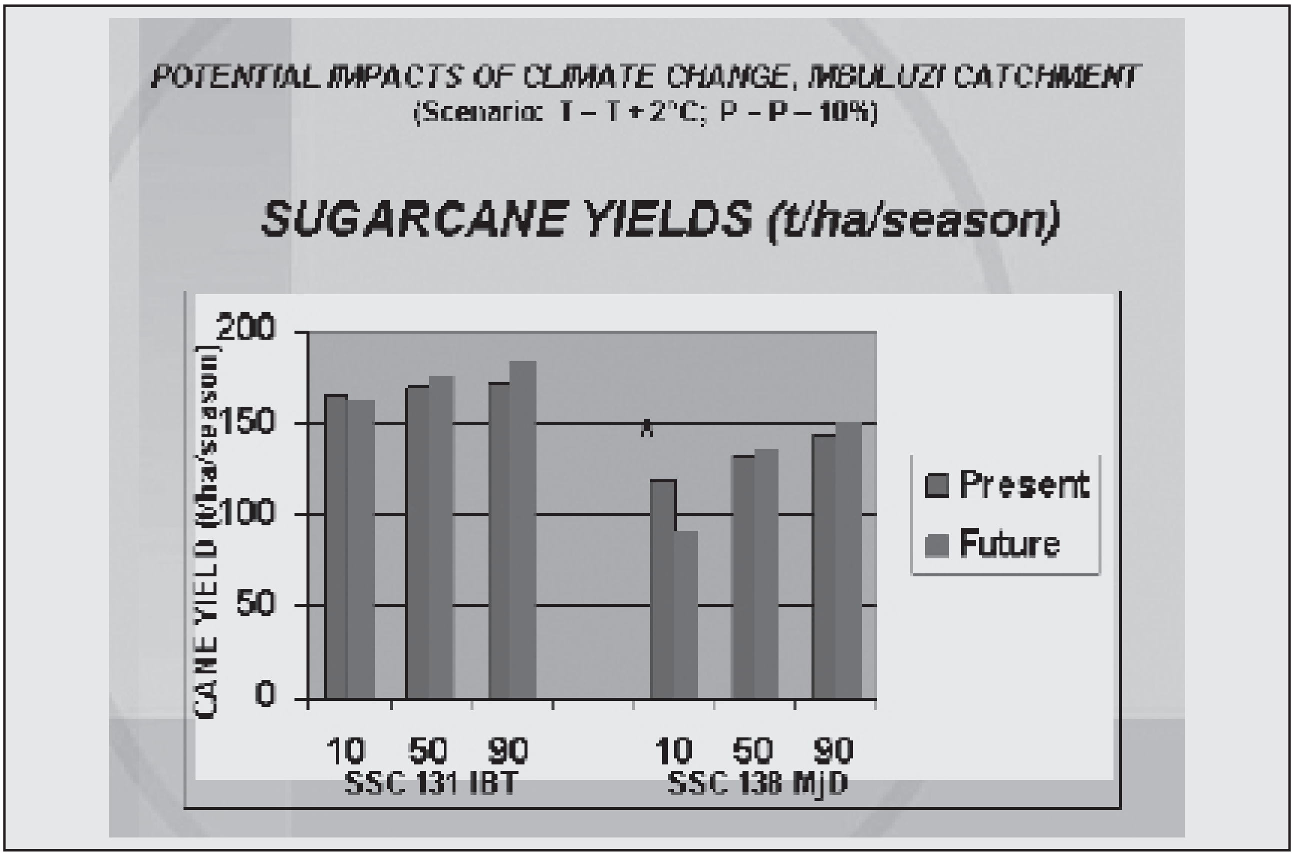
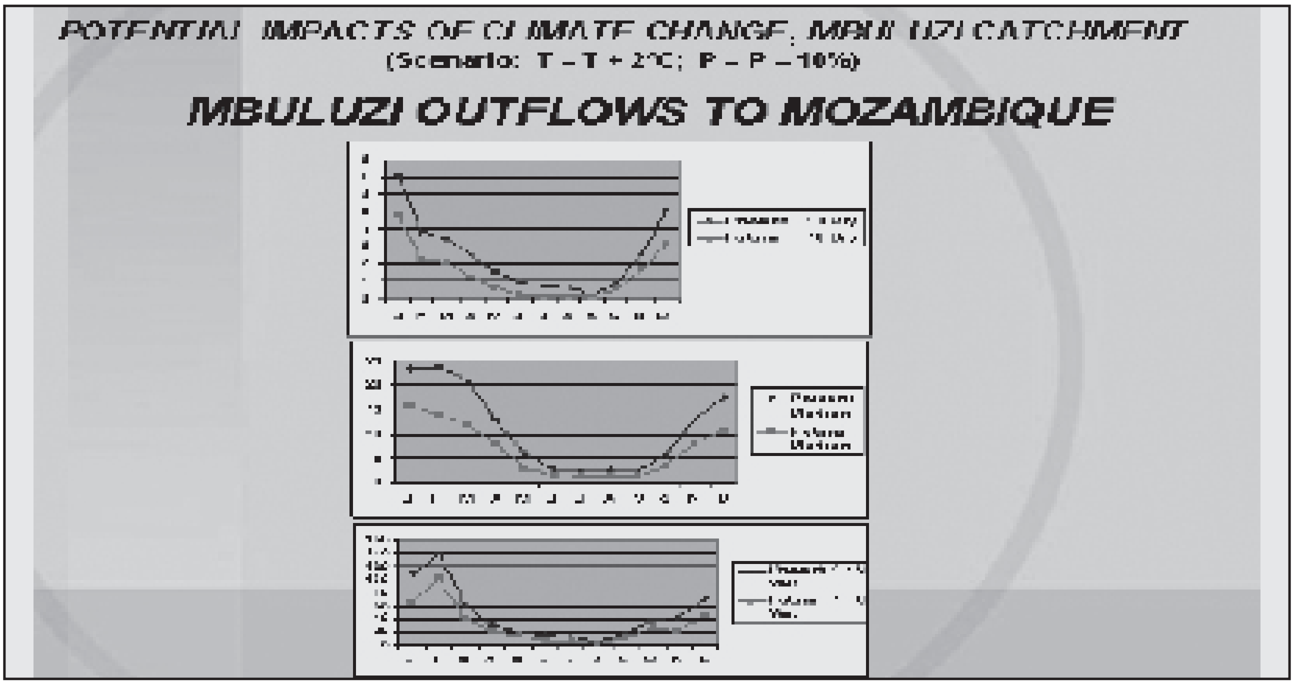


Fig 57



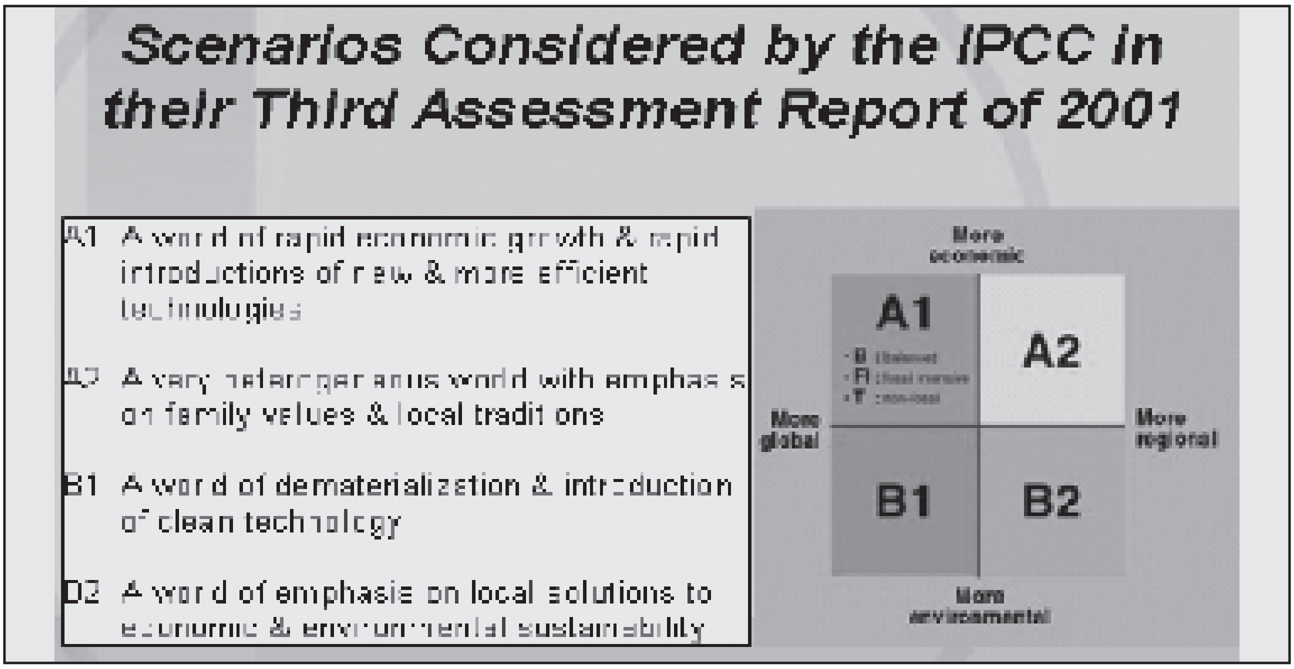
Prevailing uncertainties in the climate change debate

Uncertainties around the climate change debate are somewhat philosophical and elusive but comprehensive as they are dealing with the very existence of man on earth.

Considering the IPCC 3rd assessment report (2001), four global scenarios (Fig. 58) could be considered, namely a more economic, a more global, a more regional and a more environmental scenario. It is highly unlikely that any of these can become an exclusive approach, as environmental, socio-cultural and economic elements are intimately interlinked. However, the characteristics entailed by these scenarios are:

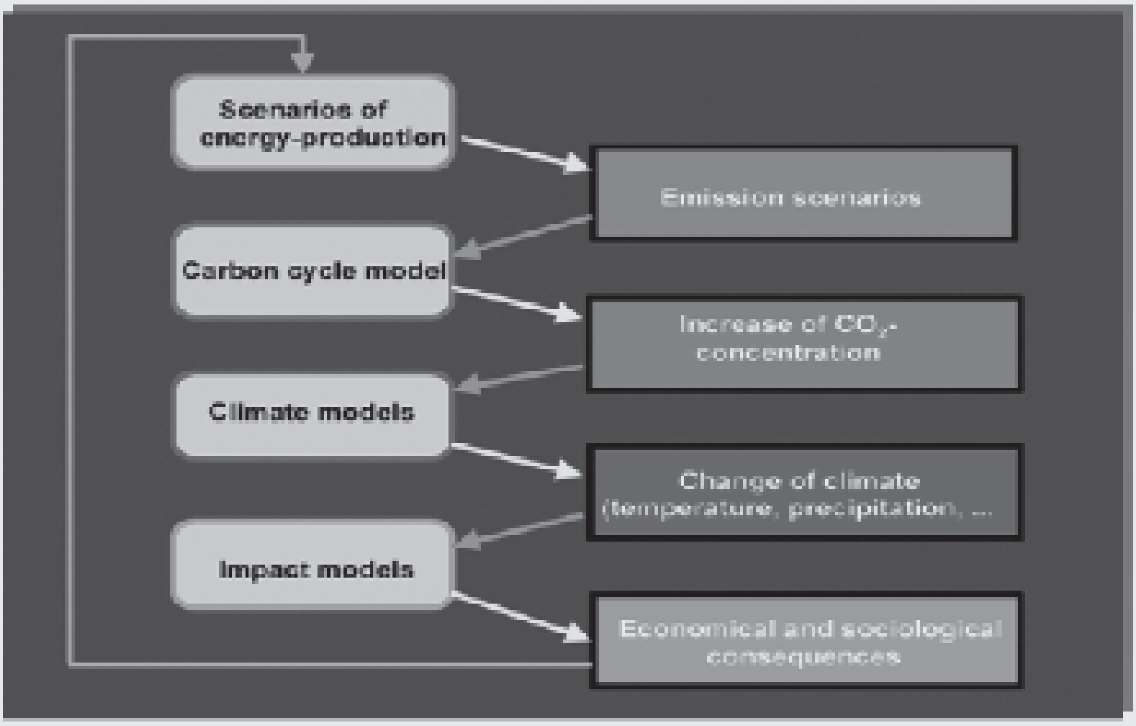
- A world of rapid economic growth and the rapid introduction of new and more efficient technologies;
- A very heterogeneous world with emphasis on family values and local traditions;
- A world of dematerialization and introduction of clean technology; and
- A world of emphasis on local solutions to economic and environmental sustainability.

Fig 58



Other scenarios and models to address uncertainties are scenarios of energy production; a carbon cycle model; climate models and impact models (Fig. 59). These can be interlinked successfully.

Fig 59



The future

Bearing in mind the above deliberations, the question is asked, involuntary, *where to now?* It is quite obvious that agriculture and water resource management will have to adapt to inevitable climate change effects as survival strategy. The adaptation process is, however, intricate and multifaceted bearing in mind that socio-cultural, environmental and economic elements, each with its own objectives and sentiments, must be interlinked and complied to as a unified front in the face of the challenges of climate change.

Adaptation process

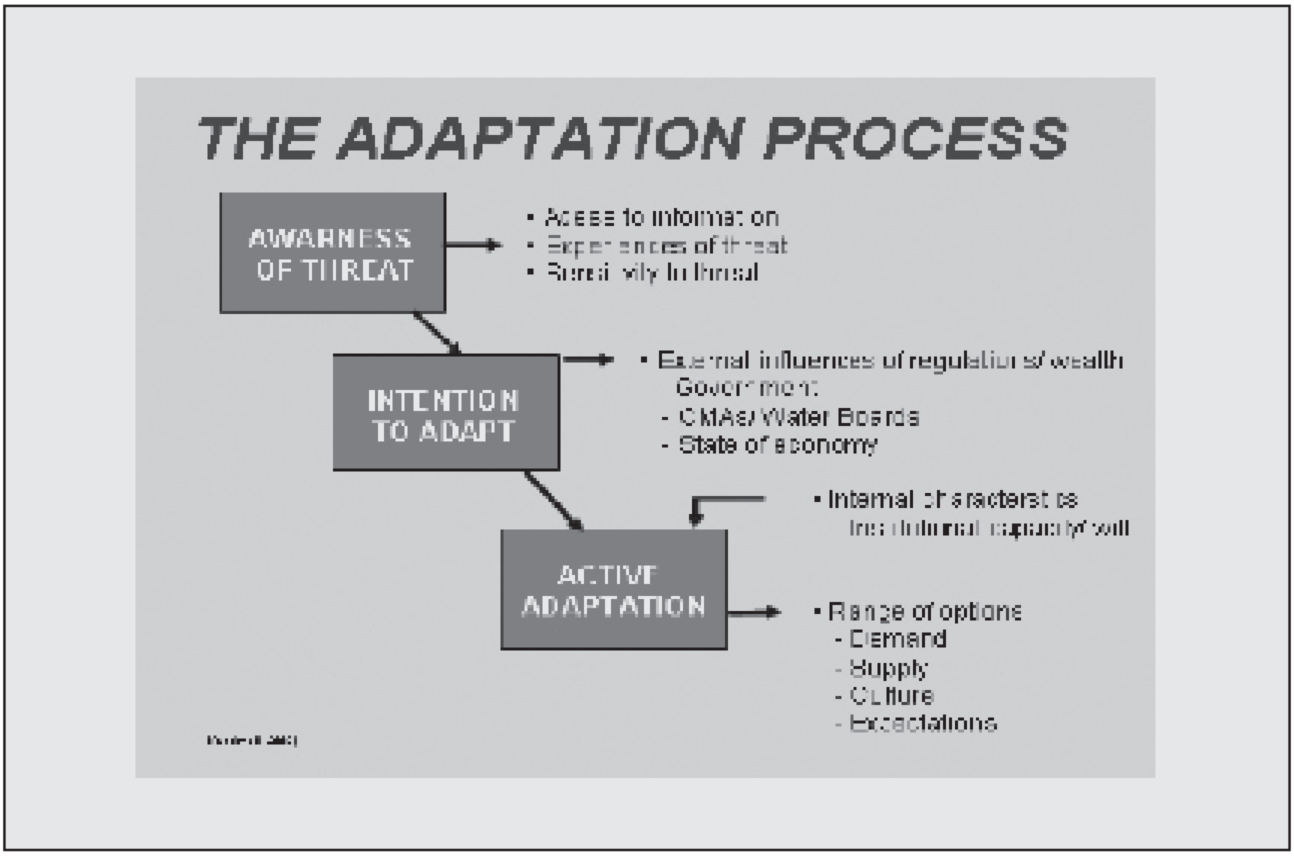
The adaptation process can be divided into three interlinked phases, each with its own requirements, influences, characteristics and options (Fig. 60). The phases are briefly discussed:

Awareness of threat: The major components of this phase are access to information to provide a knowledge base; experiences of threat; and sensitivity to threat.

Intention to adapt: Intention is largely underpinned by the external influences of regulations and wealth. These external influences could be government, catchment management associations (CMAs) and water boards, and the state of the economy.

Active adaptation is dominated by internal characteristics such as institutional capacity and the will to adapt. To facilitate active adaptation, there are a range of options, including demand, supply, culture and expectations.

Fig 60



The adaptation process is dynamic and is characterized by many uncertainties. There are many types of risk likely to increase over time (Fig.61). Using thresholds as point of departure, trends may shift beyond thresholds, variability could increase beyond thresholds, and thresholds may even decrease. These should be taken cognizance of in a decision framework on climate variability and climate change (Fig. 62).

Fig 61

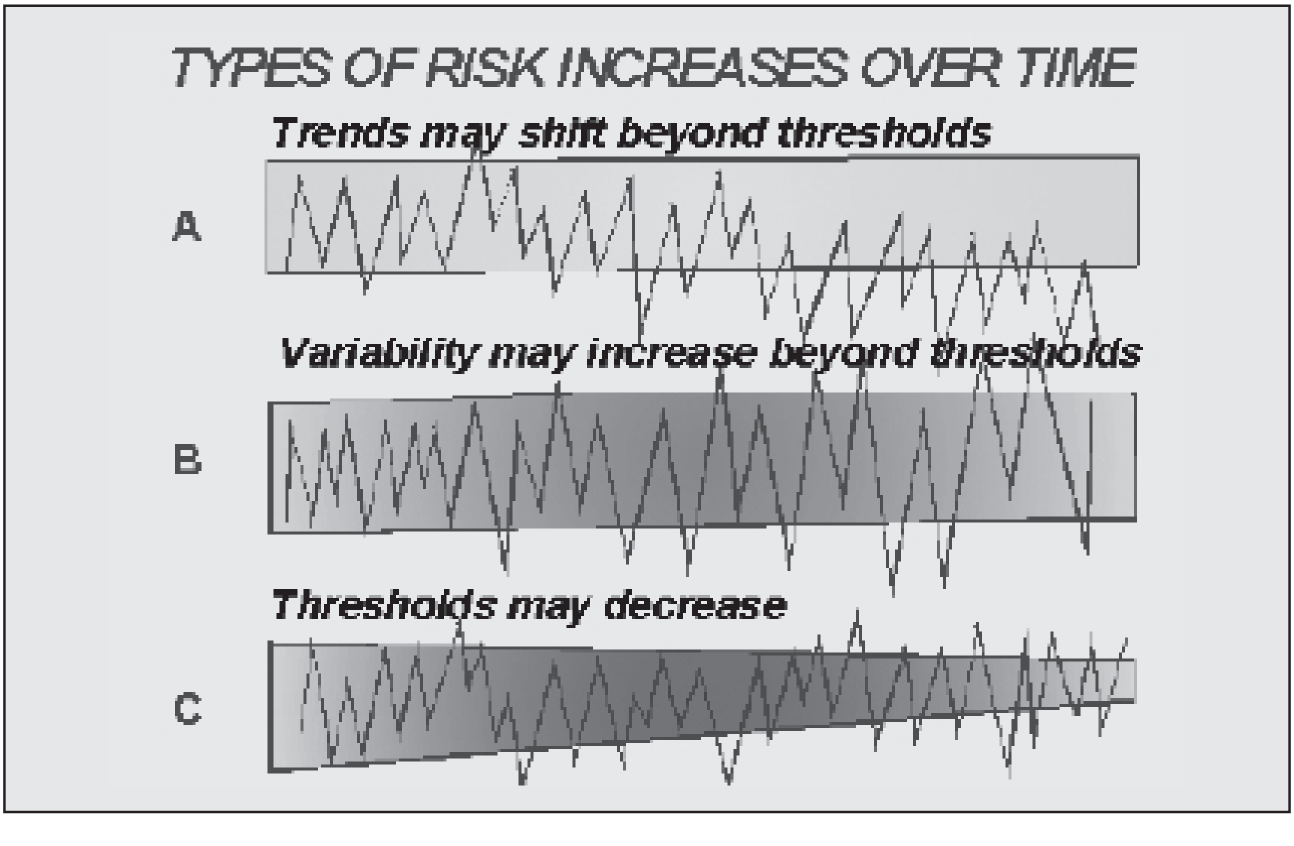
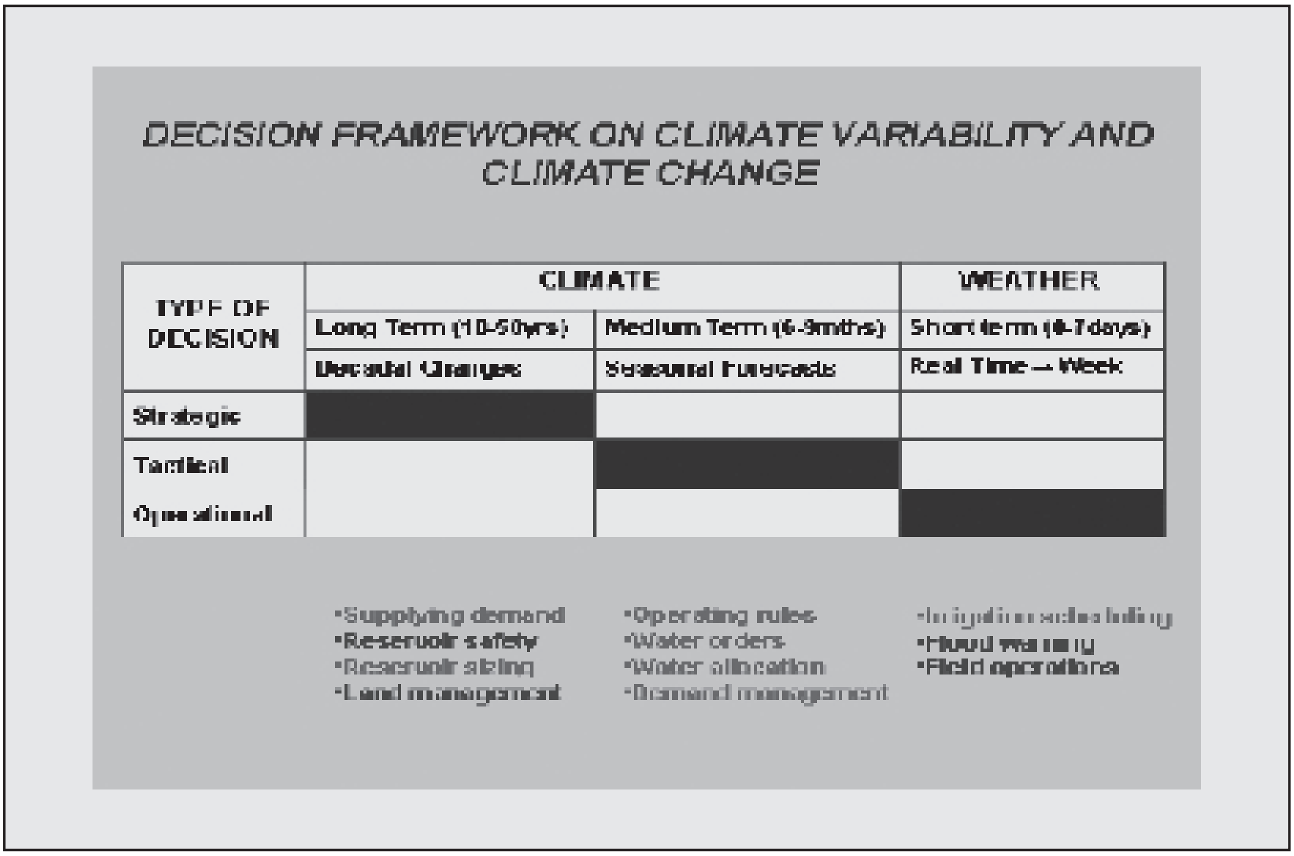


Fig 62



A South African adaptation framework for climate change impacts on the water sector (Fig. 63), would, ideally, be long-term with legal and policy implications, institutional and management implications and a monitoring, research and information component. This framework is idealistic as the devil lies in the detail. The details of each implication are listed in Fig. 64.

Fig 63

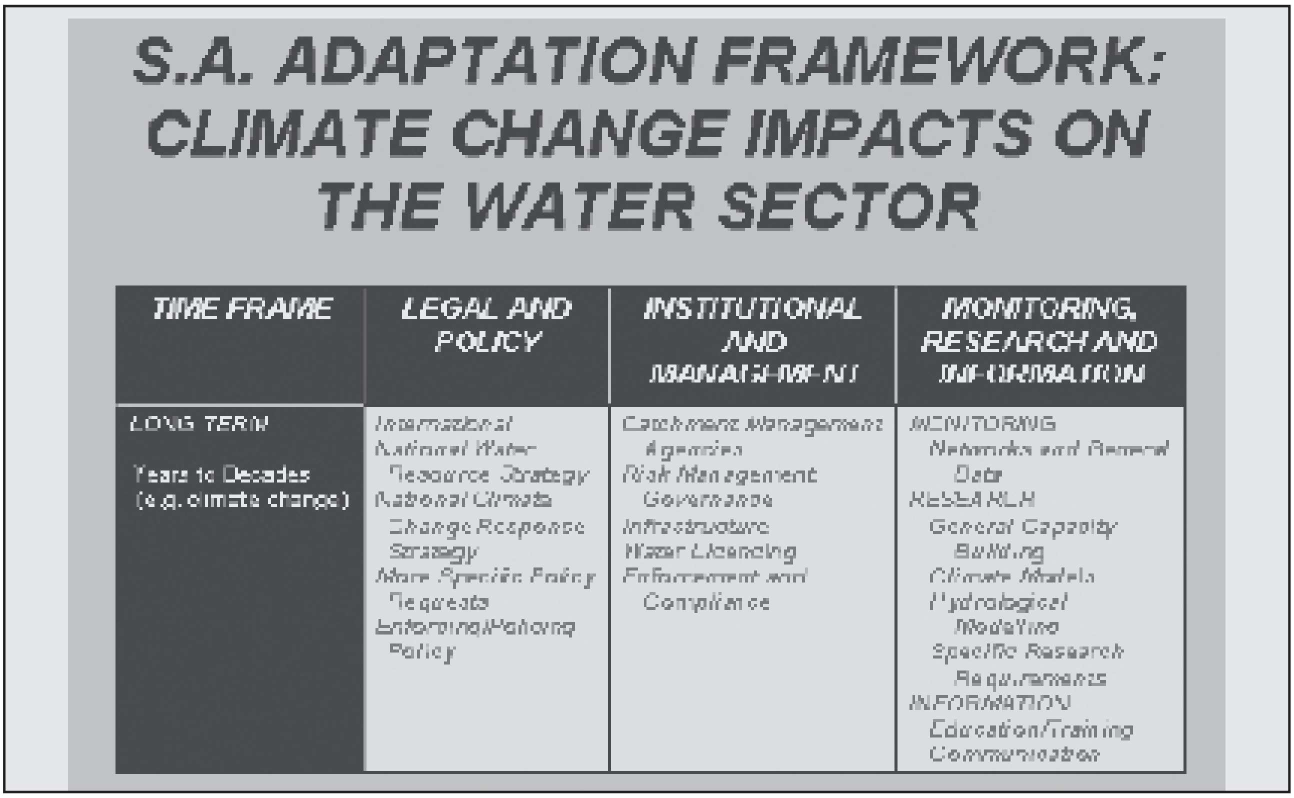


Fig 64

BUT… THE DEVIL LIES IN THE DETAIL!

LEGAL AND POLICY	INSTITUTIONAL MANAGEMENT	MONITORING, RESEARCH & INFORMATION
International • Mobilize the implementation of the Kyoto Protocol in southern Africa • Re-negotiate international water agreements with neighbouring states in the light of Climate Change (CC) National Water Resource Strategy • NWRS must recognize the importance of CC and cater for it more explicitly • NWRS needs to be updated routinely to address new finding on CC impacts • NWRS needs to be provided with more "teeth" re CC • More co-participation required in the NWRS with political, social and economic sectors • NWRS needs to define clearly the boundaries of accountability and responsibility between - national - CMA/WMA - District Municipality and - City specific issues **National Climate Change Response Strategy (NCCRS)** • Department of Environmental Affairs and Tourism (DEAT) needs - a more strategic approach to CC - greater commitment to apply the NCCRS - to develop more specific legislation re CC **More specific Policy Requests/Requirements** • Re Risk management - review existing national disaster management legislation w.r.t. CC, e.g. fires, floods, droughts - floodplain zoning and management :spatial considerations; urban areas - dam safety and spillway standards - property risk policies w.r.t. predicted…	**Catchment Management Agencies (CMAs)** • Establish CMAs which operate effectively re integrated Water resource Management (WRM) and including CC • Improve co-ordination within and between CMAs re activities, methodologies • Ensure wider stakeholder participation **Risk Management** • Revise/improve risk management (RM) plans re floods, droughts • Set up an advisory to advise land owners in flood prone areas re risks, flood probabilities • Implement a state insurance scheme for disasters • Develop policy on water restrictions **Governance** • Establish incentive schemes for initiatives in co-operative governance • Ensure that institutions adapt to CC findings at all levels of government and the private sector **Infrastructure** • Need improved strategic plan for new infrastructure re WRM • Construct more dams in relevant areas to make provision for additional water needs with CC • Review systems operations re assurance of supply **Water licensing** • Exercise more care in evaluating/awarding of licences to water users in light of CC • Raise tariffs to fund effective IWRM **Enforcement/Compliance** • Enforce compliance with regulations/laws • Increase enforcement re controlling groundwater abstractions…	**Monitoring** 1. Networks & General • Revise the entire network of rainfall and streamflow gauges w.r.t. detection of CC and adapt, if necessary • Identify and maintain high quality flow gauges - with long records - on unaltered catchments • Measure streamflow at all strategic points • Improve monitoring of land use change • Improve and regularly update WARMS database for better application in granting water use licences • Create an independent Earth Systems monitoring agency for SA **2. Data** • Ensure integrity of streamflow data • Achieve greater integration of hydroclimatic and related databases • Make data more readily available • Ensure transparency in sharing data **Research** 1. General capacity building • Build more capacity in CC research • Create incentives for new techniques in CC-related water research **Climate models** • Improve CC projections for SA to increase confidence levels in their application to WR • Improve downscaling techniques for application in SA **2. Hydrological modeling** • Improve process representations in hydrological models for application in a range of hydroclimatic regimes (e.g. semi-arid zones)

Take-home messages

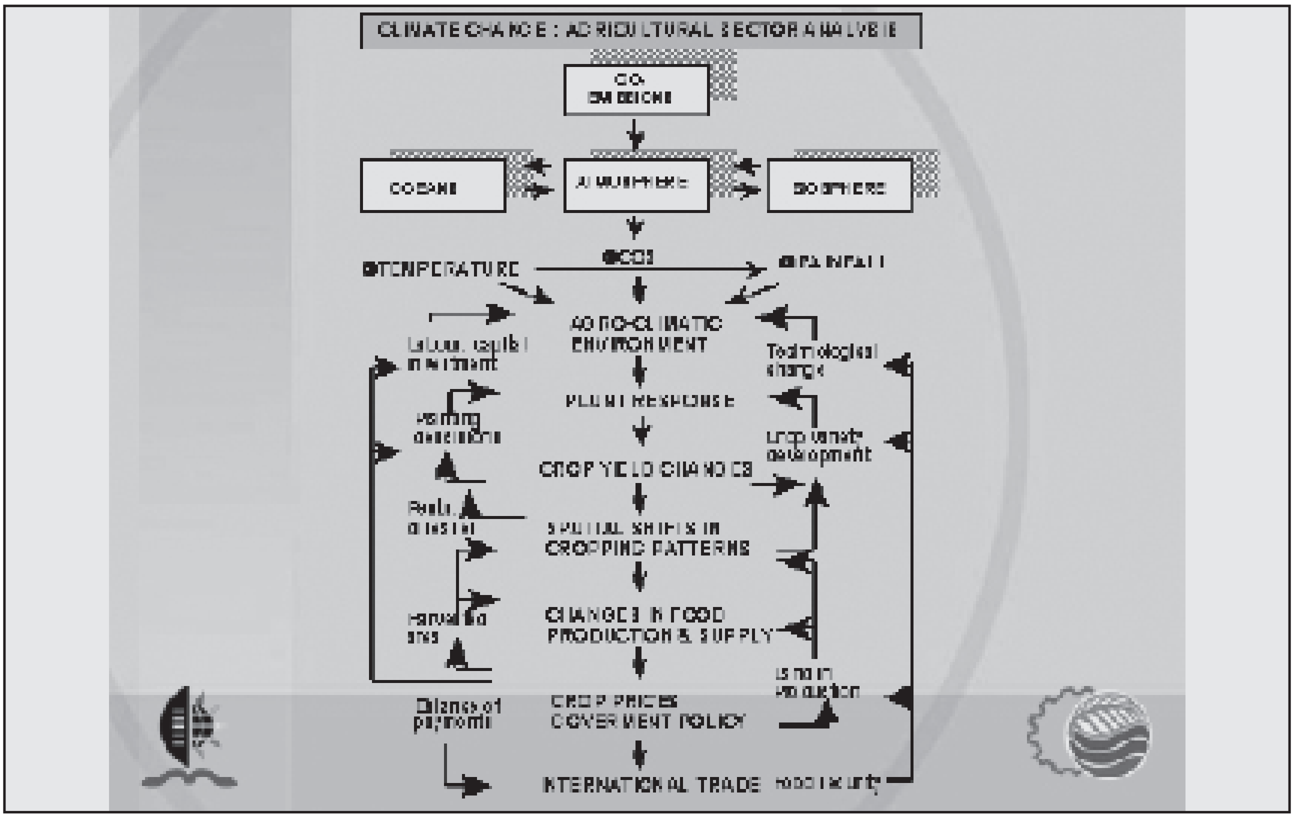
Despite frameworks, detail, and knowledge on processes and climate change, solutions are not as simple as they appear. The impacts of climate change on the water sector may be felt sooner than we like, seriously jeopardizing the agricultural sector. The following needs cannot be ignored:

• Need to apply appropriate
- GCMs and RCMs
- Integrated agrohydrological models
- Operational scales (field, farm, catchment)

• Need to evaluate/consider
- Real world catchment situations
- Environmental consequences
- Food security (both household and national)
- International consequences

• Need to develop appropriate adaptation strategies with immediate effect
• Need to view agriculture within the bigger scheme of IL and water resource management/risk as per the agricultural sector analysis in Fig. 65.

Fig 65


TEMPERATURE
CROP YIELD CHANGES
CROPPING PATTERNS
CHANGES IN FOOD
PRODUCTION & SUPPLY
INTERNATIONAL TRADE
Technological
change
development

Adaptation to negative effects of climate change in the agricultural sector

B.M. Molope

ARC, P.O. Box 8783, Pretoria 0001
Tel. 012 427 9712; Fax: 012 430 5811; E-mail molope@arc.agric.za

Introduction

Much has been said about climate change and its potential negative effects on the three pillars of sustainable development, namely social, economic and environmental. This paper focuses on adaptation and adaptation measures in agriculture to better manage the potential negative effects of climate change.

Climate variability and climate change

Climate is variable and it is important not only to realise this, but also to take steps to reduce our vulnerability to the negative effects that accompany this variation – in other words to adapt.

Apart from intrinsic climate variability, and much can be said about this and about trends and cycles and models, human induced climate change is being increasingly recognised as having a negative effect. Although temperature changes to date have not shown more than a slight increasing trend, projections of these, at the current rates of change, would certainly result in dramatic effects on agriculture, the environment, economics and people. How this will impact on water distribution is extremely important, as is the influence on extreme weather events.

Vulnerability

The effect that changes in the intensity and distribution of both temperature and water can have on individuals and communities, on their livelihoods, general quality of life and on the environment, both built and natural, needs to be interrogated.

As has been pointed out many times, the poor and unsophisticated are the most likely to experience the negative effects. They have normally neither the means nor the knowledge to adapt to predicted changes or to the ongoing vicissitudes of the climate. This has recently been emphasized, yet again, with the flooding that has accompanied the abnormally high rains experienced over much of the country in the past weeks. Intrinsic in this, is the gender and vulnerable group debate, as it is women, children and the aged who are destined to bear the brunt of the negative effects.

From an agricultural perspective, the effects that climate change can have on the natural resources and on plant and animal production systems need to be assessed and preventative action – adaptive measures – timeously strategised.

Adaptive strategies

In essence, adaptation strategies that need to be developed or refined revolve around the possible negative effects of temperature changes on the hydrological cycle, people and the environment and the possible negative effects of changes in precipitation on the water sector. These are briefly discussed.

Higher temperatures

The challenges that are likely to be encountered and for which adequate adaptation strategies need to be developed, would include at least the following:

- *Organic matter decline*
  Soil health: The decline in soil organic matter that is associated with elevated temperatures and probably reduced plant cover, can have catastrophic effects on soil chemical, physical and biological properties. It can also actually further contribute to global warming through the CO_2 released in the process. Soils become more acid, nutrients depleted and microbiological diversity diminished. Structural decline reduces water-holding capacity, increases runoff and aggravates the water use efficiency problem. General soil degradation and desertification follow. Ways in which this retrogression can be countered need to be encouraged.

  Reducing exposure of the soil through reduced tillage, minimum till or no till, encouraging rotational and multi-cropping and generally adopting sound conservation agricultural principles are realistic adaptation strategies.
- *Plant distribution*
  Biodiversity: Climate change, in the medium to long term, will certainly have a drastic effect on South Africa's biodiversity. The distribution and population dynamics of many species will change. Some species will suffer a contraction of their ranges and some may

locally die out, while other species will benefit and will expand their ranges.

Entire ecosystems may suffer degradation or collapse. For example, the fragile fynbos biome has evolved in response to the reliable Cape winter rainfall regime, while the grassland biome is very vulnerable to unpalatable invasive grasses and other weeds that are able to respond more aggressively to increased carbon dioxide levels in the atmosphere. Weeds, by their very nature, are able to adapt more rapidly than indigenous flora and more severe weed infestations will develop, which will degrade ecosystems.

This is a problem that is difficult to handle and adaptation strategies are likely to be of limited effect.

The National Collections of insects, arachnids, fungi and nematodes, housed at ARC-PPRI, will provide a vital baseline to monitor the effects of climate change on the biodiversity of South Africa. The changing distribution of species can be monitored to provide an early warning system of ecosystem health.

Invasive species: The ability of species to adapt to changing temperature regimes will determine their relative dominance. It is generally accepted that many invasives have an advantage in this regard and their spread is likely to increase.

- *Crop suitability*

The agricultural landscape will change with different temperature (and rainfall) patterns, which will probably have a dramatic effect on the areas in which different crops and cultivars will be able to be grown.

Indigenous crops: Information on the adaptive ability of indigenous crops will become important, as these form the basis of the livelihoods of our rural communities. In this regard Amaranthus, Cowpea and Bambara groundnuts are important.

Breeding and selection: Cultivar development has been conducted in the agricultural sector for many years and currently a number of programmes continue at the ARC as well as elsewhere. Adaptive abilities, especially heat tolerance, through both conventional breeding and biotechnology are important attributes.

Biodiesel: With the vastly increased interest in the production of biofuel, suitability of different crops in specific areas will receive increasing attention.

- *Pest and diseases*

In response to land use and local climate change, the dynamics of insect pests and disease complexes of crops will change. New pests may emerge, while other pests may expand their ranges or increase the intensity of their outbreaks. Biological control agents that are currently effective in controlling agricultural pests may also loose their efficacy due to climate change. Alien invasive plants, as well as indigenous weeds, will rapidly adapt to changing conditions and the costs of weed control in agriculture will increase.

The capacity to react to changing pest and disease dynamics in agriculture is becoming increasingly important and predictive early warning models, biological control and integrated pest management (IPM) techniques provide adaptive capabilities.

- *Animal performance and health*

South Africa is characterized by a large arid interior and highly variable climate, which, because ruminant livestock production is largely natural resource based, poses restrictions on the competitiveness of this extensive livestock sector. Due to the high level of climate variability and expected global warming, droughts occur regularly and under these conditions the amount of available grazing (fodder) is a major constraint influencing animal production. The vulnerability (probability) to and preparedness for drought/climate change will determine the degree to which the drought event/climate change will result in disaster or be coped with. Decision support systems (DSS) can assist the livestock farming community to handle the effect and consequences of adverse climatic conditions.

Climate change can have a severe impact on animal health, mainly due to the influence it has on distribution, competence and abundance of vectors and ectoparasites.

The southern Africa subcontinent and South Africa in particular, with its variable climate and resultant extensive range of ecological habitats, harbours an equally extensive range of external parasites of livestock. Ticks form a major parasitic component and apart from various toxicoses and direct damage caused during feeding, many species are also vectors of debilitating diseases of economic importance to the livestock sector. Major diseases transmitted to livestock and game by ticks throughout the distributional area of the relevant tick species in South Africa are Corridor disease, Heartwater, Redwater and Tick-borne gall sickness. As invertebrates, tick bio-ecology is extremely dependent on climate that ultimately determines their habitat and the distribution of their hosts and therefore, spatial and temporal distribution, prevalence, abundance, seasonality and resultant host infestation.

Global warming coupled with conditions of higher rainfall, creates ideal conditions for the eventual spread of certain tick species beyond their endemic distribution into areas where transmission of disease organisms to susceptible livestock hosts could reach epidemic proportions. Climatic models such as CLIMEX® have predicted such events on a global scale for *Boophilus* ticks that transmit both Redwater and Gall sickness.

Climate change/global warming will not only expand the geographical distribution of known vector species, but could increase the competence of vectors, meaning that species that were not previously shown to transmit disease, could do so in future. For example, an outbreak of African horse sickness (AHS) occurred in Clarens, Free State, during the summer of 1996, presumably as a result of a change in climatic conditions. Unpredicted outbreaks of AHS have not only occurred in the Free State, but also in the Eastern Cape and in the AHS surveillance areas (AHS free) around Stellenbosch (Western Cape). A survey in the Stellenbosch area in 1988 indicated a very low abundance of the proven AHS vector *Culicoides imicola.*

- *Human health*

The effect that an increase in the spread of malaria could have on human health could prove catastrophic. Appropriate adaptation measures are therefore essential.

Water

- *Distribution*: Rainfall variability is well known and many attempts have been made to quantify, predict and manage this natural phenomenon.

  Evidence seems to support the contention that rainfall variability is likely to increase due to the effects of global warming, as is the occurrence of extreme weather events. In approaching these, early warning systems and risk and disaster management are vital.

  Pressure on the already limited and stretched water resources is on the increase and the fair and equitable access to water resources is vital.

  Wetlands are of particular importance in ensuring general environmental health in a landscape.
- *Water use efficiency*: As far as agriculture is concerned, it is most important to maximize the effectiveness of water usage and storage in soil. When water becomes available through rain or irrigation, as much as possible should infiltrate into the soil profile where it can be stored for future use by plants. Ideally, there should be as little runoff as possible and runoff should be from vegetated surfaces and never from bare soil. A healthy soil with good structure is far more effective in this regard that one that is depleted of organic material, crusted and lifeless.
- *Water harvesting*: Water harvesting, in its many forms and variations, is showing dramatic results in communities, where yields have been increased by concentrating runoff to those areas of the soil occupied by actively growing plants. The rest of the soil surface, from which the runoff occurs, is covered by mulch of plant or geologic origin to reduce evaporation. Roof water and road/path runoff have also been successfully collected for later use. Innovative approaches are necessary.
- *Irrigation*: In the field of irrigation, efficiency of water usage also needs optimizing. There are differences in the efficiencies of different systems of irrigation and the most appropriate need to be identified. One should, however, never lose sight of the fact that salts tend to accumulate due to evapotranspiration, especially where water of high salt load is used. Periodic leaching of these soils is essential to ensure the sustainability of the endeavour.

  Many small to medium sized irrigation schemes have failed in the past and a huge effort is currently being made to revitalise them. We would do well to look into the reasons for their failure in the past.
- *Potential influence of increased rainfall and heavy flooding on animal diseases*: It has been shown that periods of heavy flooding lead to outbreak of rift valley fever (RVF) in areas where the disease is absent in dry periods. This is due to the spread of the mosquito vector during wet periods. Should climatic changes lead to increased rainfall in certain areas, the distribution of RVF may expand. Since RVF can cause acute abortions in livestock and is a zoonosis, it is of great importance to agriculture.
- *Water borne diseases*: The danger of outbreaks of diseases such as cholera need to be managed.

This list is by no means exhaustive and there could be other considereations.

The way forward

This would presumably include at least the following: Awareness, research, technology transfer and individual contributions.

- *Awareness*: Climatic change is an emotive issue that needs realism and appropriate action at all levels.
- *Research*: Needs to be focused and appropriate and would include at least the following:
  - Water use efficiency in soils and plants (rainfed/irrigated);
  - Suitability maps based on change scenarios for communal areas/development nodes/municipalities;
  - Appropriate land-use planning;
  - Adaptation in crops and animals;
  - Integrated pest and nutrition management;
  - Carbon (CO_2/CH_4) and nitrogen (NH_4, N_2O, NO_3) dynamics; and
  - Closing the cycle (minimum tillage, conservation agriculture, soil health).
- *Technology transfer*: Effective transfer of existing knowledge. Choice of media and appropriateness are some of the critical criteria.
- *Individual contributions*: It is important to realize that this is an issue that requires attention at all levels, namely international, national, local, communal and personal.

  At a personal level one can make a difference through actions, choices and example. The use of solar panels, composting, water conservation and harvesting and even walking or cycling could all add up to a real and meaningful contribution.

Conclusion

Climate change will, to varying degrees, affect the three pillars of sustainable development. There is, therefore, a need to better understand what generates vulnerability and what enhances resilience to change. The most important need to be addressed is the enhancement of adaptive capacities to reduce the risk of climate change and the magnitude of its consequences.

Climate change is adding additional stress to vulnerable communities already coping with multiple stresses and adaptive strategies and adaptation policies will have to focus on this part of the agricultural sector. An integral part of such strategies and policies will have to address water use efficiency and the conservation of water resources as climate change response deals implicitly and explicitly with the water sector.

As it is anticipated that the effects of climate change may become more marked, extreme and more frequent in future, adaptive strategies are of the utmost importance. These include sound conservation agriculture principles and practices by following an integrated ecosystems approach; the goal-directed development of early warning and decision support systems; and monitoring to provide an early warning system of ecosystem health.

Climate change and agriculture: Exploring new and old landscapes of change

C. Vogel

School of Geography, Archeology and Environmental Studies,
University of the Witwatersrand, Private Bag 3, WITS 2050
E-mail: vogelc@geoarc.wits.ac.za

Extended Abstract

Climate change and climate variability may result in several impacts for the agricultural sector in Africa. Such impacts may constrain certain livelihood sources, particularly in those areas where agriculture contributes significantly to GDP and to overall livelihoods. Various model projections or scenarios have been undertaken to determine the possible impacts of warming on agriculture. Mendelsohn, Dinar & Delfelt (2000), for example, have shown possible impacts on agriculture, including GDP, using a range of climate assessments. Losses in GDP, in the order of between 2% and 7%, could be experienced for countries in Sahara and EGAD. Other areas of Africa could experience slightly reduced impacts. Southern Africa, using some climate results, is expected to experience GDP losses from 0.4-1.3%.

Other assessments (e.g. Fischer, Shah & Van Velthuizen, 2002) show that about 11% of the total land area of 266 million ha, that could be used for agriculture, may undergo severe constraints imposed by climate change. The total area of potentially good agricultural land may decrease in some areas (estimates of between 0.1 and 1.5% for southern Africa) with particular changes in South Africa. Impacts on rainfed agricultural production are shown not to improve for sub-Saharan Africa and in some regions, for instance in southern Africa, losses of average potential cereal production, as compared to the beginning of the 20th century, are shown.

The role of water supplies and the role that rainfall plays in hydrological systems and agriculture are varied in the region with future climate scenarios, with certain winners and losers in the southern African region (e.g. Schulze, Meigh & Horan, 2001 and a recent paper by De Wit, to be published in the Journal of Science). Other impacts on agriculture, including those associated with fisheries, have also been assessed. Clark (2006), for example, has recently shown some of the projected impacts associated with climate changes for the spectrum of fishing activities (e.g. small-scale fishing communities to larger scale commercial fishing enterprises).

When addressing the issues of climate change and climate variability we need to also remember, however, that there is a range of other human dimensions issues that serve to make certain communities and/or ecosystems vulnerable to climate change. We thus need to view current and future climate changes and risks against the backdrop of a range of other factors (e.g. macro-structural controls and influences) currently influencing agriculture. A key issue, for example, is to better understand the role of agriculture currently in South Africa among commercial and small-holder farmers including the range of questions such as: What is the role of subsistence farmers? Is agriculture still a key livelihood resource? What role does diversification play in farming and what types of diversification are being undertaken? What are the aspirations of those farming? Is the farming support system and infrastructure able to support such activities?

In South Africa, for example, agriculture contributes about 4.5% to GDP but this figure masks the roles that agriculture plays for many, such as an estimated six million who rely either directly or indirectly on agriculture (Mather & Greenberg, 2003). Notwithstanding this figure, some argue (e.g. Bryceson, 1996) that deagrarianization is a critical factor that influences contributions being derived from agriculture in some rural areas in Africa in terms of rural livelihoods and GDP. In sub-Saharan Africa, for example, the percentage of total GDP derived from agriculture has been falling in some cases.

To fully investigate the role of climate change, one needs to view these issues against the backdrop of the variety of other stresses that impact on the agricultural sector and those engaged in agriculture, such as the role of deregulation of agricultural markets; the roles of privately owned enterprises in agriculture; Mather & Greenberg, 2003), the role of food markets and supermarket outlets and small scale growers of produce; and a range of other stresses and factors (Mather & Greenberg, 2003; Vogel, 2005).

Are we factoring in issues of social safety nets, credit facilities and the roles that such interventions could play in possibly boosting resilience to climate stress, both now and in the future? Rather than only focusing on 2020 or 2050 climate time slices, the questions to pose include: Do we understand how farmers currently live with, cope with and adapt to a range risks including climate risk? Are

the interventions that are being implemented carefully targeted? Are these evaluated from time to time?

When one takes such an integrated, human-dimensions or socio-economic approach then the factors enhancing/driving the vulnerability to climate change and variability are better understood and more closely reflect real-case situations rather than merely focusing on impacts or outcomes and response model to climate change. Such an approach is also consistent with the Disaster Management Act 2002, in which the need to better understand vulnerability to a range of risks and stresses is strongly profiled. The vulnerability focus is also closely allied to a stronger adaptation approach to climate change – how do farmers currently cope with drought, what factors (e.g. subsidy, access to fertilizer, credit, inputs and information etc.) *currently* may be heightening their risks to farming in variable climates and are the range of options available going to be able to ensure that farmers can cope and adapt in *future*!

Finally, we need to begin recording past experiences and ensuring that new data are available for all assessments. South Africa has long experienced drought and floods and other weather- and climate-related phenomena. To what extent are we capturing this information, the lessons learnt (not learnt) of past extreme climate periods and the coping and adaptive capacities by various groups (e.g. commercial and small-scale farmers) as we go forward in preparing food security strategies? Are we ensuring that we grow and increase our pool of scientists (e.g. agro-meteorologists and meteorologists and those who can cross the divides between disciplines) to assist us in facing the challenge of climate change? Do we have the most effective institutional designs to help incorporate and manage such multiple stressors in the region?

These are some of the questions, the author suggests, that we should be posing alongside those that push for greater and further skill from down-scaled climate models. Recent experiences such as the energy problems in the western Cape, increased and persistent famine in southern Africa and the problems of flooding and water discharge experienced the past few months in some city areas (all largely within the normal realms of climate) are possible signals urging us to be more proactive in addressing climate change and climate variability in South Africa, from a holistic perspective.

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Climate change mitigation for South Africa with particular reference to the agricultural and forestry sectors

C. Turner

Corporate Consultant, Eskom Corporate Sustainability, Box 1091, Johannesburg 2000
Tel. 011 8004994; Fax 011 800 2938; E-Mail clive.turner@eskom.co.za

Introduction

It is generally understood that any successful programme to respond to climate change will depend on tackling the mitigation of greenhouse gas (GHG) emissions, to eliminate the root cause of such change, while simultaneously preparing to adapt to climate change, as some degree of change is inevitable given the historic build up of greenhouse gas concentrations in the atmosphere (IPCC, 2001). Adaptation is essentially local in nature and has to take account of national vulnerability and resource availability. However, in the case of mitigation, the emphasis must be distinctly global in nature, as climate change is a consequence of the sum total of all greenhouse gas emissions from all sources. Thus it is clearly evident that attention to the largest emitters will yield the most effective results. This short overview is intended to be a discussion document which briefly examines the potential for GHG mitigation in the South African agricultural sector and also examines the synergy between mitigation and adaptation measures, both within the agricultural sector and in other sectors that will have impacts on agriculture.

In planning mitigation measures for South Africa, it is emphasized that, as a non-Annex I country, South Africa is not required to reduce its emissions of greenhouse gases as things currently stand (DEAT, 2004). However, the South African economy is highly dependent on fossil fuels and the country can be judged to be a significant emitter due to the relatively high values that can be derived for emissions intensity and emissions per capita. Such calculations put South Africa as one the world's top 15 most energy intensive economies, with a significant contribution to greenhouse emissions at a continental level. In any event, there could be significant co-benefits to be derived from adopting a future strategy that is designed to move the economy towards a cleaner development path.

Further, according to DEAT (2004), the Government's national priorities include the creation of employment, the alleviation of poverty and the provision of housing, which implies a commitment to the process of sustainable development and advancement. Thus South Africa's stated position is to view climate change response as an opportunity for achieving these aims, that is, to inexorably link climate change response to sustainable development.

It is generally accepted that many GHG mitigation measures in the agricultural sector also support sustainable development in one or more of its three domains, namely environmental, social and economic development factors. Other mitigation options have more uncertain impact on sustainable development. Further, mitigation and adaptation in the agricultural sector can often be tackled by simultaneous and mutually supportive actions in both the agricultural and other sectors where short-term benefits may be achieved but, significantly, the principle gains may only be realized over time. In many respects, non-climate policies, including macro-economic, agricultural and environmental policies, may have the greatest impact on agricultural mitigation options. Further, many agricultural mitigation options could have both co-benefits such as improved efficiency or environmental improvement and could be implemented immediately, without further technological development. Despite the potential for beneficial mitigation measures to be taken up in the agricultural sector, the rate of uptake has been somewhat less than optimal due to a number of barriers including both economic and social factors.

Greenhouse gas emissions from the South African agriculture and LULUCF sectors

According to the South African 1994 greenhouse gas inventory (DEAT, 2003), the local agricultural sector contributes effectively nothing to emissions of actual carbon dioxide (CO_2). Further, the land use, land use change and forestry (LULUCF) sectors provide a sink for nearly 6% of South Africa's total CO_2 emissions. However, there are areas with significant potential in which the agricultural and silviculture sectors could be adapted to mitigate greenhouse gas emissions in other sectors, notably energy and industry.

In contrast to the case for CO_2 emissions, the South African agricultural sector is responsible for about 46% of national methane (CH_4) emissions and 76% of nitrous oxide (N_2O) emissions. Whereas on a straight tonnage basis these gases are only emitted in relatively small quantities compared to the amount of CO_2 emitted, according to the literature (IPCC, 2001) the effective global warming potential of a molecule of CH_4 is 23 times greater than that of a CO_2 molecule and a molecule of N_2O has a warming potential of 296 times that of CO_2. When these factors are taken into account, the agricultural sector is responsible for about 10% of South Africa's effective greenhouse gas emissions, a small but nonetheless significant amount.

Vulnerability and GHG mitigation as an agent for development in the South African agricultural and forestry sectors

Although the situation is not uncommon among developing countries, in many respects South Africa faces something of a dilemma in that the agricultural sector is divided into two distinct regimes. On the one hand, there is the well-organized commercial farming sector and, side by side with this, is the subsistence farming community who inhabit traditionally rural areas. With a rising population and the competition for viable agricultural land, the available land per capita of the population is continually decreasing (DEAT, 2003). Further, the Government is implementing an essential programme of land reform and redistribution to address past inequities and there is continually increasing competition for access to the relatively scarce national water resources. This gives a coherent picture of the vulnerability of the agricultural sector with regard to climate change.

According to DEAT (2003), South Africa is extremely vulnerable to potential climate change. Even without climate change it is predicted that South Africa will utilise most of its surface water resources by about 2030. The most significant impacts of climate change on water resources are the potential changes in both the intensity and seasonality of rainfall. While some regions may receive more surface water flow, water scarcity, increased demand for water and water quality deterioration are very likely to be problems in the future. Climate change may also alter the magnitude, timing and distribution of storms that produce flood events. The arid and semi-arid regions, which cover nearly half of South Africa, are particularly sensitive to such changes. Desertification, which is already a problem in South Africa, could be exacerbated as the climate changes. Adaptation options identified to limit the effect that climate change may have on water resources include strategic resource management issues, drought relief measures, design of infrastructure and communication.

Further, DEAT (2003) predicts that climate change will result in the aridification of rangelands. The predicted lower rainfall and higher air temperatures will affect fodder production and impact on the marginal costs of ranching. Over the savanna regions in the northeast of the country, forage production may decrease by about one fifth, which would impact on the cattle ranching industry by reducing the national cattle herd by about 10%. Beef production would, however, not be affected to the same degree, as greater numbers of the beef herd are fattened in feedlots before being slaughtered. Fire intensities are predicted to increase by about 20% due to the increase in grass fuel load. Climate change may also affect the frequency and spatial extent of livestock disease outbreaks, such as foot and mouth disease. An improved monitoring and forecasting system for fire hazards and droughts will assist and will be beneficial even without climate change occurring.

With regard to crops, DEAT (2003) states that, to meet the increasing food demand, agriculture has to expand by approximately 3% annually. Under the climate scenario that predicts a hotter drier climate, maize production will decrease by approximately 10 to 20% over the next 50 years and that speciality crops grown in specific environmentally favourable areas may also be at risk. An increase in pests and diseases would also have a detrimental effect on the agricultural sector and invasive plants could possibly become a greater problem. Adaptation measures should mainly focus on changing agricultural management practices, such as more effective use of water resources, planting drought resistant crops, or changing the land use to grazing. To reduce the risk of famine, marginal production areas could be kept economically viable by planting drought resistant crops or changing land use to grazing.

The outlook given for the forestry industry in DEAT (2003) is also not optimistic. It states that the local forestry industry is highly sensitive to climate change. Currently, only 1.5% of the country is suitable for tree crops and the forestry sector is affected by factors such as land availability, water demand and socio-economic conditions. General aridification, due to lower rainfall and higher air temperatures, will affect the optimal areas for the country's major tree crop species and impact on the marginal costs associated with planting in sub-optimal areas. Shifts in the optimum tree growing areas could impact on the profitability of fixed capital investments such as saw mills and pulp mills. The decrease in production would also be detrimental to the planting of trees to serve as carbon sinks. More temperature tolerant cultivars within the current tree species could be selected, but it is more probable that more lucrative uses for the land, such as sub-tropical fruits, may compete for the land currently under tree plantations.

Thus, given these factors, it may at first glance be assumed that there is little scope for GHG mitigation in the South African agricultural and forestry sectors. However, if mitigation measures can be integrated into a framework of continuous improvement, development and vulnerability reduction, then this may not be true. Indeed, GHG mitigation could rather act as a positive forcing agent for agricultural reform that can increase and diversify production to the overall benefit of the nation. This needs to be encouraged as, given the national circumstances described in DEAT (2003) and the likely changes to those circumstances in time, agricultural reform will be essential in any case, even without climate change.

Direct GHG mitigation measures

According to DEAT (2003), direct GHG emission reduction benefits could be realized through a number of means. The following measures are specifically cited:

- Optimisation of the national herd sex, age and breed would allow it to be reduced while maintaining the same level of production. Supplementing the feed with high protein forage would reduce the methane production and increase productivity. It was estimated that total GHG emissions can be reduced by 207 756 Gg carbon dioxide equivalents over the period 2000 to 2030.

- By assuming that 40% of the manure from feedlots is digested anaerobically and that the methane gas is collected for re-use, 10% in lagoons and the remaining 50% by dry spreading, then, it was estimated, that total GHG emissions can be reduced by 49 817 Gg carbon dioxide equivalent.
- By substantially reducing the fraction of area planted with sugar cane that is burned prior to harvest, it was estimated that total GHG emissions can be reduced by 9 120 Gg carbon dioxide equivalents.
- It was estimated that total GHG emissions can be reduced by 22 200 Gg carbon dioxide equivalents by halving the frequency of veld fires over the period 1990 to 2030.
- By promoting savanna thickening throughout the region, it was estimated that total GHG emissions can be reduced by 237 000 Gg carbon dioxide equivalents.
- An additional 330 000 ha of forests planted as a mitigation option would reduce total GHG emissions by 116 100 Gg carbon dioxide equivalents.

This gives a total saving of 856 000 Gg carbon dioxide equivalents between 2000 and 2030, which represents about 4% of the expected total national GHG emissions for this period, assuming a business as usual scenario. This is a relatively small but significant gain.

Synergy and related factors

In looking for synergy in climate change mitigation and adaptation measures, agriculture, in addition to being strongly linked to sustainable development and the attendant socio-economic factors, is most consistently allied to the water and energy sectors. However, to achieve success in identifying synergistic measures that have multiple benefits, while avoiding unforeseen impacts, it will be essential to break out of the common dysfunctional behavioural mode of thinking inside silos.

Water projects

South Africa's rainfall is already highly variable in spatial distribution and is also unpredictable, both within and between years (DEAT, 2003). Much of the country is arid or semi-arid and the whole country is subject to droughts and floods. Bulk water supplies are largely provided via a system of large storage dams and interbasin water transfer schemes and such infrastructure takes years to develop. Thus a reduction in the amount or reliability of rainfall, or an increase in evaporation would exacerbate the already serious lack of surface and ground water resources. Water availability in the arid and semi-arid regions, which cover nearly half of South Africa, is particularly sensitive to changes in precipitation. Desertification, which is already a problem in South Africa, could be exacerbated by climate change. Furthermore, climate change may alter the magnitude, timing and distribution of storms that produce flood events. Whereas water saving schemes can assist in remediating the impacts of water scarcity, extensions of the country's existing bulk water management systems, including new infrastructural development such as dams, could fundamentally alter the way in which agriculture is practised in a particular region. This has been done in the past long before the risk of climate change impacts had been anticipated and could be looked at again with renewed vigour. Even without new dams, more effective collection and distribution of water in particular districts such as the Eastern Cape could promote efficient agriculture and alleviate the basic need to rely on subsidence farming for communities to survive. Actions specifically cited in DEAT (2003) that could be used to promote GHG mitigation in the agricultural sector include:

- Plan and co-ordinate the use of river basins.
- Infrastructure changes to allow for increased capacity.
- Use interbasin transfers.
- Maintain options to develop new dam sites, which are currently very limited in South Africa.

All of these possibilities need to be seen jointly within the context of agricultural extension and not just in the supply of water.

Energy Efficiency

Energy efficiency can provide a win-win opportunity for nearly every potential application. Energy efficiency is promoted by the Department of Minerals and Energy (DME, 2005) who have set certain sector targets that they expect to be achieved by 2015 through a phased approach. Simply reducing input costs to any process is usually attractive as it inevitably results in either a reduction in the price of the final product, making it more competitive in the market, or it can make a specific operation more profitable, encouraging investment and employment. This is equally applicable to agriculture as it is to any other sector, even though DME do not mandate a specific target for the agricultural sector. Energy efficiency studies can reveal hitherto unrevealed opportunities for energy saving that can directly impact on the need to access bulk energy supplies. These may encompass both changes to the actual physical means by which a process is carried out to a reorganization of the way or sequence in which it is done. Energy efficiency can also be promoted through the process of dematerialization, which is the replacement of a physical product with a non-physical product or service thereby reducing production, demand and use of physical products and the end-users' dependence on them. This should then realize cost-savings in materials, transportation, consumables and the need to manage the eventual disposal and/or recycling of the physical product. It also reduces energy demand. Dematerialization can be achieved by making products smaller and lighter or by replacing material products with an immaterial substitute. Such opportunities could be sought and evaluated for the agricultural sector.

Energy substitution

South African agriculture has often used wind power directly as a cost effective and convenient means of pumping water from boreholes. Normally such applications can discount the non-continuous nature of this energy source. However, given advances in modern storage batteries, wind power may become cost effective and reliable for other agricultural applications too.

Increased use of waste and residue streams as a source of primary energy is an obvious way of mitigating GHG emissions, limited only by the economics of such systems compared to obtaining energy from a source of bulk or traditional supply. More widespread use of biogas and crop residues in the agricultural sector are likely to become economically viable as the price of fossil energy increases as it is expected to do so in time (IPCC, 2001). Further, it is possible that increased use of biomass as a carbon-neutral energy resource could eventually revolutionize the global agricultural system.

In addition to waste streams from the industrial and food sectors, biomass has a number of potential sources in the agricultural and forestry sectors as well. These include, *inter alia*, energy crops, short rotation crops, crop residues, animal wastes and direct forest products, together with the waste streams from the wood and paper processing industries. Biomass is used directly in the form of fuelwood and animal dung from agricultural production. However, these products are responsible for large scale exposure to toxic levels of air pollution and eventually need to be discouraged over time for health reasons (Mishra, 2003; Smith *et al.*, 2000). Whereas processes such as afforestation, reforestation and savanna thickening can act as significant carbon sinks as already discussed, bio-energy conversion facilities are used in many applications to change the basic bio-energy into bulk easily useable forms such as electrical power (with or without a heat stream), solid gaseous and liquid fuels, chemical stocks and a host of other products that can be used in a variety of non-agricultural purposes such as household, commercial and transport applications, and in industry. Present examples of this are the conversion of sugar cane to ethanol, used extensively in South America, or from woody products to methanol, which is rapidly gaining ground in Europe.

Despite the potential for biomass energy, there are often difficulties cited in implementing such projects. These include its dirty and low technology image by the public, the challenge in securing biomass fuel supplies, its relative low energy density compared with fossil fuels, the high demand for water and nutrients by some energy crops and the difficulties in achieving economies of scale for conversion plants using widespread feedstock potential. However, although biomass may have some serious limitations as an energy resource, it nonetheless provides parallel opportunities for eventually providing a significant degree of GHG mitigation, resolving the inevitable shortage of liquid fossil fuels and simultaneously providing a strong lead for sustainable development. Research shows that there is little doubt that we are at or near the oil peak, predicted some time ago, where demand for oil is increasing whereas reserves have dropped to a point where production cannot be significantly increased on a sustainable basis (Peak Oil Portal, 2005). This will tend to accelerate the move towards biofuels, particularly in the transport sector, and, further, would also promote one of the important focuses of sustainable development, which is access to modern energy services. However, competition for land to produce both food and energy crops will essentially push the agricultural sector into a process of modernization to realize the necessary efficiency and this suggest an eventual move away from subsistence farming as a basic means of support, heralding a significant shift in socio-economic norms.

Conclusion

Some degree of climate change is inevitable, given the historic build up of greenhouse gas concentrations in the atmosphere. National climate change response programmes require attention to both adaptation and mitigation elements, which in any case are not usually mutually exclusive. Further, such response programmes should aim to maximize the co-benefits of adaptation and mitigation measures and to promote sustainable development, while focusing on the national priorities of the country. Greenhouse gas mitigation measures in the agricultural sector often do support the three principle elements of sustainable development. Although not a significant CO_2 emission source, agriculture is responsible for about 10% of South Africa's effective greenhouse gas emissions in the form of CH_4 and N_2O, a relatively small but significant quantity.

South Africa is vulnerable to the impacts of climate change, particularly with regard to water resources. However, mitigation and adaptation measures may assist in eventually providing the country with a well-developed and efficient agricultural sector and, at the same time, acting as an agent to redress some of the historically derived rural poverty, despite the pessimistic prognosis that an examination of the current state of affairs appears to provide.

Direct mitigation measures that could be undertaken include optimization of the national herd, improved manure management, reducing the amount of sugar cane burned prior to harvest, improved management of veld fires, savanna thickening and afforestation projects. This represents about 4% of total greenhouse gas emissions that would occur between 2000 and 2030, assuming a business as usual scenario.

Projects undertaken in other sectors could have major impacts on agriculture and synergistic relations need to be examined and exploited. Such relationships exist between agriculture and the water and energy sectors. Energy efficiency and energy substitution are likely to provide many opportunities for mitigation, either directly in the agricultural sector or through co-benefits.

Whereas biomass may have some serious limitations as an energy resource, it provides parallel opportunities for eventually providing a significant degree of GHG mitigation, resolving the inevitable shortage of liquid fossil fuels, particularly for the transport sector and, simultaneously, providing a strong lead for sustainable development. This could essentially push the agricultural sector into a process of modernization to realize the necessary efficiency and this suggests an eventual and consequential move away from subsistence farming as a basic means of support.

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Identifying approaches to climate change risk reduction activities at local levels: Enabling vulnerable communities in South Africa, Mozambique and Tanzania adapt to impacts of climate change

Lwandle Mqadi

The SouthSouthNorth Group –Southern Africa Office, 138 Waterkant Street, Greenpoint 8001
Tel.: 021 425 1465; Fax: 021 425 1463; E-mail: lwandle@southsouthnorth.org

Introduction

The SouthSouthNorth (SSN) Group[1] is currently developing a generic methodology for identifying, designing and implementing Community Based Adaptation (CBA) projects in both Least Developed Countries (LDCs) and Developing Countries (DCs). This generic methodology is called the SouthSouthNorth Adaptation Project Protocol (SSNAPP) for community based adaptation (CBA) projects. The countries targeted for the Southern Africa region are South Africa, Mozambique and Tanzania. The SSN group team members in these countries will work in partnership with various community based organisations (CBOs) to liase with the vulnerable communities in these countries. In partnership with various CBOs, project design teams will be formed to inform the process of identification, designing and implementation of community based adaptation to climate change project activities at local levels. The project design teams will consist of community based organisations, identified communities, local climate scientists, local climate change specialists, disaster management specialists, anthropologists, development workers and other specialists who will also be project advisors.

The overall objective of this SSN project is to enhance poor communities' ability to adapt to the impacts of both climate variability and climate change. Specific objectives are:

- To develop and apply a generic methodology for identifying, designing and implementing CBA projects in both LDCs and DCs;
- To strengthen linkages between climate change science and community based adaptation to climate change by identifying, developing and implementing adaptation to climate change project activities within communities, using informed climate change science and science based dialogue tools;
- To implement community based adaptation to climate change projects which will alleviate poverty and build the capacity of vulnerable communities in three countries, namely Mozambique, Tanzania and South Africa;
- To build technical capacity with regards to appropriately intervening, implementing and raising awareness amongst existing Community Based Organisations (CBOs) and Non-Governmental Organisations (NGOs) in the three participating countries with regards to the implementation of community based adaptation to climate change project activities;
- To intervene with and influence local, national and sectoral policy making processes in the three countries concerned on integrating and promoting adaptation to climate change into national development policies and sustainable development planning processes.

Methodology

The methodology entails a process whereby the three SSN group country team members will:

- Identify and review existing adaptation-related projects that have been undertaken in these three countries; draw on lessons that have been or can be learnt from these experiences so as to inform the development of future feasible adaptation to climate change projects; and

[1] SSN is a consortium of research institutions, non-governmental organisations and expert consultants in six developing countries i.e. Brazil, Bangladesh, Indonesia, South Africa, Mozambique and Tanzania working together to facilitate the implementation of climate change projects (both mitigation and adaptation to climate change) in partnership with various project developers and community based organisations. The SSN Group core activities have been funded by the Dutch Foreign Ministry since 1999 and will until 2008.

include elements to build on previous successes while avoiding the repetition of previous shortcomings;
- Undertake action research studies to identify regions most vulnerable to impacts of climate change and regions where the poorest populations are located. This will be done in partnership with country based research institutions to inform the process of establishing linkages between climate change science, vulnerability dimensions and sustainable livelihoods. The main output(s) of this activity will be the identification of "hot spots" in each of the three countries, that is, areas that are highly vulnerable to the impacts of climate change and where there are high levels of poverty. This will culminate in a report per country, entitled Potential Adaptation Projects Report.
- Action research studies will further be undertaken within the identified hot spots to identify current coping and adaptation strategies to climate variability and needs to enhance their capacity to adapt to future climate variability and change. The process will be undertaken in consultation with the project design teams. The main output(s) of this activity will include four potential community based adaptation to climate change projects, which will each include a range of sustainable and feasible community based adaptation to climate change activities.
- Undertake feasibility assessment of the four identified potential community based adaptation to climate change project activities for each of the three countries. The feasibility assessments will include engaging the vulnerable community and institutional structures operating in the identified region to assess the feasibility of the proposed adaptation activities within the four identified potential projects per country. The main output(s) of this activity will include project and institutional feasibility assessments of the four identified potential projects. This process will also inform the process of designing, implementing and learning generated by the identified projects. A report on this exercise will be produced for all interested stakeholders. Two most feasible adaptations to climate change project activities will then be selected for implementation. A comparative study on this process across the three countries will also be undertaken.
- Two adaptation to climate change project activities per country will be implemented. Knowledge gained by the implementation of these projects will inform the policy making process and climate change science based dialogue, as they would have a strong focus on how to use climate change science to enable poor communities to reduce their vulnerability.

Beneficiaries

These community-based actions/activities will have both direct and indirect beneficiaries.

Direct beneficiaries
- Climate vulnerable and poor households (who will be identified through a participatory needs assessment exercise) will be the direct beneficiaries of this action. Beneficiaries will consist mainly of poor and vulnerable groups, such as smallholder farmers, informal settlement/low income households and other groups who will be particularly vulnerable to climate change impacts.
- Identified CBOs and technical intermediaries with whom local partners are going to work in identifying, designing and developing CBA project activities.
- Inter-country and regional discussions among all the involved partners will be undertaken on a very regular basis in order to share project developments and learnings and to build the capacity of the teams involved in the process.

Indirect beneficiaries:
- Other CBOs, local governments, research institutions and other vulnerable communities will benefit as learnings from activities undertaken will be shared locally through the print media, NGO networks and other networks of which local partners are current members.
- National and sectoral policy development processes will be targeted by sharing lessons and by informing these processes with regards to climate change adaptation issues.

Lessons learned so far and provisional conclusions of the project

- Climate variability and extreme events play a significant role in the basket of vulnerabilities faced by the poor due to their disproportionate dependence on natural resource-based livelihoods;
- Communities are not homogeneous. Sharing climate impacts/threats does not imply that each member of the community is affected in the same way. Access to resources, for example, plays a highly significant role in vulnerability/adaptive capacity. It is, therefore, of critical importance to understand intra-community vulnerability dynamics;
- There are existing institutional and coping capacity systems at local level e.g. traditional knowledge;
- Community based knowledge should be linked to provincial-national systems focusing on how communities, as key agencies, could be strengthened;
- There is a need to establish procedural and institutional frameworks to ensure that locally determined adaptation needs are linked to district, provincial and national integrated development plans;
- Vulnerable communities/sectors should take centre stage in conducting vulnerability analysis and institutional support should be provided. This support could be provided through extension officers, farmer settlement support programmes, farmer co-operatives, etc.;
- Vulnerable communities should be involved in development processes, formal scientific processes and policy processes. There should be sustainable livelihood frameworks.

Some of the key research questions currently being raised from this process

Some of the key research questions which need to be addressed to strengthen linkages between community based adaptation to climate change and national policies, may include the mainstreaming of adaptation to climate change activities; technology transfer and receptivity; and adaptive capacity at local levels. Key questions are listed:

Mainstreaming adaptation to climate change activities

- How to differentiate between mainstream development and the additional component of adaptation to climate change;
- How to integrate adaptation to climate change issues into urban issues, which is still largely lacking – perhaps the focus should be on integrated demand management;
- How to design a feasible and sustainable CBA project with climate change science at the core;
- How can we mainstream climate change/variability considerations into development programmes;
- Gender issues and targeting the most vulnerable: How can we ensure that the different needs of males, females and children are addressed; and
- How can we ensure that the needs of the most vulnerable are addressed and that research results are shared with them.

Technology transfer and receptivity

- How to ensure and sustain the flow of information, especially climate change science, to people who need it most, using existing institutional arrangements;
- How community based agencies could revisit the basic principles of technology transfer/receptivity in its broadest sense to successfully implement CBA projects;
- How can we ensure that lessons learnt/best practices are shared among all stakeholders at all scales;
- How can we learn/document from relevant indigenous knowledge systems to develop innovative ideas; and
- How to deal with short-term response strategies (the reality of climate variability) *vs* long-term response strategies (climate change) linking with other institutions.

Adaptive capacity at local levels

- How to improve knowledge on anticipatory *vs* responsive adaptation strategies and ensure sustainability;
- What innovative measures could be put into place to ensure long-term adaptive capacities e.g. ensuring adequate and effective early warning systems;
- What indicators can we use to find out whether a community is adapting;
- What hinders communities from reaching their maximum adaptive capacity; and
- How to enhance local capacity as a response to climate change.

Methodology towards a participatory project approach to climate change adaptation for rural communities[1]

K.G. Banda

Novafrica, Centre for Innovation in Development, Centurion
*Tel: 012 654 8710;E-mail:*khamarunga@novafrica.org.za

Introduction to Novafrica

Novafrica is a regional NGO aimed at accelerating service delivery. Novafrica is tasked to train and to carry forward the guiding principle for a people-centered approach in training, facilitation and action research. Learning together for renewal in community development is, to a large extent, Novafrica's motto. This is achieved by community emancipation through fostering innovation and local organizational capacity.

In its attempt to achieve its objectives, Novafrica's process to facilitate change towards a people-centered principle, entails the following:

- The empowerment of people so that government will take notice of peoples' requirements/needs/demands and to influence policy;
- To change the top-down/bottom-up approach so that people meet halfway in a mutually beneficial way;
- To empower people to articulate clearly what they want;
- To develop a structure that will meet demands.

Successes with this approach include the linkage between provincial, national, regional and global women enabling them, for example, to export products and produce to Europe. LPDA's approach regarding policy change was adopted by Novafrica's PEA approach.

In addition to its PEA approach, Novafrica adopted the principles of PDA. PDA and PEA were selected as they:

- Facilitate a process of self-organisation and emancipation of rural communities to enable people to better articulate their agricultural and social needs and to represent themselves at service providers and authorities;
- Build on the *life world* of rural people who have agriculture as common foundation and who spreads from this to other spheres of development;
- Help extension staff and other facilitators of development to develop the necessary competency to work with rural people. PDA and PEA empower extensionists and facilitators to internalize important values and skills needed in the facilitation of their work.

Novafrica is concerned with the following types of projects:

- Adaptation methods, such as climate change;
- PEA training;
- Gender mainstreaming in agriculture and PEA;
- Leadership training and collaboration with NAFU;
- Mentorship;
- Training of trainers;
- HIV/AIDS in agriculture;
- Fish and aquaculture development at a regional level;
- Energy issues and development by integrating energy for rural development and by promoting alternative modern energy.

This paper introduces the reader to the evolution of Novafrica's involvement in climate change; and challenges facing those involved in climate change studies and applications. It is concluded that climate change research and application should be based on a methodology with peoples' approach to uncertainty as point of departure.

Evolution of Novafrica's involvement in climate change

The climate change debate started off as a top-down approach but the UNCCD soon called for bottom-up approaches involving local communities in decision-making and related aspects. Novafrica, involved in food security projects in Bohlabela in the Limpopo Province, used the same community to create climate change, gender and biodiversity awareness in facilitating a bottom-up debate. Through its awareness campaign, Novafrica revealed a wealth of indigenous knowledge as well as testimony on the effects of climate change on resource poor communities. The community reported on the following environmental impacts observed as a result of drought: loss of biodiversity; reduced income; food shortages because of

[1] As the author did not submit a paper for publication, the Organising Committee drafted this paper from the author's notes. The Organising Committee takes no responsibility whatsoever for the correctness of the contents of this paper.

increased crop withering and dying; lower accessibility to water; desertification and soil degradation; and changes in animal behaviour. The community declared that the agriculture practiced could no longer sustain livelihood demands. A biodiversity audit revealed that there was a noted decline in the quality, quantity and even the disappearance of certain plant and animal species. On the positive side, there is an increase in the creative use of certain plants to enhance income generation while the presence of medicinal plants in the area have significant potential to supplement income and to curb money spent on medication.

As Novafrica places much emphasis on gender issues, the impacts described above were related to the impact on gender. As a result of deficient rain, there was a decrease in yield; crops were not heat resistant; and the use of manure was ineffective. Most people reverted back to traditional preserved seeds more resistant to drought. The major impacts on women are nutrition and water shortages. The knowledge gained could be used to inform policy and programme support.

Novafrica's climate change stakeholders are the LPDA extension staff, the research team climate change forum and communities.

The results from Novafrica's participatory project are, indeed, impressive but project implementation followed major efforts in developing and evaluating a participatory project methodology, a participatory model and the implementation process. These are briefly discussed.

Participatory project methodology development

Novafrica, in line with President Thabo Mbeki's philosophy of community involvement in decision-making, follows a participatory approach in their community climate change project methodology. This approach, called the participatory project (PP) methodology, involves communities in decision-making and bridges the gap between the people and decision-makers. To ensure that the technology developed by Novafrica is more than lip service and that it considers complex and diversified vertical and horizontal linkages, Novafrica was confronted by many and complicated decisions including: how do you involve communities; how do you reach local level participation that is meaningful and empowering; how do you make an integrated and holistic approach; how do you link research policy and practice; and how do you make research demand-driven.

The search for a new and dynamic methodology was by no means new or unique. LPDA, for example, initiated such an ideal methodology search as early as 1995 and much success with PEA has been achieved in, for example, Malawi, Zambia and Zimbabwe. All information and data available from a literature review and survey were taken cognizance of in search of a methodology and much attention was paid to lessons learnt in the past. The following step was to adapt the selected methodology within the agro-systems context of the Limpopo Province and to assess its links to the guiding principles.

Participatory project methodology development gained a lot of impetus following the establishment of a democratic Republic of South Africa. The Limpopo Department of Agriculture, in cooperation with Novafrica, for example, was in search of a method to ensure effective service delivery and to empower emerging farmers. In their search for a suitable technology, guidelines were developed to empower emerging farmers. These are:

Guidelines

- Equitable distribution of resources;
- *Bathopele:* the people first principle;
- Inclusivity;
- Learning process (capacity building);
- Ecological awareness;
- Innovation (peoples knowledge);
- Job creation;
- Conscientiousness;
- Build capacity for extension, researchers and communities;
- Select a method tested somewhere in similar context; and
- Frame a renaissance (regional).

Methodology objectives

Methodology development started in 1998 and the following objectives were stipulated:

- To develop the individual and collective capacity of rural people so that they could select and disseminate options to improve their livelihoods;
- To establish representative and democratic community-based organizations capable of establishing permanent linkages with service providers;
- To institutionalize PDA/PEA approaches into the service delivery system; and
- To develop the innovation capacity of communities and service delivery systems.

Participatory project process

The first phase in implementing the project in 1998, was to select the first batch of extension staff to implement the project. Extensionists are pivotal in the implementation and facilitation of the project and they were trained in the methodology during the first project phase. In view of the critical importance of methodology training, expertise from neighbouring countries was sourced.

The second phase of the project entailed the selection of pilot areas in three districts of the Limpopo Province. Fig. 1 introduces the reader to the action research process.

Without providing detail, the success of the methodology in the pilot areas was such that it created demand for the approach in other areas. A public company was subsequently formed to accelerate delivery to other provinces and countries.

Participatory model

The participatory model (Fig. 2) consists of five phases. It is important to note that the training phase is dominated by learning by practicing (70%) rather than by theory (30%) and that the training process is long (18 months) divided into five cycles. The length of the training period is based

Fig 1

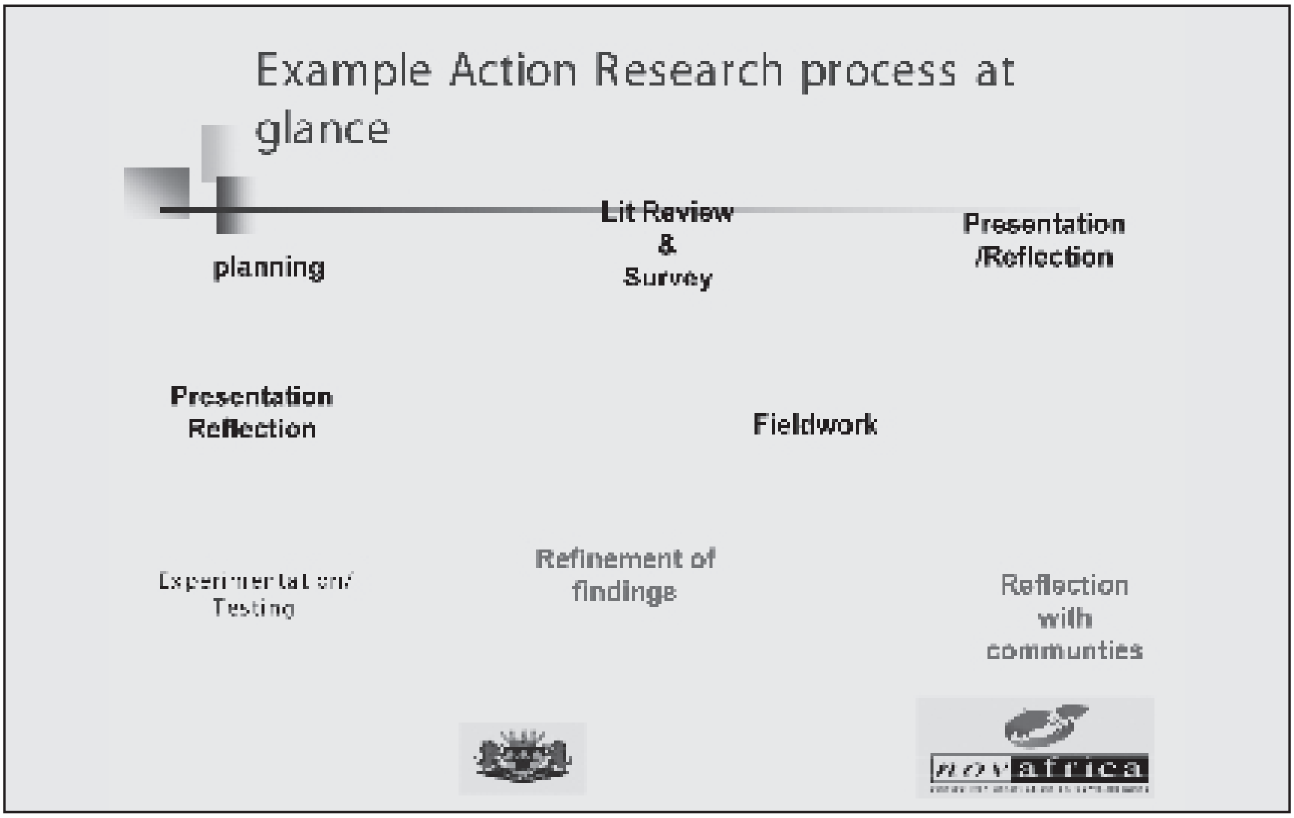
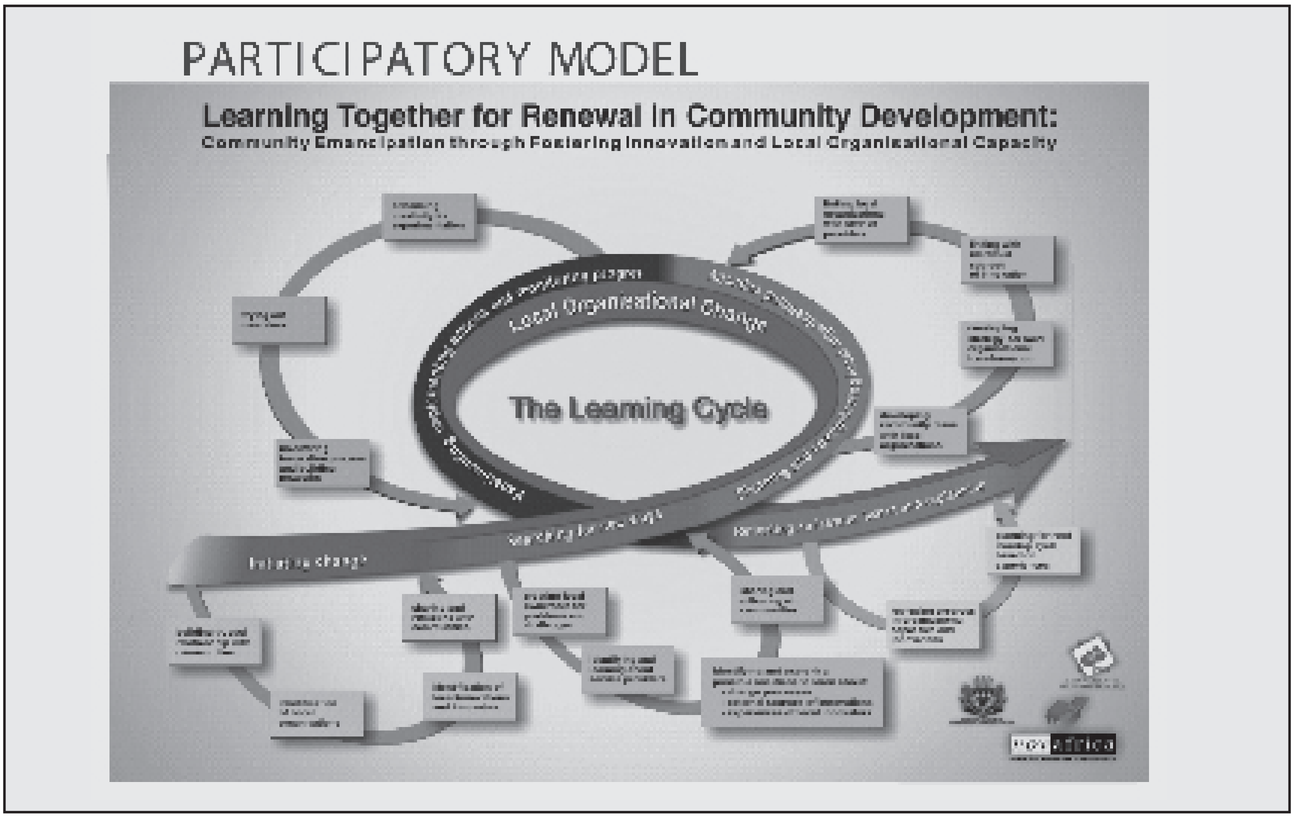


Fig 2



on the multiple actions involved – from backstopping to the establishment of teams. Extensionists, being the facilitators of training, are tasked with the training.

Research, within the context of the methodology, is people centered. Community engagement, reorganization and lobbying are therefore pivotal.

Methodology progress

Providing for the needs of people follows a dynamic and most complex process. To address poverty, is possibly the apex of complexity as so many equally important and basic requirements, issues and therefore challenges arise. The Novafrica methodology towards a participatory approach to climate change adaptation for rural communities is such an example of complexity. If poverty and its components such as sufficient and healthy food, health, shelter, water, energy and other basic life requirements are not addressed, the priority of the hierarchy of basic human needs dictates that climate change will not concern the people. It also dictates that training of these people must address additional development issues. This is very demanding as far as material and concept development is concerned. As people development progresses, so do new demands. The farmers participating in the project, as they developed, moved from simple issues to new demands such as for computers, bookkeeping skills and better service from service providers, necessitating an integrated, community-driven approach.

The methodology followed resulted in the formation of an umbrella organization for local organizations, which gave the communities leverage and negotiation power. Service providers now comply to the needs of communities and extension officers now provide quality services and answer to communities. The question involuntary arises as to why partnership responses often take so long to materialize.

Project result areas

- The approach followed by Novafrica and its partners has been implemented on a large scale by 20 municipalities and 211 communities;
- 60 Umbrella organizations have been established with provincial representation. The seed growers association is such an example;
- Economic benefits have been obtained through an economy of scale. Communities now have access to inorganic fertilizer, for example;
- Cash and high value crops such as sweet potatoes and certified maize are being produced;
- On-farm experimentation, one of the most successful methods to facilitate training and the adoption of best management practice technologies, is successful as capacity has increased;
- Crop diversification and selection have resulted in a lower vulnerability to agricultural risk and to regular cash flow;
- Representatives and democratic community-based organizations have been established;
- The Department of Agriculture has adopted and is institutionalising the PEA approach;
- The approach is a vehicle for stakeholder empowerment.

Challenges

Numerous and complex challenges are facing the agricultural sector and its value chains in view of climate change and climate perturbations. It is imperative that a peoples approach become the core in addressing challenges and that gaps between research and communities and between policy and communities are bridged. Pressing challenges are the following:

- Links between research and practice;
- Community empowerment as capacity needs/demands are growing;
- As the complex demands of livelihoods increase, so should the concepts of development and involvement;
- Local knowledge/the innovation component of farmers must be linked to research;
- Institutions doing similar work should join hands;
- Training material should be developed to include climate change. This should include the *curricula* of extensionists.

Conclusion

Climate change scenarios are being deployed and the uncertainties on a number of climate change issues are on the increase while people are living with the consequences of climate variability and climate change.

Climate change adaptation for rural communities endeavours should adopt a people-centered methodology and an action research process, using the peoples’ approach to uncertainty as point of departure.

An approach to adaptation and mitigation should be abstracted from the peoples’ approach towards climate change. This would enable policy, science and the people to meet halfway and join hands in ensuring sustainable rural livelihoods.

Climate change and South African agriculture: A Ricardian analysis of impacts and adaptation options (preliminary results)

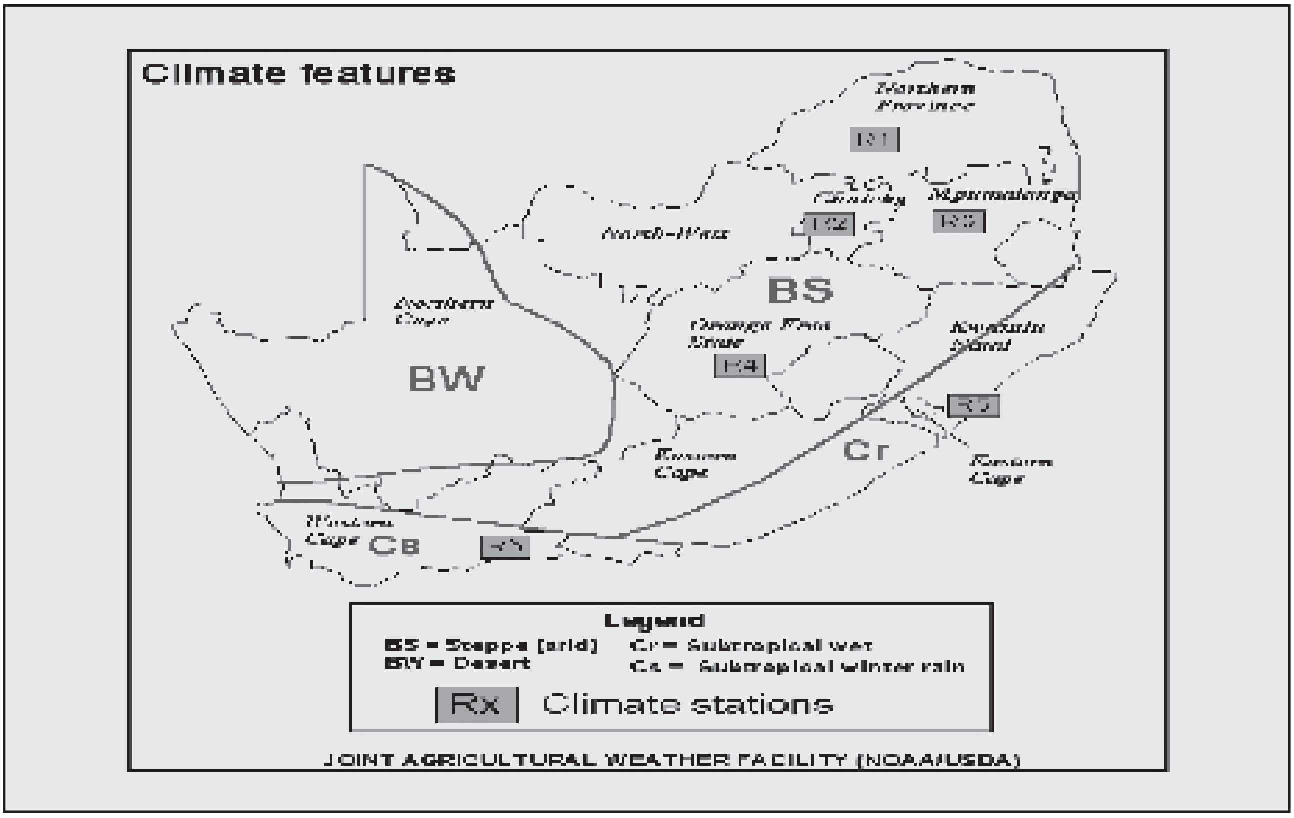
J.K.A. Benhin & R. Hassan

CEEPA, University of Pretoria, Pretoria 0002
E-mail:james.benhin@up.ac.za

Introduction[1]

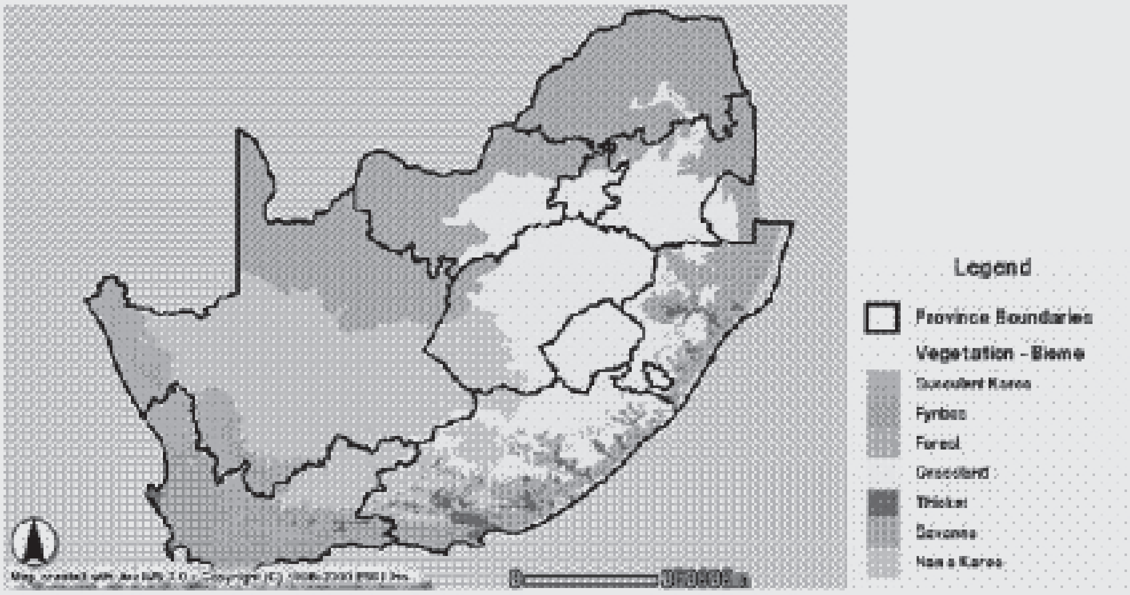
Agriculture in the Republic of South Africa is very diverse in terms of the types of crops produced, cropping calendar and production levels. The different agro-climatic zones from the dry northwest region to the wet eastern region influence this diversity (Fig. 1, 2 and 3). Major crops produced are maize, wheat, sugarcane, sorghum and minor crops are groundnuts, sunflower seed, dry beans, tobacco and potatoes (Fig. 4 – 6). Fruit crops of importance include apples, grapes, pears, peaches and dried fruits. In addition, the country's national commercial cattle herd is estimated at 13.5 million and a herd of 29 million sheep and 6.6 million goats in 2003 (NDA, 2000; 2004). Agricultural land consists of 100.7 million hectares (81%), nature conservation, 11.8 million hectares (9.6%), forestry, 4.4 million

Fig 1: Climate zones in South Africa



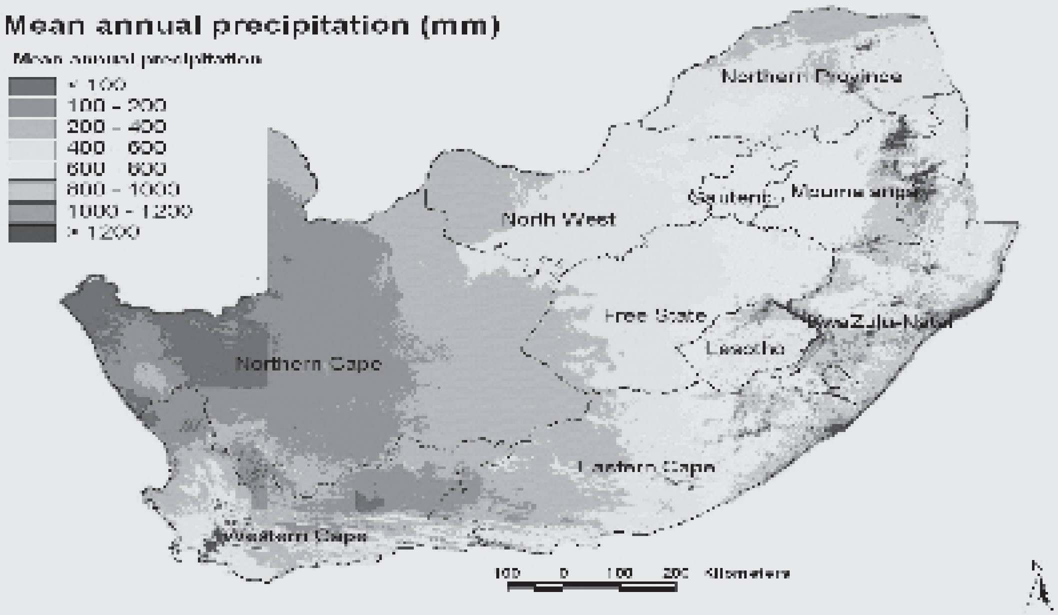
1 This study is part of an 11 African-wide study on "regional climate, water and agriculture: impacts on and adaptation of agro-ecological systems in Africa" coordinated by CEEPA, University of Pretoria. We acknowledge major funding support from the Global Environment Facility (GEF), the World Bank's Trust Fund for Environmentally and Socially Sustainable Development (TFESSD) and complementary funding from the following organisations and institutions: CEEPA, Finland Trust Fund, National Oceanic and Atmospheric Agency, Office of Global Programs (NOAA-OGP)

Fig 2: South African natural vegetation- Biome



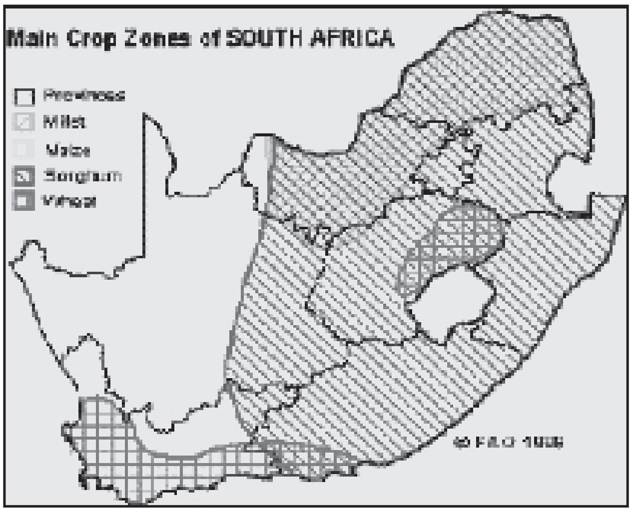
Source: South African Agricultural Geo-referenced Information System (2000)

Fig 3: Distribution of mean annual precipitation (mm) in South Africa



hectares (1.2%), and other land uses, 8.4 million hectares (6.9%) of the country's total land area of 122.3 million hectares. Eighty-four million hectares (68.6%) of the total agricultural land is under permanent pasture, while the rest, 16.7 million hectares, is potentially arable (NDA, 2005). Highly potential arable land comprises of 22% of the total arable land. About 12.7 million hectares (10%) of the total land area is under cultivation, with slightly more than 1.2 million hectares (10%) under irrigation (NDA, undated).

Fig 4



Source: FAO/GIEWS (2001)

Fig 5a

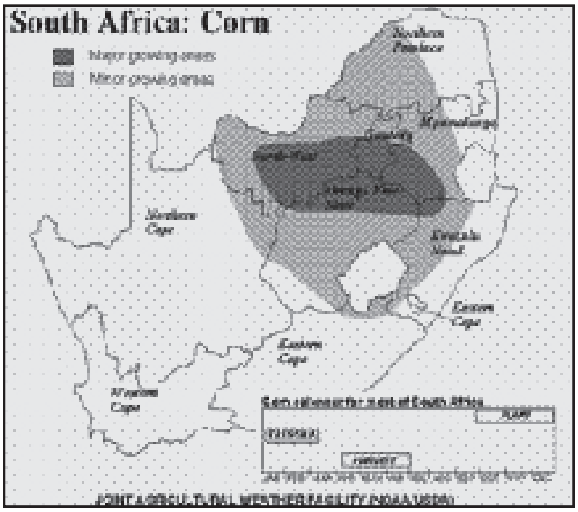


Fig 5b

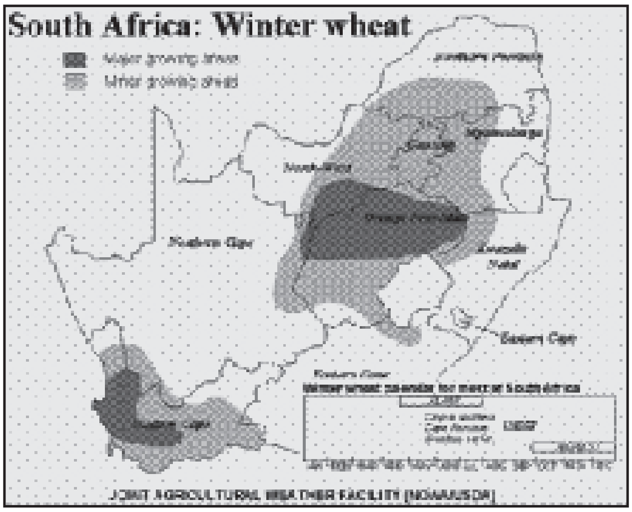
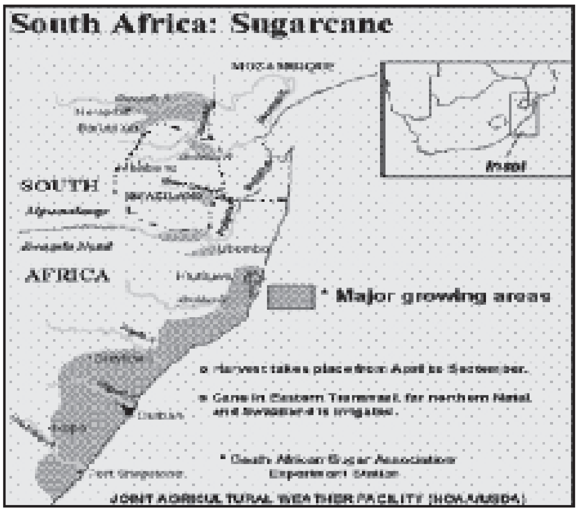


Fig 6



In general, agriculture in South Africa is widely regarded as a highly sophisticated and successful sector. The dominant form of agricultural production in the country is the medium to large-scale farms, which accounts for 90% of the value added and covering 86% of agricultural land. This sector is commercially oriented, capital-intensive and generally produces a surplus. On the other hand the small-scale farming sector, constituting a high proportion of the farming population, is mainly subsistence in nature and relies mainly on traditional methods of production.[1]

The most important factor limiting agricultural production in the Republic of South Africa is the availability of water. Rainfall is distributed unevenly across the country, with humid, subtropical conditions occurring in the east and dry, desert conditions in the west (Fig. 1 and 3). Average rainfall for the country is 450 mm per year, well below the world's average of 860 mm, while evaporation is comparatively high (DWAF, 2002). Only 10% of the total area receives an annual precipitation of more than 750mm (Fig. 3) and almost 50% of South Africa's water resource is used for agricultural purposes. Both commercial farming and especially subsistence farming would be affected by adverse climate change effects on the availability of water. Such an impact is expected to vary across the different agro-climatic zones and the Provinces in the country.

The vulnerability of agriculture to climate change has become an important issue because of reduced crop productivity from adverse changes in climate, especially in Africa. Although there have been some studies of climate change impacts on Africa (both agronomic and economic), it is still not very clear how Africa will be affected and what adaptation interventions are opened to the continent. This paper presents preliminary results on an economic impact assessment of climate change on agriculture in

[1] Current land reforms in the country, is likely to change the distribution of farm activities. The land reform consists of restitution, tenure reforms and redistribution of land. Restitution deals with changing the historical rights of land and tenure reforms deal with the forms of land holding. Most importantly, redistribution aims at transforming the racial pattern of land ownership where more white-owned lands will be redistributed to historically disadvantaged groups

South Africa. One area of focus is climate effects on water resources and subsequent impact on agriculture. The paper also presents preliminary observations of adaptation mechanisms opened to different groups of the farming population in the country.

In the Southern African region, the effects of climate change on agriculture are expected to be severe. For the Republic of South Africa in particular, the impact will have carry-over effects on the whole region for a number of reasons: (i) the semi-arid nature of the country with increased farming on marginal lands; (ii) the high frequency of droughts; and (iii) the scarcity of water which is exacerbated by a high spatial variability of rainfall. Moreover, technology change is very slow in a country where more than a million people (about 13% of the labour force) directly depend on agriculture for their livelihood. Domestic agriculture is also the main source of food for the country population of 46 million and South Africa is the major source of food for the rest of the region. For example, 50% of maize (the main staple) in the Southern African Development Community (SADC) region is produced in South Africa. Agriculture also contributes about 2.9% to the GDP and it is a major source of foreign exchange. Adverse climate impacts on agriculture in the Republic of South Africa may therefore de-stabilize, not only the country but also the whole region.

In spite of these concerns, there have been limited studies on climate change impacts on agriculture in South Africa (as in most African countries) in terms of economic losses and social welfare impacts. Existing studies cover either a few crops or small parts of the country and mostly examined how individual crops behave in control experiments, addressing largely grain crops and mainly maize (Schulze *et al.,* 1993; Du Toit *et al.,* 2002; Kiker, 2002 and Kiker *et al.,* 2002). Among a few of these studies, Du Toit *et al.* (2002) show that in the dry western production areas, crop production will become more marginal, while in the high potential eastern production areas a slight increase may occur. A recent study by Poonyth *et al.* (2002), using a Ricardian model to explore the agriculture sector performance with respect to climate change, concluded that rising temperatures will be detrimental to agriculture production and will even be worse without proper adaptation by farmers. The focus of the Poonyth *et al.* study was commercial farming. However, the riskier sector is subsistence farming with very little adaptability abilities. The study also focused less on the extent of adaptation. The effects of climate change on agriculture in South Africa may therefore be worse than what the Poonyth *et al.* study found if such analysis incorporates subsistence farming. On the other hand, the overall impact may not be as worse as envisaged if the role of adaptation interventions were also considered (Deressa *et al.,* 2005; Gbetibouo & Hassan, 2004).

Moreover, one of the most significant impacts of climate change, as noted earlier, is likely to be on the hydrological system and hence on river flows and water resources in the country. This is especially important given the semi-arid nature of the country where water resources are very sensitive to climate variability and change. The Poonyth *et al.* (2002), Deressa *et al.* (2005), and Gbetibouo & Hassan (2004) studies suffer from the same criticism levelled against earlier Ricardian studies of agriculture for the non-inclusion of water supplies in the analysis (Mendelsohn & Dinar 2003; Darwin, 1999). Using cross-sectional data for the 2002/2003 farming season, the study extends those of Poonyth *et al.*, Deressa *et al.*, and others, by using a revised Ricardian model with the incorporation of relevant hydrological variables in the analysis, to assess the economic impact of climate change on agriculture in the Republic of South Africa. It also investigates possible adaptation options for farmers in the country.

This paper discusses the analytical framework of the Ricardian approach, the empirical model specification for South Africa, the results of the preliminary analyses and adaptation options open to farmers.

Analytical framework

Two major economic approaches, namely agronomic-economic and cross-sectional models, have been employed to study the interaction between climate, water and agriculture. The agronomic-economic approach begins with calibrated agronomic models and predicts outcomes, using economic simulations. The cross-sectional approach compares the choices and performances of existing farms that face different climate and soil conditions. These two approaches have both confirmed a number of hypotheses such as the harmful effects of hot temperatures on agricultural activities and an indication of the robust nature of the results across all the assumptions inherent in each method. The cross-sectional method referred to as the Ricardian approach, has linked farm values to climate (Mendelsohn & Dinar, 2003).

The Ricardian method is an empirical approach to studying sensitivity of agricultural production to climate change based on cross-sectional data. The method was named after Ricardo because of his original observation that land rents would reflect the net productivity of farmland at a site under perfect competition (Ricardo, 1817; 1822). This method has been developed by Mendelsohn *et al.* (1994) to measure the economic impact of climate on land prices in the USA. The model accounts for the direct impacts of climate on the yield of different crops as well as the indirect substitution of different inputs, introduction of different activities and other potential adaptations to different climates.

Given the market price P_i for commodity i and profit maximising farmers, on a given site under perfect competition, land market will drive profits to zero. Put differently, the implication of this is that land rent per hectare will be equal to the discounted sum of future net revenue per hectare P_{Lt}. Following Ricardo, land value (V) will reflect the present value of future net productivity of land per hectare (P_{Lt}) captured by the following equation:

$$V = \int_0^\infty P_{Lt} e^{-\phi t} dt = \int_0^\infty \left(\sum P_i Q_i(X, F, Z, G) - \sum RX \right) e^{-\phi t} dt \quad (1)$$

Where Q_i is the quantity produced and X is a vector of all purchased inputs in the production of commodity i.

F, Z, G are vectors of exogenous environmental variables such as climate (temperature, precipitation, etc.) (F), soil types (Z) and economic factors (market access, etc.) (G), which are common to a production site. R is a vector of input prices, t is time and δ is the discount rate. P_L is the annual cost or rent of land at that site and L is the land under the production of commodity i.

The main interest of the analyses is measuring the impact of exogenous changes in environmental variables (F, Z, G) on land value as captured by changes in land values across differing environmental conditions. By regressing farm values on climate, soil and other control variables, the method enables the measuring of the marginal contribution of each variable to land value. Cross-sectional observations, showing spatial variation in normal climate and edaphic factors, can hence be utilized to estimate climate impacts on production and land value.

The standard Ricardian model relies on a quadratic formulation of climate. The quadratic terms reflect the non-linearities between crop output and climate variables that are apparent from various field studies and other Ricardian studies applied elsewhere (Mendelsohn *et al.*, 1994, 1996; Dinar *et al.*, 1998; Poonyth *et al.*, 2002; Deressa, 2003; and Mendelsohn & Dinar, 2003). For each crop, there is a known temperature where crops grow best across the seasons, although the optimal temperature varies by crop. The relationship of seasonal climate variables, however, is more complex and may include a mixture of positive and negative coefficients across variables (Kurukulasuriya *et al.*, 2005).

Empirical specification of the Ricardian model for South Africa

The empirical model estimated, relies on a quadratic formulation of climate and extends the standard Ricardian model to thoroughly capture the impact of water on farm value following Mendelsohn & Dinar (2003). Mendelsohn and Dinar have noted that it is true that water comes to farms in the form of precipitation, which is already reflected in the Ricardian model. However, farmers have two other sources of water, namely surface water and groundwater. Because the sources of this additional water can be remote from the farm, the climate at the farm may give little indication of the amount of surface and groundwater accessible to the farm. The authors introduced both sources of water in linear and quadratic forms, using relevant hydrological (runoff, flow, etc.) plus irrigation variables:

$$V = \beta_0 + \beta_1 F + \beta_2 F^2 + \beta_3 Z + \beta_4 G + \beta_5 W + \beta_6 W^2 + u \qquad (2)$$

Due to imperfect land markets and weak documentation of agricultural farm values in the developing world including South Africa, land values could not be used as a dependent variable as suggested by equation (1). Following the approach of Sanghi *et al.* (1998) and Kumar & Parikh (1998) for India, net revenue per hectare was used as the response variable. This formulation assumes that expected future net revenues are a good reflection of land prices.

Equation (2) captures the relationship between the indicators of farm revenues, climate variables (F), soils (Z), socio-economic variables (G) and hydrological and irrigation variables (W). u is the error term. By adding the hydrological and irrigation variables, we tested whether farmers who have access to more water, have higher farm values.

In spite of the inclusion of the water variables in the revised Ricardian model to address the importance of access to other water sources in agricultural activities, the method still has certain drawbacks. The Ricardian approach does not measure the effect of different levels of carbon dioxide across space, which may be relatively important in farm productivity and therefore farm revenue. Relatively, this is not a problem in this study, since carbon dioxide levels do not vary across South Africa. Another drawback is that the variation in climate that is observed across space, may not resemble the change in climate over time. In this case the analysis will not be able to evaluate such effect.

However, one main advantage of the Ricardian empirical model is the inclusion of adaptation responses by farmers to local climate, which are incorporated in the estimation of the value of land. The model reflects the cost and benefits to farmers for introducing a new crop as climate warms, such as costs of seed, equipment and land preparation. Thus, the model provides a more optimistic result than the generally pessimistic results found with purely agronomic studies (Fig. 7 and 8).

Sources of Data

- Net revenues and socio-economic variables: A cross-sectional farm household survey was undertaken in selected districts in South Africa for the 2002/2003 farming season, covering both crops and livestock. The survey provided information for the estimation of net revenues, such as the value of farm output and the cost of production. The survey also provided relevant socio-economic data, which may directly and indirectly affect farm net revenues, such as household income, family size, farm size, type of ownership of farm, distance to markets, number of working hours, access to capital, extension services and machinery, plus irrigation and irrigation technologies. In total 416 farm households were interviewed in 17 districts across the nine Provinces of South Africa (Appendix 1). Of these, 53% were large-scale farmers and 47% small-scale farmers. Twenty-nine percent of the farmers were crop farming with maize as the major crop, while 27% were livestock farming only. The remaining 44% were mixed farming (Appendix 2). In addition, secondary data provided national and district level information.
- Soil data: These data were obtained from the Food and Agriculture Organization (FAO). The FAO data provides information on major and minor soils by district in the country (FAO, 2003).
- Hydrology data: These were provided by the University of Colorodo, Boulder, and the International Water Management Institute (IWMI) (IWMI and University of Colorado, 2003). Using a hydrological model for Africa, estimates were provided for flow and runoff for each of the surveyed districts.

Fig 7: The importance of Adaptation

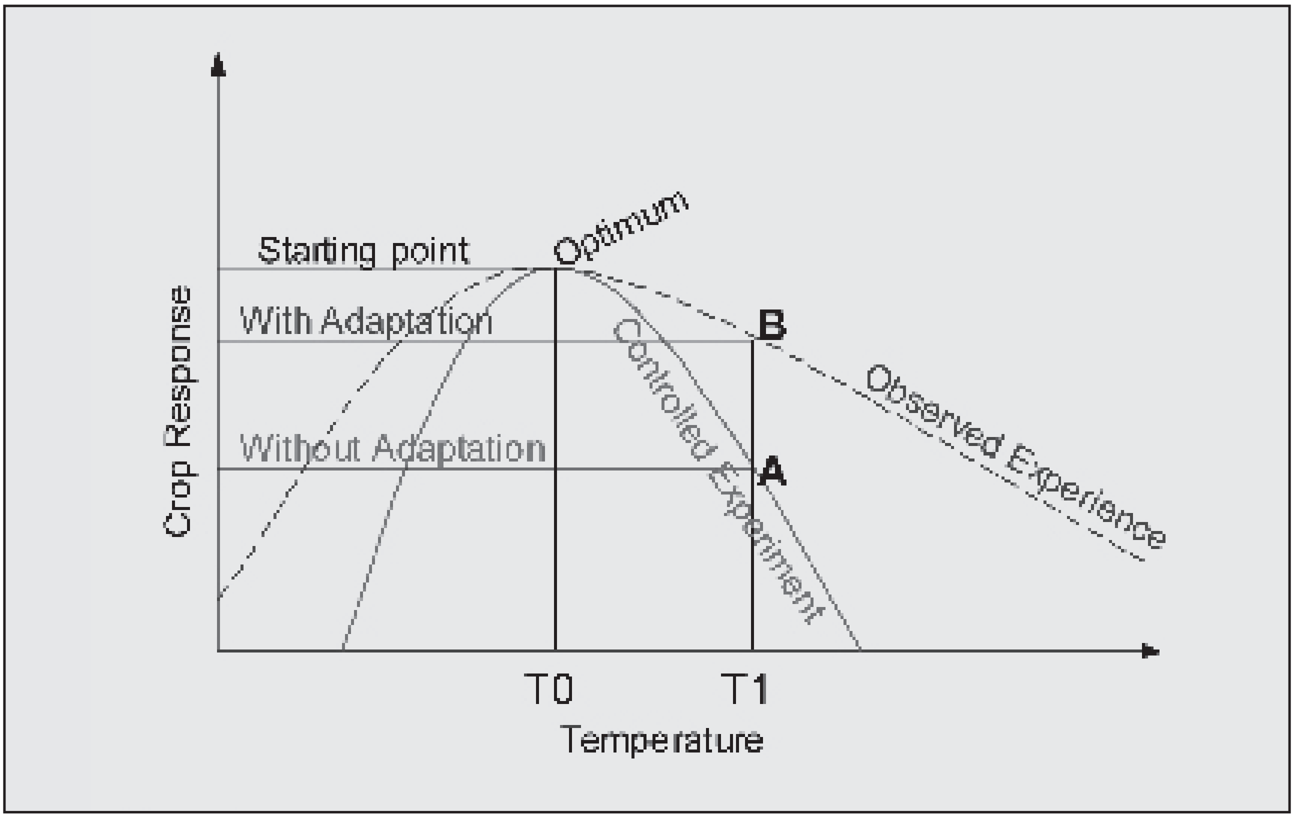
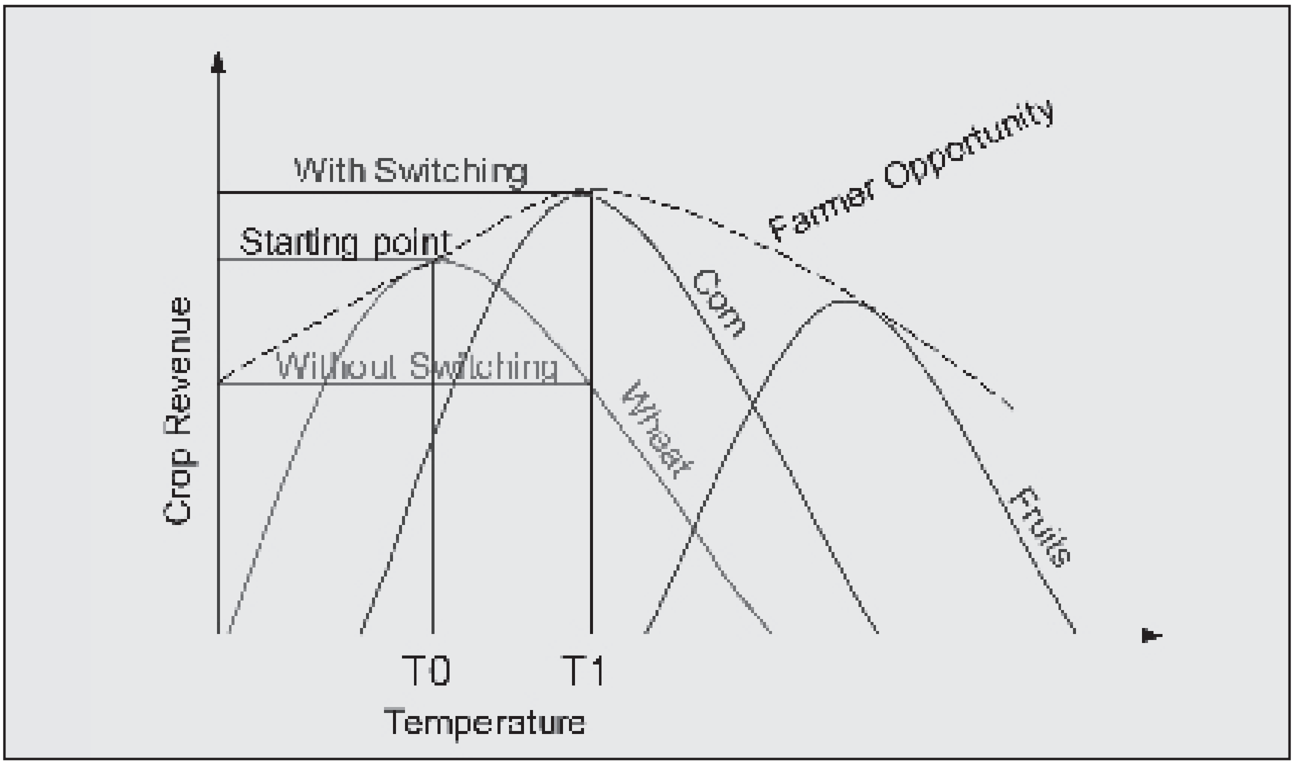


Fig 8: Crop Choice



- Climate data: These were compiled by Yale University and gathered from two main sources. Satellite data on temperature and soil wetness was provided by the US Department of Defence. The data is derived from a set of polar orbiting satellites that are equipped with sensors to detect microwaves through clouds and estimate surface temperature and surface wetness. The satellite conducts daily overpasses at 6 a.m and 6 p.m. The remaining data comes from the Africa Rainfall and Temperature Evaluation System (ARTES) (World Bank, 2003). This dataset, created by the National Oceanic and Atmospheric Association's (NOAA's) Climate Prediction Center, is based on ground station measurements of precipitation, minimum temperature and maximum temperature.

Discussion of estimated models

Two sets of models for equation (2) were estimated. Model 1 included only climate, hydrology and soil variables (referred to as "without adaptation" model). Model 2 (referred to as "with adaptation" model) assesses the influence of adaptation by including adaptation related variables, which directly or indirectly affects farm net revenues such as irrigation, technology, hired labour, markets and livestock ownership. The dependent variable was net revenue per hectare of cropland, which was estimated as gross crop farm revenue less the cost of fertilizer and pesticides. Two functional forms for these two models were estimated, namely a linear form and a log-linear form. The estimated models are presented in Table 1.

Table 1: Estimated Ricardian Model for South Africa: Without and with adaptation models

	Model 1: No adaptation		Model 2: With adaptation	
Variable	**Col. 1 Linear**	**Col. 2 Log-linear**	**Col. 3 Linear**	**Col. 4 Log-linear**
Summer temperature	-16710.09***	-69.92***	-13025.46***	-38.33**
Summer temperature Squared	329.12***	1.39***	258.53***	0.83***
Winter temperature	7828.87***	30.62***	6142.48***	16.15***
Winter temperature Squared	-283.19***	-1.13***	-225.89***	-0.68***
Summer precipitation	-1823.93***	-7.63*	-1308.86***	-1.50
Summer precipitation Squared	6.21***	-0.026	4.37**	0.003
Winter precipitation	2128.42***	8.03*	1477.07***	1.23
Winter precipitation Squared	-37.99***	-0.147*	-26.51***	-0.025
Summer temperature and precipitation	81.43***	-0.34	58.92**	0.066
Summer temperature and precipitation squared	-0.013***	-5.4E-05	-0.009*	-5.80E-06
Winter temperature and precipitation	-129.87***	-0.486*	89.02***	-0.0611
Winter temperature and precipitation squared	0.157***	6E-04	0.11***	-9.9E-05
Mean Flow	23515.47***	106.48**	19325.86***	41.06
Mean Flow Squared	-42195.88***	-196.48**	-33563.86***	-72.64
Chromic Luvisols	-539	-1.19	-210.66	-0.684
Chromic Vertisols	-4401.17	-18.36	-3671.39**	-6.428
Irrigation (dummy – 1/0)			188.36***	0.51**
Livestock ownership (dummy – 1/0)			-1.59	0.184
Access to electricity (dummy – 1/0)			131.62	0.97***
Hired adult labour (dummy – 1/0)			155.28	0.64**
Household size			13.89	0.085***
Farming experience (Number of years)			2.73	0.018**
Distant to output market (in kilometres)			-0.038**	-4.97E-05
Constant	154.18***	663.52***	118776.8***	346.51***
Observations	224	216	176	171
F-stat	12.98***	10.70***	6.40***	13.58***
R-squared	0.318	0.305	0.3809	0.443
*** Significant at 1%, ** Significant at 5%, *Significant at 10%				

Out of the 416 observations 224 were used for the initial analysis. One hundred and eleven observations were livestock farming only and therefore were excluded. Additional observations were also excluded because of the difficulty in estimating gross and net revenues. From the two sets of functional forms, the log-linear form was found to be a reasonable fit for the model, given it's relatively high F-statistic and R-square, especially for model 2. This model therefore forms the basis for the discussions, which follows.

Comparing the without and with adaptation models (that is col. 2 and 4 respectively in Table 1), the inclusion of the adaptation related variables improved upon the overall estimated model as indicated by the relatively higher F-statistic and R-square. This implies that these adaptation-related variables are important in the discussion of crop net revenues in South Africa. The estimates also show that summer and winter climate variables seem more relevant to crop production activities in the country.

The estimated models indicate that climate variables do indeed affect crop net revenues in South Africa as shown by the significant coefficients of most of the climate variables. A better interpretation of the impact of the climate variable is undertaken by estimating the marginal impacts of these variables as indicated in Table 2 to which we turn to shortly.

The estimated models (col. 2 and 4) indicate that access to sources of water other than precipitation on a given location, positively influence net revenues. This is indicated by the positive and significant coefficient of the flow mean variable in col. 2 of Table 2. It also indicates that there is a limit to which this flow would be beneficial to crop farming. Beyond a certain limit, the impact becomes negative (as indicated by the negative coefficient of the flow mean squared term). Both soil types (*Chromic Vertisols* and *Chromic Luvisols*) included in the model are negative with the latter being significant. The implication is that these soil types are not beneficial to increased crop production and crop net revenues in the country.

The use of irrigation has a positive influence on net revenue, so has improved technology (using the access to electricity as a proxy which is a reflection of modern technology). Hired labour and household labour (using household size as a proxy) also positively influence crop net revenue. Hired labour is important for large-scale farms while household labour is important for small-scale farms. The result also shows that farm experience positively influences net revenues. One expected the distance to the market variable to positively influence net revenues given that the further away the market, especially at urban areas, the higher returns one expects from crop sales. But the variable is negative though not significant in the log-linear function. There is the possibility that a quadratic formulation of this variable may indicate that there is a limit to which the distance to the market may influence net revenues. Ownership of livestock is positive though not significant. But it is an indication that farmers with livestock may expect to have higher returns from crops farming per hectare of farm land.

In order to interpret the climate coefficients, we estimated the marginal impacts on net revenues of a change

Table 2: Marginal impacts of climate on net revenue (US$/HA)

1°C increase in temperature			
	Model 1: Without Adaptation		
Season	**South Africa**	**Provinces**	**Northern Cape**
Summer temperature	-10.60	[-5.36] – [-16.75]	-0.28
Winter temperature	4.21	[-4.26] – [9.11]	7.48
Annual temperature	6.37	[-3.06] – [-12.51]	7.20
	Model 2: With Adaptation		
Summer temperature	-2.97	[-0.14] – [6.64]	3.17
Winter temperature	0.21	[-4.93] – [3.16]	2.18
Annual temperature	-2.76	[-0.77] – [-6.43]	5.35
1° increase in temperature and 1mm fall in precipitation			
	Model 1: Without Adaptation		
Summer temperature and precipitation	-7.10	[-14.32] – [1.99]	5.85
Winter temperature and precipitation	6.02	[-4.53] – [8.45]	2.86
Annual temperature and precipitation	1.08	[-12.53] – [53.88]	8.72
	Model 2: With adaptation		
Summer temperature and precipitation	-1.97	[-5.67] – [1.61]	4.50
Winter temperature and precipitation	0.63	[-2.40] – [3.17]	1.52
Annual temperature and precipitation	-1.33	[-5.34] – [6.28]	6.01

in the climate variables (temperature and precipitation). Table 2 indicates that a 1˚C increase in annual temperature will negatively affect revenues in the country by a fall of US$6.37 per hectare of crop land. The expected impacts are, however, significantly different for summer and winter. A similar increase in summer temperature will lead to about US$10.60 fall in net revenue in the country with a range of US$5.36 and US$16.75 fall in eight of the nine Provinces, while a similar change in winter temperature will rather increase net revenue per hectare in the country by US$4.21 with a range -US$4.26 and +US$9.11 across the nine Provinces.

When adaptation variables were considered, the impacts change significantly. The annual negative impacts reduced from US$6.37 to US$2.76, summer from US$10.60 to US$2.97 and the winter positive impacts reduced from US$4.21 to US$0.21. The important observation here is that adaptation options do indeed reduce the impact of climate variables on crop net revenues in the country and this should be an important policy tool in the direction of efforts aimed at controlling the impact of climate change on the agriculture sector in the country. Table 2 also indicates that increased temperatures plus decreased precipitation will reduce net revenues in the country. One important observation is that, in all the estimates of the marginal impacts, the Northern Cape Province seems to be better off or have relatively lower impact than the rest of the Provinces. One explanation for this result may be that, because the Province is already hot and dry, farmers have already adapted to such harsh climate and further warming may not significantly affect farm activities in the country. This needs further investigation.

Climate change would therefore negatively influence crop net revenues in the country. However, adaptation options will help reduce these negative impacts. Moreover, the nine Provinces will not be equally affected. Some Provinces, such as Northern Cape, will be least affected or gain from the change, while other Provinces such as Mpumalanga and KwaZulu-Natal may be more affected. One other differential impact will be between irrigated farms and non-irrigated farms as the positive coefficient of the irrigated variable in the estimated model indicated. Small and large-scale farms may also be affected differently. The extent of these differential impacts also needs further investigation for policies to be well directed to help control the impacts on these different segments of the agricultural sector in the country.

Perception of climate change and adaptation options

The preceded section has noted the importance of adaptation in helping to curtail the impact of climate change on the agriculture sector in the country. It is important

Table 3: Perception of change in temperature and rainfall patterns by farmers in South Africa

Province	District	Total number of Household	Temperature changeNumber (%)			Changes in RainfallNumber (%)		
			Yes	No	No resp-onse	Yes	No	No resp-onse
Eastern Cape	Aberdeen	20	9	8	3	9	7	4
	Humansdorp	11	5	6	0	4	7	0
	Kirkwood	24	11	11	2	11	11	2
	Total		**25 (45)**	**25 (45)**	**5 (10)**	**24 (44)**	**25 (45)**	**6 (11)**
Free State	Bethlehem	29	22	5	2	21	5	3
	Kroonstad	27	19	5	3	21	3	3
	Total		**41 (73)**	**10 (18)**	**5 (9)**	**42 (75)**	**8 (15)**	**6 (10)**
Gauteng	Bronkhorspruit	**11**	**10 (90)**	**1 (10)**	**0 (0)**	**11 (100)**	**0 (0)**	**0 (0)**
Kwazulu Natal	Estcourt	20	19	1	0	19	1	0
	Hlabisa	38	37	1	0	36	2	0
	Mont Currie	11	9	2	0	9	2	0
	Port Shepstone	26	20	6	0	21	3	2
	Total		**85 (90)**	**10 (10)**	**0 (0)**	**85 (90)**	**8 (8)**	**2 (2)**
Mpumalanga	Lydenburg	21	17	3	1	19	1	1
	Middelburg	25	23	2	0	21	4	0
	Total		**40 (88)**	**5 (10)**	**1 (2)**	**40 (88)**	**5 (10)**	**1 (2)**
Northern Cape	Hopetown	**40**	**29 (72)**	**8 (20)**	**3 (8)**	**29 (72)**	**8 (20)**	**3 (8)**
Limpopo	Soutpansberg	**27**	**16 (60)**	**11 (41)**	**0 (0)**	**9 (33)**	**18 (66)**	**0 (0)**
North West	Vryburg	43	**32 (75)**	**9 (20)**	**2 (5)**	**31 (72)**	**11 (25)**	**1 (3)**
Western Cape	Caledon	19	8	11	0	8	11	0
	Piketberg	24	16	8	0	20	4	0
	Total		**24 (56)**	**19 (44)**	**0 (0)**	**28 (65)**	**15 (35)**	**0 (0)**
NATIONAL TOTAL		**416**	**302 (72)**	**98 (24)**	**16 (4)**	**299 (72)**	**98 (23.5)**	**19 (4.5)**

to note what farmers are already doing to counteract any perceived impact of climate change on farming activities. This would help in effective policy direction. This section provides a brief summary of what farmers conceive of long-term or short-term changes in the climate in terms of temperature and precipitation in their respective districts and whether they have observed these changes. Their adaptation mechanisms to these perceived long-term and short-term climate change are also discussed.

Farmers' perception of changes in the climate

About 72% of the respondents were of the opinion that there have been some changes in the climate over the years with warmer temperatures, delays in the timing of the rain and a reduction in the volume of the rain. This perception varies somewhat in the nine Provinces (Table 3).

In the Eastern Cape Province (Aberdeen, Humansdorp, Kirkwood districts), 45% of the respondents had noticed long-term changes in the pattern of temperature and rainfall. According to this group, there has been a general increase in temperature and a decline in the volume of rainfall. Summers are becoming longer and hotter and winter periods have now shortened and are warmer. However, about half of the respondents did not seem to agree with this observation. For them, the changes that have occurred are not long-term changes but rather a consistent occurrence over a 10-year cycle in the climate, where in every tenth year the Province experiences drought and warmer temperatures (Table 3).

In the Free State (Kroonstad and Bethlehem districts) 75% of the respondents have noticed long-term changes in the climate of the Province. According to these farmers, it is becoming windier, dustier, dryer and hotter. Temperatures are increasing and the volume of rainfall has decreased. There has also been an increase in the occurrence of drought and the timing of rainfall fluctuates from year to year. These changes in the climate have induced a shift in the agricultural season with a three-week delay in the planting period. The other 25% of the respondents in this Province have not noticed any long-term changes in the climate, mainly because many of them have been farming for less than three years.

All the farmers in the Gauteng Province (Bronkhorstspruit district) were of the opinion that the temperature has increased over the years. They have also observed a fall in the volume of the rain and a delay in the timing of the rain, which has shifted from early September to late October or early November.

In KwaZulu-Natal (Estcourt, Hlabisa, Mount Currie and Port Shepstone districts), 90% of the respondents have noticed a long-term shift in the temperature and rainfall in the Province. According to them, the Province is becoming hotter, with the maximum temperature increase from 28°C to 32°C since the late 90s. There has also been an increase in the occurrence of droughts. The beginning of the winter season has also shifted from early April to May. For most of them the rainfall has become erratic from year to year. The annual average rainfall has decreased and its distribution throughout the year has changed, with the rainfall concentrated in shorter periods and much heavier.

Eighty-eight percent of the respondents in the Mpumalanga Province (Lydenburg and Mpumalanga districts) have observed changes in the climate, which are indicated by higher temperatures and a decline in rainfall. To them the climate is now more dry and hotter. The occurrence of extreme events such as heavy showers, hail and drought has increased over the years. The average annual rainfall has decreased by half from about 500 mm to 300 mm per year. The rainy season has also shortened from the September – February period to October – January (Table 3).

In the Northern Cape Province, 72% of respondents in the Hopetown district observed that the climate is getting worse. The volume of rainfall has reduced and it fluctuates a lot from year to year. The temperature also varies from one extreme to another. They experience not only high temperatures but also very cold weather.

In the Soutpansberg district of the Limpopo Province, the views of the farmers are a little bit different. About half of them are of opinion that there has been no noticeable change in the climate, while the other half have noticed less rainfall and higher temperatures.

Seventy-five percent of respondents in the Vryburg district of the North West Province perceived that the climate is changing, with the volume of rainfall reducing and temperatures rising. For them, there is a shift in the duration of winter and summer. They have experienced longer and colder winters and summers have become hotter.

In the Western Cape Province (Caledon and Piketberg districts), for about 50% of the farmers the climate seems to be more or less the same over the past few years except for very high temperatures during the last 12 months. However, the other 50% observed that the climate is becoming dryer and hotter, the winter season has shortened and the rain was coming later than expected (Table 3).

Long and short term adjustments to climatic changes

The focus here is on the various adjustments that farmers in the survey have made in their activities in response to the perceived changes in climate. About 30% of respondents did not have any adaptive strategies, mainly because they lack the necessary funds, information and government support. Although money appears to be a constraint, the other 70% of the farmers interviewed across South Africa identified a number of adaptations options they are applying to address the perceived climatic changes (with respect to higher temperatures, the timing and reduced volume of rainfall). There was, however, no significant difference between long-term and short-term adjustments. The main adjustments in farming activities are discussed.

Adjustments in farming operations

Some of the adjustments made by farmers in their operations include changes in planting dates of some crops, planting of shorter period growing crops such as cabbage and the planting of short season maize crops (120 days – 140 days). Others include the increased use of crop rotation and the early harvesting of some crops. In KwaZulu-Natal for example, farmers prefer to cut their sugarcane at an early age to avoid loss of production, due to the dryness of the cane (as a result of increased temperature) if they had to wait for the cane to mature on the field.

With the current situation of heavier rainfall, concentrated in shorter periods and with the starting period, which shifted from the early September to late October in some Provinces, farmers have responded by: (i) delaying planting period, (ii) increased use of modern machinery to take advantage of the shorter planting period, (iii) collection of rain water by making furrows near the plants, and (iv) increased use of irrigation.

In response to higher temperatures, farmers have resorted to the use of (i) heat tolerant crop varieties, (ii) crop varieties with high water use efficiency, (iii) early maturing crop varieties and increased crop and livestock farming (mixed farming). For example, because of the high temperatures, sugarcane farmers have shifted to the production to macadamia nuts and tea, which they consider less complicated to irrigate than sugarcane farms.

Livestock farmers have adopted numerous farm practices aimed at efficient use of water and scarce fodder. There is a general tendency of the livestock farmers to resort to more heat tolerant animal breeds rather than the traditional ones. Most livestock farmers also now produce their own fodder such as lucerne or maize and stock them for use during the long dry seasons. In response to the long drought periods, farmers have adjusted the stocking intensity of their livestock by selling their animals at younger ages. An additional practice of the farmers is to change the timing, the duration and location of grazing.

Increased chemical application

With higher temperature and increased evapotranspiration, farmers have resorted to increased application of chemicals such as Erian to slow down evapotranspiration. They also apply more farm manure to maintain a high moisture content in the soil and retain soil fertility.

Increased use of irrigation

With water being the most important factor limiting agriculture in South Africa, irrigation appears to be the most appropriate adaptive strategy. Hence 65% of the respondents choose irrigation as an option to adjust to climatic changes. Farmers have, furthermore, shifted from flood irrigation to sprinkler irrigation for an efficient use of the limited water. Several farms have also drilled their own bore holes to make effective use of the underground water. There has also been an increased use of wetlands for agricultural production.

Shade and shelter

When it is hot, livestock farmers plant trees to provide natural shade for their livestock or as a wind or hail storm breaks. In South Africa, farmers generally plant pine trees such as *Acacia karroo* and *Celtis afrikaaner* for this purpose. In some instances, farmers use fishnets, grass and plastics as cover to protect their plants against the dry and hot weather, cold and frost. Heating provided by firewood and paraffin are used by livestock farmers to protect their animals against the cold.

Conservation practices

Farmers, in response to the increased occurrence of drought, have adopted various soil conservation practices in order to maintain or improve soil moisture and fertility. Principally to fight erosion, farmers have built protective areas around their farms by tilling or planting trees. Farmers have also increased their fallow periods ranging from one to two agricultural seasons (instead of continuous cropping), to allow the land to restore its nutrients. Another conservation technique farmers use to protect the soil against erosion, is to maintain crop residues of the previous harvest on the land. Again to preserve soil moisture, cool the soil surface and stabilize soil temperature, farmers use mulching (layer of muck peat, compost and plastics) to cover the land. To avoid excessive extraction of nutrients from the soil of their farms, farmers have also reduced the density of the crops or livestock on their land.

Other practices

To reduce the risk of loss of incomes due to greater losses in farm produce as a result of the increased variability in the climate, some have insured their farms (especially large-scale farmers) while others are increasing their involvement in non-farm activities (especially small-scale farmers). Most large-scale farmers have also opted to taking lesser risks by reducing their cropping areas to manageable sizes.

Conclusions and recommendations

The results presented here are preliminary outcomes and should be interpreted with caution. Further investigations are needed to support these initial findings and to serve as a basis for policy recommendations with respect to climate, water and agriculture in South Africa.

However, the estimated models provide very good insights into the sensitivity of farm revenues to climate variables in the country. They indicate that the Ricardian approach is a useful tool in helping to understand the effect of climate change on farm revenue and agricultural activities in the country. The analysis indicates that indeed, climate change, will negatively affect agricultural activities in the country with different parts of the country being affected differently.

This outcome of the estimation is supported, to a large extent, by the perception of farmers on climate change. Most farmers were of the view that they have observed increased temperature and indications of changes in precipitation, such as the reduced volume of the rainfall, shift in the timing of the rainfall and the shortened period of the rain, especially in the summer season. They also asserted that these changes have and are affecting their farming activities in the summer season. Given this perception, some farmers have adopted coping mechanisms which could be categorized into six main ways, depending on their type of farming, namely (i) adjustments in farming operations; (ii) increased chemical application; (iii) irrigation; (iv) provision of shelter and shade for crops; (v) soil conservation practices; and (iv) insurance policies and other sources of income to cover risks. However, the most common adaptation options across all types of farming activities in the country in response to higher temperatures and lower rainfall are: (i) adjustments in farming operations, specifically changes in the variety of crops and livestock breeds and (ii) increased irrigation. Some of these suggested adaptation options plus improved farming technologies were confirmed in the estimated crop net revenue models for the country. Given that 65% of the respondents choose irrigation as an option to adjust to climatic changes, there is the need to build more dams and increase the capacity of existing ones in the country. However, with increasing water scarcity there is also the need for increased research in new crop varieties and new animal breeds that are heat tolerant and less water stressed.

Policy makers may need to accept the fact that the impact of climate on agriculture, especially in the summer period, is real and farmers are doing their best to adapt to these changes. Policies may therefore need to be directed at clearly identifying and assessing the efficiency of these coping mechanisms and find ways of supporting them in order to limit the negative effect of climate change. Efforts have to be made towards the proper management of the scarce water resource, given that a higher proportion is already being used for agriculture and even more would be needed as the climate worsens.

The expected impact of the climate change is, however, not all that bleak. Winter periods are expected to bring some benefits. Again, if current practices persist, this advantage may not be realized. Policy makers may therefore need to identify ways of helping farmers to take advantage of these benefits through, for example, changes in crops and crop varieties as indicated in Figure 8.

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Appendix 1: Farm household sample in the 9 Provinces

Province	Number of districts	Number of Farmers	
		Large-scale	Small-scale
Eastern Cape	3	29	26
Free State	2	38	18
Gauteng	1	4	7
KwaZulu-Natal	4	20	75
Limpopo	1	7	20
Mpumalanga	2	20	26
North West	1	32	11
Northern Cape	1	34	6
Western Cape	2	37	6
Total	17	221	195

Appendix 2: Distribution and Typology of the farms households interviewed

No	Province	District	Farming systemNumber (%)			Major crops		Large-scale			Small-scale		
				Mixed farming	Livestock only			Number (%)			Number (%)	Average land size(ha)	
1		Aberdeen	2 (10)	7 (35)	11 (55)	none	Cattle, Goat, sheep	13 (65)	5144	17	7 (35)	12	7
2		Humansdorp	4 (36)	3 (28)	4 (36)	none	Cattle	10 (91)	241	12	1 (9)	1.5	30
3		Kirkwood	19 (79)	2 (8)	3 (13)	Citrus fruit	none	6	430	10	18	40	10
Province average			**25 (45)**	**12 (22)**	**18 (33)**	**Citrus fruit**	**cattle**	**29 (52)**	**2472**	**14**	**26 (48)**	**30**	**10**
4	**Free State**	Bethlehem	6 (21)	8 (27)	15 (52)	Maizewheat	Cattle meat, Pig, poultry	17 (59)	711	16	12 (41)	1	3
5		Kroonstad	7 (26)	12 (44)	8 (30)		Cattle meatSheep	21 (78)	870	7	6 (22)	8	8
Province average			**13 (23)**	**20 (36)**	**23 (41)**	**Wheatmaize**	**Cattle meat**	**38 (68)**	**798**	**11**	**18 (32)**	**3**	**5**
6	**Gauteng**	Bronskhorst-pruit	4 (36)	6 (54)	1 (10)		Cattle meat	4 (36)	50	5	7 (64)	34	14
7	Kwazulu Natal	Estcourt	5 (25)	15 (75)	0 (0)	Maizepotato	Cattle meat	2 (10)	1520	24.5	18 (90)	5	23
8		Hlabisa	10 (26)	28 (74)	0 (0)		Cattle meatchicken	0 (0)	-	-	38 (100)	4	15
9		Mount Currie	2 (18)	9 (82)	0 (0)		Cattle meat	7 (64)	1550	23	4 (36)	18	3.5
10		Port Shepstone	13 (50)	12 (46)	1 (4)		Cattle meat	11 (52)	640	15	15 (58)	3.5	12
Province average			**30 (31.5)**	**64 (67)**	**1 (10.5)**		**Cattle meat**	**20 (21)**	**1046.5**	**19**	**75 (79)**	**5**	**16**
11		Lydenburg	8 (38)	13 (62)	0 (0)		Cattle meat	7 (33)	1778	9	14 (67)	40	15
12		Middelburg	9 (36)	12 (48)	4 (16)		Cattle meat	13 (52)	1450	13	12 (48)	1	3
Province average			**17 (37)**	**25 (54)**	**4 (9)**		**Cattle meat**	**20 (43)**	**1565**	**11**	**26 (57)**	**22**	**9**
13	**Northern Cape**	Hopetown	3 (7.5)	6 (15)	31 (77.5)	Maizewheat	Cattlesheep	34 (85)	2688	16	6 (15)	19	4
14	**Limpopo (Northern Province)**	Soutpansberg	11 (41)	11 (41)	5 (18)	maize	Cattlechicken	7 (26)	115	9	20 (74)	9	9
15	**North West**	Vryburg	6 (14)	19 (44)	18 (42)	maize	Cattle meat, sheep, goat	32 (74)	1925	19	11 (26)	7	17
16	**Western Cape**	Caledon	3 (16)	8 (42)	8 (42)	Citrus fruitwheat	Cattle	17 (89)	500	4	2 (11)	32.5	20
17		Piketberg	10 (42)	11 (46)	3 (12)	Citrus fruitwheat	cattle	20 (83)	1150	18	4	3	4.5
Province average			**13 (30)**	**19 (44)**	**11 (26)**	**Citrus fruitwheat**	**cattle**	**37 (86)**	**851**	**20**	**6 (14)**	**13**	**9.5**
NATIONAL AVERAGE			**122 (29)**	**182 (44)**	**112 (27)**		**cattle**	**221 (53)**	**1537**	**15**	**195 (47)**	**12.5**	7

Agri SA concerns

N. Opperman

Director Natural Resources, AGRI SA, P.O. Box 1508, Pretoria 0001
Tel. 012 322 6980; Fax 012 320 0557; E-mail: nic@agriinfo.co.za

Introduction

Essential background provided under the United Nations Framework Convention on Climate Change (UNFCCC), indicates that the average temperature of the earth's surface has risen by 0.6° C by the late 1800s. It is expected to increase by another 1.4 to 5.8° C by the year 2100 – a rapid and profound change. Even if the minimum predicted increase takes place, it will be larger than any century-long trend in the last 10 000 years. The principal reason for the mounting thermometer is a century and a half of industrialization: the burning of ever-greater quantities of oil, fossil fuels and coal, the cutting of forests and the practice of certain farming methods.

The 1990s appear to have been the warmest decade of the last Millennium and 1998 the warmest year. The current warming trend is expected to cause extinctions. Numerous plant and animal species, already weakened by pollution and loss of habitat, are not expected to survive the next 100 years. Human beings, while not threatened in this way, are likely to face mounting difficulties. Recent severe storms, floods and droughts, for example, appear to show that computer models predicting more frequent extreme weather events are on target. The average sea level rose by 10 to 20 cm during the 20th century and an additional increase of 9 to 88 cm is expected by the year 2100.

How does a changing climate affect South Africa

According to the South African Weather Service:
Higher temperatures: will influence the rainfall, but it is still uncertain how the annual rainfall will change. It could increase in some parts of the country and decrease in other parts.
Water resources: South Africa's agricultural users are highly dependent on a reliable supply of water. A reduction in rainfall amount or variability, or an increase in evaporation (due to higher temperatures) would further strain the already limited amount of water resources. An increase in rainfall, or a reduction in plant water use (due to a higher atmospheric concentration of carbon dioxide) would ease the problem slightly.

Schulze (2006) highlighted research findings on the possible effects of climate change on irrigated agriculture. Some of the early climate detection studies allude to the following:

- First results indicate, from an agriculture perspective, that over many regions of South Africa changes in frost patterns, heat units and temperatures over critical thresholds can already be detected;
- The timing of higher rainfall patterns has changed over the past 50 years;
- Change in evaporation rates takes place (10-20%);
- Shifts in the distribution of run-off are projected to occur (scheduling to change);
- More irrigation will be required and planning will become more complicated;
- Variability from year to year may be experienced and may even double; and
- Base flow decreases of up to 50% could be expected (water quality issues).

Human and animal health: There are several important insect-carried diseases of humans and livestock, which are sensitive to the climate. A small increase in temperature would allow, for instance, malaria to spread into areas, which are currently malaria-free and would increase its severity in areas where it already occurs.
Maize and wheat: It is currently estimated that a 10% increase in rainfall coupled with an increase in carbon dioxide could lead to a 10-20% increase in wheat and maize production, while a 10% decrease in rainfall would be approximately balanced by the rising carbon dioxide content of the atmosphere. Slightly warmer temperatures can apparently lead to a small reduction in wheat yields, but would have little effect on maize [predictions are not certain].
Grazing livestock: Most of South Africa, especially the drier part, is used for grazing by cattle, sheep and wildlife. Higher carbon dioxide will lead to less protein in the grass, which will reduce any benefit resulting from increased plant growth. Less rainfall would lead to proportionately less animal production.
Forestry: The forestry industry could probably tolerate a small increase in temperature, but a decrease in rainfall would reduce the area, which can support plantations and the growth rate of the trees. A positive point is that rising

carbon dioxide could help reduce water use by plantations.

The coastal zone: If the warming of ocean water were to continue unabated, the polar icecaps will melt and the sea level will rise. This is anticipated in the next century. The possible consequences to South Africa of a small sea level rise are not very extensive because the coastline is relatively steep.

Fisheries: Changes in the oceans have important implications for South Africa. In the recent past, variation in ocean currents has caused major changes in several fish resources important to the country. Future variations, which may be linked to climate change, could have a similar effect.

Biodiversity: Plants, in particular, have trouble keeping up with rapid climate change. Small, isolated populations could go extinct as a result. South Africa houses about 10% of all the plant species in the world, of which about half occur nowhere else on earth. Warming, and a change in the seasonal rainfall of the Cape floral kingdom, are issues of concern to conservationists and Agri SA.

What can we do to slow the process down?

Greenhouse effect

The enhanced greenhouse effects can be slowed down by following two guidelines, namely (1) Increase sinks and (2) decrease sources of greenhouse gases. A *sink* is a process, which removes greenhouse gases from the atmosphere. For example: growing a tree where one did not previously exist provides a sink for carbon dioxide, because the tree extracts carbon dioxide for photosynthesis. A *source* is a place or activity from which greenhouse gases are emitted. This can be a process such as coal burning or a location such as cultivated fields.

Renewable Energies

Agriculture is well positioned to at least partly fulfill in the needs of renewable energies, i.e. the production of commodities for biodiesel by extending the production of oilseeds and soya beans, and at the same time reducing the risks of pollution associated with fossil fuels. Sugar and maize production is most suitable for ethanol production. Wind farm projects are also looked at and a promising project by Eskom in the Western Cape has been launched.

The Kyoto Protocol

The Kyoto Protocol is a legal instrument that is separate from, but related to the Climate Change Convention, which can be used to mitigate the effects of climate change. South Africa acceded to the Protocol in July 2002. Countries ratifying the Protocol have mainly the following obligations:

- Developed countries are obliged to ensure that their greenhouse gas emissions do not exceed the amounts assigned to them.
- Climate change policies must be implemented.
- Energy efficiency must be enhanced.
- Emissions in the waste and transport sectors must be limited and/or reduced.
- Sinks for greenhouse gases must be protected.
- Market instruments that are counter-productive to the aims of the Protocol should be phased out.
- Sustainable forms of agriculture, i.e. no tillage practices and relevant research must be promoted.
- The Protocol includes an arrangement for reductions in greenhouse gas emissions with the so-called *Clean Development Mechanism*. In simplified form it works this way: Industrialized countries pay for projects that cut or avoid emissions in poorer countries – and are awarded credits that can be applied to meeting their own emission targets. All these activities must be undertaken in such a way that potentially adverse effects on developing countries are minimized.

Key findings of the agriculture sector

The possible effects of climate change should clearly be evaluated against the following brief agriculture economic perspectives:

Agriculture's contribution to the GDP over the past 5 years was between 3 and 4 percent. Despite its relatively small share in the GDP, agriculture is an important sector in the South African economy. It remains an important provider of employment (940 820 paid workers employed by the formal agricultural sector in 2002) especially in rural areas and an important earner of foreign exchange. Agriculture's strong indirect role in the economy is a function of backward and forward linkages to other sectors. According to the results of the Census of Agriculture, there were 45 818 active commercial farming units in SA in 2002.

The gross farm income from all agricultural products for 2004/2005 was estimated at R67,1 billion. Gross farm income from field crops, horticultural products and animal products amounted to R14,5 billion, R21 billion and R32,2 billion respectively. Net farm income was lower for the second consecutive year, dropping by 22% and amounting to R12,2 billion for the 12 months up to 30 June 2005. The value of capital assets in agriculture for the same period amounted to R140 billion and the total farming debt was estimated at R36 billion. The value of imports for 2004/05 came to R13,3 billion and the value of exports to R23,1 billion. Wine, citrus fruit, grapes, fresh apples, pears, quinces and sugar were the most important export products.

Conclusion

The perception is that climate change and its ramifications will adversely affect food production in South Africa where agricultural production depends almost entirely on the quality of the rainy season. Bearing in mind the significant contribution of agriculture towards national economies and the export market, in addition to food security, it is of paramount importance that the agricultural sector proactively addresses the vagaries of climate change.

The *take home message* is that there is a need to:

- Apply appropriate models and approaches;
- Evaluate and consider a real world situation;
- Develop appropriate adaptation strategies as a matter of urgency;

- View irrigation within the bigger picture of IWRM/ risk.

The Minister of Agriculture last year at the National Climate Change Consultative Conference said: *The extreme climate events also often adversely affect land use planning, level of agricultural yield, consistency in yield, cost of production, planting and harvesting, irrigation needs, transportation, storage, pests and diseases, marketing, farm management, food security and many other socio-economic indicators. Where greater responsibility is placed on farmers for environmental management, they must increasingly rely on climate/forecast information and climate predictions for operational and strategic decisions and planning affecting environmental, agronomic and economic sustainability. Agriculture planning and operations should take maximum advantage of the current climatic prediction methods, together with those, which are expected to emerge in the next century.*

Johan van den Berg, an agriculture weather expert, is of the opinion that climate changes definitely occur, but it is very difficult to quantify. The question is also – when is it climate change and when is it a normal climate pattern within the scope of 2, 5, 100 or 300 years. Therefore, it is unnecessary for farmers to loose their heads on the issue. Farmers should rather use their energy to focus on new technologies to produce more effectively.

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Climate change and NAFU's concerns

O.S. Mbangula

NAFU, Box348, Zastron 9950
Tel.: 083 763 0077; Fax: 051 673 1761

Introduction to NAFU

The National African Farmers' Union (NAFU) was established in 1991 as the agricultural wing of NAFCOC. NAFU's aim is to create a stronghold or home for thousands of black farmers who had previously been excluded from the mainstream of agriculture. NAFU strives to actively promote the interests of black farmers who are largely a disproportionately disadvantaged farming community. NAFU therefore represents the aspirations of those who have been disadvantaged, neglected or marginalized. The focus of NAFU has been on advocacy and it has, and continues to lobby for access to critical resources such as land, credit, information, extension and other support services.

NAFU plays a role in building the capacity and strength of its membership through the use of effective communication systems, training, improving management skills and exposing farming to the latest and most up-to-date production techniques. Training of member farmers is regarded as essential and the first 100 were trained earlier in 2006. NAFU, however, needs support to make a significant impact on its members by training them. Government support is suggested.

NAFU's commitment and vision is driven by the four Cs, namely commercialisation, commodities, contract farming and co-operatives. NAFU draws its members countrywide from a very broad base, which includes farmers, agribusinesses, farmers' organizations, corporations and individuals who support the objectives and goals and NAFU.

Climate change

Climate change, similar to drought, is a problem to everyone and a shared destiny. People may be able to temporarily mitigate or adapt to circumstances, but the truth is that climate change affects all of us. NAFU is committed to guiding its members through crises to ensure sustainable agricultural production, to mitigate climate change and above all, to facilitate timely adaptation.

Climate change is our own creation. The human being is responsible, for example, for the emission of greenhouse gases; we are the users of fossil fuels; we use and manage some of our natural resources irresponsibly. An in-exhaustive list can, indeed, be compiled. Regrets and pointing fingers cannot, however, reverse the situation and we are faced with the impact of climate change, which includes high temperatures; lower agricultural productivity; the drying up of natural water resources; lower average rainfall; and poverty and suffering.

Bearing in mind impacts, NAFU's concerns are deliberated by listing them.

NAFU's concerns

NAFU's concerns, measured against the needs of the black farmer, are the following:

- Unequal distribution of resources to mitigate and adapt to climatic conditions;
- The lack of properly tested and tried methodology aimed directly at farmers' needs and concerns;
- The lack of an integrated climate change approach. The proper linkage between research, policy and practice must be mapped out. What worked in another country does not necessarily mean it will work in South Africa;
- Lack of relevant information to capacitate the farmer;
- Lack of trained scientists prepared to share their knowledge with the ordinary farmer;
- Board room and conference discussions in abundance leading to significant discoveries without involving the ordinary farmer;
- Scientific knowledge is fast becoming a rare commodity for a selected few; and
- We need to move to local involvement – to a bottom-up approach.

Needs of the black farmer

- Capacity building to promote sustainable livelihoods within communities;
- Improved understanding of and the development of modern survival strategies to enable the mitigation of and adaptation to poverty and environmental changes;
- Transparent collaboration between the departments of Agriculture, and Science and Technology, at the lowest

level, on issues of climate change, and most important, the engagement of black farmers and communities;

- A multi-disciplinary institute to deal with climate change at a basic level. Such an institute should:
  - produce inputs generating various applicable scenarios and should record conclusions to benefit black farmers and communities;
  - change the mindset of most agricultural extension officers. Extensionists should be re-skilled to deal with the impact of climate and environmental changes;
  - undertake proactive research; and
  - should be selective and target the right farmers – those who want to be productive and contribute to the GDP.

NAFU would like see the Climate Change programmes/strategies and/or plans being turned into a programme of actions by government so that the farming community, particularly the second economy or emerging farmers, can benefit.

Poverty and unemployment are still a problem in the majority of the second economy farmers hence the majority of the farming community depends of farming for a living. It will be appreciated if the needs of farmers, particularly the black farmers, can be speedily and adequately addressed.

Conclusion

The wisdom of former State President Nelson Mandela summarises the message conveyed by NAFU: *We must be constrained by and yet, regardless of the accumulated effects of our historical burdens, seize the time to define ourselves; what we want to make of our shared destiny.*

Annex 1

DEPARTMENT OF AGRICULTURE:

DRAFT RECOMMENDATIONS FOR A PLAN OF ACTION ON CLIMATE CHANGE ACTIVITIES

The National Department of Agriculture, through its Directorate Agricultural Risk and Disaster Management, will:

1. Establish a Departmental Working Group on Climate Change, with clear terms of reference that would include regular meetings to discuss and address all matters related to climate change, identification of priority areas for attention and procuring of funding for appropriate research and awareness raising under all stakeholders. Active involvement in other fora addressing climate change would also be encouraged, with creation and maintenance of corporate memory, continuity and succession planning in place.
2. Continue to identify and analyse aspects of climate change that affect, or are affected by, agricultural activities.
3. Continue to be involved, and plan an active and strategic role, in activities relating to climate change, including the:
   - National Strategy on Climate Change, co-coordinated by DEAT
   - R & D Strategy on Climate Change, coordinated by DST
   - GCCC
   - NCCC
   - UNFCCC Process
4. Encourage co-operation between different role players through meetings, workshops, agreements, consortia and networking.
5. Promote risk management in agricultural and related activities that are influenced by both climate variability and climate change, through awareness creation, training, workshopping and advisories.
6. Encourage and promote awareness on the implications of climate variability and climate change on agricultural activities to all spheres of society, using the most appropriate media.
7. Identify areas in which further research into climate change science, vulnerabilities, mitigation and adaptation are considered necessary and appropriate and source funding for these activities.
8. Develop criteria for climate change related projects that it is prepared to fund, that include addressing environmental and socio-economic issues, are cross-cutting, multi-institutional, build capacity and address real agricultural challenges.
9. Ensure that the process for project identification and proposal development is aligned to that developed by the Directorate Scientific Research and Development.

(These recommendations emanate from:
- The discussion document on “Climate Change and the Agricultural Sector in South Africa”
- The Agricultural Sector Workshop on Climate Change, held in Pretoria in February 2006).

Addendum

Research areas of importance related to climate change and agriculture (not exhaustive)

- Vulnerabilities: Comprehensive audit on vulnerabilities that would identify adaptation priorities
- Contribution of agriculture to GHG generation – improved estimates and measurements
- Understanding thresholds of crops (and varieties) related to max/min temperatures, frost dates, rainfall and soils
- Carbon dynamics and conservation agriculture
- Scenario planning on climate using modeling techniques
- Renewable energy/biofuel
  Sustainability for energy vs. food security
- New, alternative and appropriate technologies to reduce GHG production
- Socio-economic aspects of different scenarios
- Awareness raising, capacity building and technology transfer