



Center for  
International  
Climate and  
Environmental  
Research - Oslo

**Report 1996:8**

# **Climate Change in Africa - Issues and Challenges in Agriculture and Water for Sustainable Development**

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*November 1996*



University of Oslo

ISSN: 0804-4562

# **CLIMATE CHANGE IN AFRICA - ISSUES AND CHALLENGES IN AGRICULTURE AND WATER FOR SUSTAINABLE DEVELOPMENT**

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**Foreword**

The objective of this report is to provide a framework for addressing climate change issues in the African Region, with particular emphasis on operational implications for the World Bank. The report explicitly addresses the issue of adapting to adverse climate change impacts and presents conceptual tools and methodologies relevant for adaptation to climate change. One set of general guidelines for climate change adaptation and two sets of sector-specific guidelines for agriculture and water resources in Africa are presented. The report examines in detail adaptation issues raised in the World Bank report *A Climate Strategy for Africa* (Helga Hernes, *et al.*, 1995).

The report consists of two parts. Part One, titled *Adaptation Guidelines*, presents one set of general guidelines for climate change adaptation and two sets of sector-specific guidelines for agriculture and water resources in Africa. The set of general guidelines for climate change adaptation is written by Lasse Ringius. The two sets of sector-specific guidelines are produced by Tom Downing.

Part Two, titled *Climate Change Adaptation - Options and Constraints in Africa*, consists of seven chapters. Chapter One discusses the concept of global overlays, introduces the concept of adaptation to climate change, and briefly discusses the role of the World Bank in the area of climate change adaptation. Chapter Two, titled *Global Climate Models and Simulations of Climate Change in Africa*, is written by Mike Hulme, the Climatic Research Unit at the University of East Anglia, England. The chapter deals with the global context of climate change in Africa, the modelling of climate and climate change, how climate change scenarios for Africa are constructed, and discusses links between the present and the future. Chapter 3 discusses the notion of adaptation and vulnerability to climate change and presents four types of adaptation policies. Chapter 4, titled *Adaptation Strategy Formulation: Analytical Tools and Steps*, presents methodologies for conducting adaptation analysis that have been developed by the Intergovernmental Panel on Climate Change and the U.S. Country Studies Program. Chapter 5, titled *Climate Change and Agriculture in Africa*, is written by Thomas Downing, the Environmental Change Unit, University of Oxford, England. It discusses the impact on climate change on agriculture in Africa. Chapter 6, titled *Climate Change and Water Supply in Africa*, is written by Dominic Waughray, the Hydrological Institute, England, together with Thomas Downing. The chapter discusses the impact of climate change on water resources in Africa. Chapter 7 contains an analysis of 23 World Bank documents and examines whether and how they pay attention to the issue of climate change. Chapter 7 was coordinated by Rolf Selrod. Chapter 1, 3, 4 and 7 are written by Lasse Ringius (CICERO), with inputs from Thomas Downing and Rolf Selrod.

A draft version of the report was examined in detail during a two-days working meeting in March 1996 in Oslo. It was subsequently presented to the World Bank in June 1996 and at the CICERO-workshop 'Climate Change and Vulnerability in Africa' in November 1996, in Oslo. At CICERO, Arne Dalfelt played an essential advising role throughout the whole process, both as an environmental expert on Africa and as a policy practitioner. The authors want also to thank Vilni Bloch and Elisabeth Meze for their research assistance. Asbjørn Torvanger, economist, and Terje Berntsen, meteorologist, both provided useful comments on the report.

The study was commissioned by the African Technical Division of the World Bank, Washington DC, and was sponsored by the Norwegian government.

## Executive Summary

Marking a significant turning point, the United Nations Intergovernmental Panel on Climate Change (IPCC) recently concluded, in its Second Assessment Report, that "the balance of evidence suggests a discernible human influence on global climate". Human activities, including burning of fossil fuels, land-use changes and agriculture, are increasing the atmospheric concentrations of greenhouse gases (GHGs) which, in turn, tend to warm the atmosphere. Many expect that human activities will cause atmospheric concentrations of GHGs to increase significantly in the twenty-first Century, resulting in some global climate change and adverse climate effects. Developing countries in particular will be vulnerable to climate change and it is important to begin the process of developing adequate adaptive response options in developing countries.

By integrating concern for climate change into its work, the World Bank could play an important role in helping countries reduce the impact of adverse effects of climate change. Three primary ways to integrate the concern for climate change adaptation have been proposed:

- integrating the issue of climate variability and longer term climate change into its analytical macro-economic and sector work<sup>1</sup>;
- modification, or retrofitting, of World Bank financed projects to increase resilience to climate variability and prepare for future climate change; and,
- integrating climate change into the environmental impact and risk assessment process.

This report is primarily focused on the issue of how the World Bank can modify its projects, especially in the agriculture and water resources sectors. The report explicitly addresses the issue of adapting to adverse impacts of global climate change and suggests conceptual tools and methodologies that might be useful for developing the World Bank's adaptive policies and response strategies. It proposes an adaptive policy framework and presents a menu of adaptive policy options. Prepared by a team of experienced analysts and policy advisors, the report focuses in particular on practical adaptation and adaptive policy responses to climate change effects in Africa.

Two overall adaptation strategies are suggested: (1) improvement of present resource management, and (2) reduction of vulnerability to climatic hazards. In addition, where large projects and development might increase vulnerability to climate change, specific, anticipatory adaptation may be warranted. By focussing on measures to increase country resilience to climate variability over the short term, the World Bank can help countries take advantage of the relatively narrow policy window over the next decade or so before the impact of climate change becomes significant. Three sets of guidelines for climate change mitigation together with good practice examples are presented.<sup>2</sup> One set of guidelines is concerned with climate change adaptation in general and two sector-specific guidelines are targeted towards African agriculture and water resources.

The second part of the report contains a comprehensive analysis and discussion of essential issues in regard to adapting to the effects of global climate change and designing adaptive policy responses. A review of twenty-four World Bank documents was also carried out. The

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<sup>1</sup> Some attention has been paid to the issue of mitigation of climate damages in K. King and M. Munasinghe (1992) 'Global Warming: Key Issues for the Bank'. Environment Department, Divisional Working Paper no. 1992-36. The World Bank.

<sup>2</sup> The term climate change mitigation global overlays good practice guidelines is used in the Terms of Reference for this report.

results presented in Annex I show that the Bank currently pays almost no attention to possible adverse climate change effects.

This report, which should be considered work in progress, can only be validated through the process of testing the tools and methodologies presented. Comments and suggestions for improvement are welcome.

## **Part One**

General guidelines for climate change adaptation briefly introduce the issue of global climate change, define policy objectives, list types of adaptation policies, draw implications for World Bank project preparation, and highlight legal aspects. The general guidelines outline four generic types of adaptive responses:

(I) Anticipatory adaptation. Included in this group of adaptation policies are: (1) modification of projects with long life spans; (2) projects that bring benefits and achieve their development goals irrespective of occurrence of climate change ('no regrets' options); (3) projects for which adaptation to climate change is inexpensive; (4) projects that increase protection against extreme events; and (5) projects which prevent irreversible impacts. Examples of appropriate anticipatory adaptation policies are given.

(II) Institutional and regulatory adaptation. Included in this group of adaptation policies are: (1) projects that aim to correct developments that otherwise would increase vulnerability to climate change in the future; and (2) projects that correct institutions in order to reduce vulnerability. Examples of appropriate institutional and regulatory adaptation policies are given.

(III) Research and education. Included in this group of adaptation policies are: (1) projects aimed at developing solutions when adaptive solutions currently are unavailable and time is needed for their development; and (2) projects that stimulate behavioral changes needed to accommodate to climate change. Examples of appropriate research and education policies are given.

(IV) Development assistance for capacity building. Included in this group of adaptation policies are: (1) projects enhancing the productivity of sectors, especially natural resource sectors; (2) projects that strengthen the overall institutional capacity of client countries; and (3) projects that reduce pollution levels and improve environmental quality. Examples of appropriate development assistance for capacity building are given.

Part I contains in addition two sector-specific guidelines for climate change adaptation. One set deals with adaptation in the agricultural sector and the second deals with adaptation in the water resources sector. Both sets of guidelines contain an introduction to the global climate change issue, summarize sector-specific impacts of climate change, define policy objectives, identify principal stakeholders in the development of adaptive responses, and list specific adaptive strategies.

## Part Two

The seven chapters of Part 2 provide a comprehensive discussion and analysis of some of the essential issues in regard to adapting to the effects of global climate change and developing adaptive policy responses.

**Chapter 1 - Climate Change Adaptation and Global Overlays** - introduces the World Bank's concept of global overlays, describes the notion of adaptation as it is presented in the United Nations Framework Convention on Climate Change, and summarizes the World Bank's current approach to and involvement in adaptation.

**Chapter 2 - Global Climate Models and Simulations of Climate Change in Africa** - reviews briefly what we know about future climate change as it will affect the world and Africa, including an assessment of the modeling tools that are available to explore such changes on both global and regional scales. The chapter describes the difference between climate predictions, forecasts, simulations and scenarios and illustrate for Africa some of the issues involved in constructing climate change scenarios. It is concluded that at least 1°C of global warming is likely to be experienced during the next century at a rate of 0.1° to 0.2°C per decade.

A representative scenario for Africa is described. This scenario assumes little direct policy intervention globally to restrict greenhouse gas emissions and assumes mid-range estimates of population and economic growth from the World Bank. In other words it follows IPCC scenario IS95a. The other assumptions that are made include mid-range settings for all model parameters and the use of the latest climate change experiment from the Hadley Centre to establish the patterns of climate change. The statements refer to the climate of the years around 2050 and the changes are expressed relative to the average climate of the period 1961-90. The scenario shows:

Atmospheric CO<sub>2</sub> concentration: about 500ppmv, a rise of about 50% compared to 1961-90 climate.

Sea-level: about a 25cm rise in global sea-level. There will be regional and local differences in this rise around the coast of Africa depending on ocean currents, atmospheric pressure and natural land movements, but 25cm gives a general figure.

Temperatures: the world will be about 1°C warmer than the 1961-90 average. Over Africa, land areas will have warmed by more than this amount, up to 1.6°C over the Sahara and semi-arid parts of southern Africa. The Equatorial countries of Cameroon, Uganda and Kenya, for example, will be about 1.4°C warmer. This represents a rate of warming to 2050 of about 0.2°C per decade. Sea surface temperatures in the open tropical oceans off Africa will have risen by less than the global average (i.e., about 0.6° to 0.8°C) and the coastal regions of the continent will therefore warm less than the interior, between 1°C and 1.2°C.

Precipitation: rainfall changes will be relatively modest compared to the large year to year variability of rainfall in most parts of Africa. In general, rainfall will increase over the continent, the exceptions most likely being southern Africa and parts of the Horn of Africa. Here, rainfall declines by about 10%. Parts of the Sahel see rainfall increases of up to 15% compared to the 1961-90 average. Equatorial Africa experiences a small - 5% - increase in rainfall. These rainfall results are not very robust in the sense that different climate models, or different simulations with the same model, may yield quite different patterns.

Other variables: the increased temperatures will likely lead to increased open water and soil/plant evaporation. Exactly how large this increased evaporative loss will be depends on factors such as physiological changes in plant biology, atmospheric circulation and land use patterns. As a rough estimate potential evaporation over Africa may increase by between 5% and 10%. Little can yet be said about changes in variability or extreme events in Africa.

Rainfall may well become more intense, but whether there will be more tropical cyclones or a changed frequency of El Niño events is largely in the realms of speculation.

Finally, it is argued that climate change is not an issue waiting to happen sometime during the twenty first century, or only when CO<sub>2</sub> concentrations double in the atmosphere, but that we are actually living here and now under conditions of climate change<sup>3</sup>, albeit poorly defined and contentiously argued over.

**Chapter 3 - Vulnerability and Adaptation** - defines the concept of adaptation and examines stakeholders in responding to climate change. It is argued that adaptation to adverse effects of climate change under some conditions is warranted and that developing countries will be particularly vulnerable to global climate change. Four generic types of adaptation responses to climate change are identified;

(1) *Anticipatory adaptation*. Included in this group of adaptation policies are:

- modification of projects with long life spans (e.g. dams, bridges, forests). The policy is to modify projects so that they can perform satisfactorily for the entire range of likely climate changes;
- projects that bring benefits and achieve their development goals irrespective of occurrence of climate change ('no regrets' options). The policy is to realize 'no regrets' options to the extent possible, e.g. improvement in the capability to adjust to existing climate variability;
- projects for which adaptation to climate change is inexpensive. Where inexpensive opportunities exist, projects should be modified so that they are able to perform satisfactorily for the entire range of likely climate changes, e.g. sewage systems may be modified inexpensively to prepare for future changes in ground water level;
- projects that increase protection against extreme events (e.g. floods, storms, drought). Projects should reduce the vulnerability to extreme events when it can be achieved with no or few additional costs, e.g. by increasing drought early warning and preparedness;
- projects which prevent irreversible impacts (e.g. preservation of biological diversity). Projects should help to preserve valuable biological resources, e.g. by protecting against sea-level rise threatening valuable coastal resources.

(2) *Institutional and regulatory adaptation*. Included in this group of adaptation policies are:

- projects that aim to correct developments that otherwise would increase vulnerability to climate change in the future (e.g. infrastructure, coastal-zone development, land use). By using regulatory measures, projects aim to reduce future social and economic vulnerability to climate change, for example, by removing economic incentives that stimulate population increase in coastal areas in Africa that are endangered by rising sea-level, or adopting land-use regulations;
- projects that correct institutions in order to reduce vulnerability (existing institutions may produce 'perverse effects'). Policy should correct economic institutions and alter markets, investment and subsidy structures when they increase vulnerability to climate change, e.g. removing economic subsidies that create an economic disincentive for shifting to drought-resistant crops (e.g. from maize to millet).

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<sup>3</sup> Climate change in this report is taken to mean a sustained change in climate due either to human or natural factors. Climate variability describes the normal (natural) fluctuation in weather conditions from year to year and which is unrelated to human factors. Climate change may, of course, lead to a change in climate variability.

(3) *Research and education.*

Included in this group of adaptation policies are:

- projects aimed at developing solutions when adaptive solutions currently are unavailable and time is needed for their development. When costs are modest, projects might, for example, contribute to the development of drought-resistant crops and cultivars and support policy research;
- projects that stimulate behavioral changes needed to accommodate to climate change. Projects might help to raise awareness of climate change and opportunities for adaptation, e.g. by supporting relevant activities of government agencies and NGOs in countries in Africa.

(4) *Development assistance for capacity building.*

Included in this group of adaptation policies are:

- projects enhancing the productivity of sectors, especially natural resource sectors. Projects should aim to increase the productivity of sectors because this will increase wealth, resources and options available for adaptation purposes in African countries;
- projects that strengthen the overall institutional capacity of countries in Africa. Projects should aim to strengthen the institutional capacity of African countries because this increases their capabilities to develop and implement adaptive responses to adverse climate change effects;
- projects that reduce pollution levels and improve environmental quality. By reducing non-climate environmental stresses, projects contribute to making natural and socio-economic systems more robust and less vulnerable to climate-related stresses.

The first two types of responses should be given priority attention. In conclusion, it is emphasized that adaptation responses should achieve net benefits that are greater than costs, increase flexibility, and increase robustness.

**Chapter 4 - Adaptation Strategy Formulation: Analytical Tools and Steps** - reviews concepts and methodologies that are relevant for analysis of adaptive responses to climate change. The chapter shows two prominent ways in which concepts and methodologies have been brought together with the explicit aim of developing concrete and justified adaptive measures to climate change. The chapter describes in some detail the proposal for analysis and development of adaptive policy strategies that have been made by the IPCC and the U.S. Country Studies Program.

**Chapter 5 - Climate Change and Agriculture in Africa** - is a case study of agriculture. It illustrates some of the impacts of climate change and evaluates suggested adaptation strategies in Africa, following the categories proposed in Chapter 3. The case study does not provide a detailed inventory of adaptive responses, or the best mix of strategies for all of Africa or for specific regions. Rather, by illustrating how adaptive responses can be evaluated, it provides examples of issues and methods to be considered during project preparation. The chapter begins with a review of the effect of climate change on agricultural environments. The case study then focuses on three scales of the agricultural sector: field/household production, national food balances and international trade. The three levels of concern are matched by identifying the stakeholders who would be involved in responding to climate change and coping with its consequences. Finally, adaptive responses for different types of stakeholder are reviewed.

It is concluded that it is essential to begin planning effective adaptive strategies for climate change. This is particularly true for large investments, such as dams and irrigation schemes. It is equally true for sustainable agricultural development. The extent to which Africa is able to

intensify production and enhance resiliency to existing resource, social and economic threats may well be the critical measure of its capacity to cope with climate change.

In the near term, however, agricultural adjustments specifically required to cope with climate change are few. What matters in the next half decade is building the research and institutional capacity to respond appropriately and effectively as climate forecasts improve.

One logical starting place is implementing regional climate monitoring and forecasting systems that meet the needs of farmers and resource planners. Planning responses to take advantage of improved information on short-term, seasonal and longer climate requires a concerted effort.

Over the medium term, the first effects of climate change may well be signaled by persistent drought, or possibly floods in some regions. Disaster preparedness is therefore critical. More specific and robust regional scenarios of climate change in Africa may be available in the next ten years or so, allowing some lead time for implementing specific strategies if required.

The research effort on climate systems should be matched by further research on the impact of climatic variations, vulnerability and coping strategies. For example, although numerous studies of drought hazard and vulnerability have been undertaken in Africa, there is not at present a regional or continental assessment supported by climatic, soil and crop data, vulnerability modeling, and response evaluations. Specifically regarding climate change, the cost of potential adaptation is wholly lacking. Integrated assessments, spanning agriculture, water, biodiversity and health, need to be compiled in such a way that they can link to ongoing global efforts, yet building up from present resource understanding and issues in Africa.

**Chapter 6 - Climate Change and Water Supply in Africa** - is a case study of water resources and illustrates some of the impacts of climate change and evaluates suggested adaptation strategies in Africa, following the categories proposed in Chapter 3. The chapter begins with a review of the effects of climate change on water resources. The case study then focuses on the principal stakeholders and adaptive interests in the water resources sector. Drawing upon the general guidelines of adaptation options, specific strategies for water resources are suggested. Finally, evaluation of adaptive responses is discussed. It is concluded that climate change will have various effects on water resources and water management in Africa. Unlike agriculture, runoff and groundwater recharge is less likely to benefit from CO<sub>2</sub> enrichment and increases in water use efficiency by plants. And, it is more difficult to ship water than food, especially if supplies are affected throughout a region at the same time. Potential scenarios of higher temperature, modest decreases in precipitation and prolonged droughts are a real cause for concern. While some regions may get wetter, water scarcity looms in the future with or without climate change.

Organizing effective national water strategies, in the context of both Agenda 21 and the Framework Convention on Climate Change, is of paramount importance. Water management with full cost recovery pricing, a balance between supply and demand management, concern for environmental impacts and quality, waste water treatment, and other adaptive options is costly and a long way from present resource management in most countries. The transition from the present to water systems that meet future demand and are prepared for climate change will require additional investment.

Implementing responses to climate change in the water sector takes a long time. Even developing trustworthy, practical national strategies can take five years. Transforming institutions and implementing new operating procedures can take a decade. Designing and building new reservoirs can take 25 years, especially if social and political issues are addressed.

Thus, African water managers will need to respond to climate change earlier than most other sectors. They will need to enhance flexibility and make choices about investment in the face of a range of climate scenarios. Integration in the management of water supplies and demand is essential – new supplies are not the automatic solution to climate change. Irrigation efficiency is key since most water is used in agriculture.

Developing drought contingency plans will mitigate the risk of a water crisis having severe social and economic impacts. For example, water users in the US have developed agreements regarding transfers of rights during a drought. Irrigated agriculture is bought out, at a fair price, and the water saved is used for domestic, municipal and industrial purposes. Particularly important is keeping power stations functioning and ensuring industry can operate efficiently. The loss in agriculture can be made up by food imports, although some income support may be necessary to support farm laborers.

Developments in seasonal and interannual (up to 5 years) climate forecasts are promising and offer the prospect of greater predictability of water supplies and demand. Water systems can then be managed to achieve targets over 2-5 years, rather than unconstrained releases in wet years followed by diminished supplies and a water crisis before the next wet year. Managers should begin now to plan how such forecasts could be incorporated into their operating procedures.

**Chapter 7 - The Attention Given to Global Climate Change in the World Bank** - contains a review and evaluation of twenty-four World Bank documents, including Country Environmental Strategy Papers (CESPs) and agricultural and infrastructure sector work from 1990 to 1995, to determine the attention given to climate change and their usefulness in developing climate adaptation policies. The reviewed documents are from country and sector studies in fifteen Sub-Saharan countries. On the basis of this review it is concluded that the Bank currently pays almost no attention to possible adverse climate change effects but that some of the reviewed documents might be useful in developing future adaptive policies. This finding is mirrored in a review of a number of National Environmental Action Plans (NEAPs), showing that climate change issues have not yet been integrated in the environmental strategies of many African countries.

# **PART ONE**

## **Adaptation Guidelines**

### **General Guidelines for Climate Change Adaptation**

**Annex A: Climate Change Adaptation: Agriculture**

**Annex B: Climate Change Adaptation: Water Supply**

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**Draft Operational Guidelines: Climate Change Adaptation**

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## Guidelines for Climate Change Adaptation

### Introduction

1. This directive describes general Bank<sup>1</sup> policy and procedures on climate change adaptation. Bank climate change adaptation guidelines for two specific sectors are described in Annexes A and B. General economic development increases the national capability for adaptation, but cannot be relied upon solely to protect client countries from adverse climate change impacts. In particular, natural resource sectors (e.g. agriculture, forestry, water resources, fisheries, and coastal infrastructure and habitats) are subjected to the risks of adverse climate change.

2. According to the United Nations Framework Convention on Climate Change (FCCC), ‘the Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects’ (Art. 3.4). The World Bank has developed the concept of ‘global overlays’ which is concerned with global environmental externalities and, more generally, global environmental dimensions of economic and social activities at national level. Global overlays address the question of how sectoral strategies need to be modified when global externalities are taken into account.

3. Climate change will have both adverse and beneficial impacts on natural and socio-economic sectors. The biological and economic productivity will decrease for some sectors, but increase for others. Natural resource sectors and biological diversity could in extreme cases be severely affected, reduced or depleted. In developing countries whose economies often to a large extent rely on climate-sensitive sectors, adverse climate change

impacts could inflict damage to the national economy, with significant social consequences. Cost-effective adaptation measures which are taken in advance of climate change may help avoid costly remedial measures at a later stage.

4. Economic and social adaptation to climate change should not be looked upon as an alternative to a directed response to mitigating emissions of greenhouse gases (primarily carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O)). Mitigation and adaptation measures should both be part of a comprehensive policy response to global and national climate change. Climate change mitigation global overlays consider the causes and effects of climate change, and are dealt with in two separate sets of guidelines. This set of global overlays guidelines for climate change deals with adaptation to the effects of climate change. Additional global overlays guidelines for climate change abatement deal with emissions of greenhouse gases and their reduction.

### Policy Objectives

5. Bank policy seeks primarily to mitigate adverse effects of climate change through a reduction of the vulnerability of economic, social and biological sectors. Bank policy seeks to increase the capabilities of individual sectors in client countries, and when possible, the overall capabilities of these countries, to adjust in a cost-effective manner to climate change.

6. The objective of the Bank’s climate change adaptation policy is to ensure that client countries benefit from measures to adapt to climate change. The benefits of adaptation to climate change are in some cases narrowly related to averting adverse climate change impacts.

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<sup>1</sup> ‘Bank’ includes IDA, and ‘loans’ includes credits.

Easily achievable measures which involve only modestly increasing costs should be implemented to increase resilience to possible future climate change impacts. So-called “no regrets” adaptation strategies provide benefits irrespective of the occurrence of adverse climate change effects. Examples include improvement in the capability of sectors to adjust to existing climate variability and to extreme events. It might also be relevant to assess inter-sectoral needs and opportunities for anticipatory adaptation measures.

7. Adaptations to climate change should be cost-effective. The avoided damages from climate change is the key benefit of adaptation. Bank projects should minimize the costs of damages from climate change, and should balance the climate damage costs and the costs of adaptation. Through comparison of the total damage costs and the total adaptation costs it is, in principle, possible to determine the appropriate and economically-justified level of adaptation. When there is insufficient or under-investment in adaptation, unnecessary damage costs are incurred, and when there is over-investment in adaptation, unnecessary adaptation costs are incurred.

8. Where possible, the flexibility and robustness of projects in climate sensitive sectors should be increased. Because of existing climate variability and the current uncertainties of climate change predictions, anticipatory adaptation options should as far as possible be able to perform satisfactorily for the entire range of likely changes of climate. Also, when possible, flexibility should be achieved by increasing the ability to adapt effectively to changes in climate. The opportunities for and constraints to flexibility and robustness should be assessed at the sectoral level, see Annexes.

### **Types of Adaptation**

9. Adaptation refers to adjustments to altered environmental conditions.

Adaptation could be a biological, technical, institutional, regulatory, behavioral or economic response. Many adaptation options for climate change may be available. Among those are adjustments in management practices in forestry and agriculture, establishing early warning systems for extreme events, creating migration corridors for migratory species (both flora and fauna), coastal zone protection, and others. Adaptation measures and policies may also include infrastructure, environmental planning, education and raising awareness, land use planning, water resources management, and urban development.

10. When preparing a project, the task manager should closely examine the four types of adaptation needs and corresponding policies listed below, namely anticipatory adaptation, institutional and regulatory adaptation, research and education, and development assistance for capacity building. These represent four generic types of adaptation needs and climate change adaptive policies - they are not listed according to priority, urgency or cost. However, adaptation cost will often be incurred early in the project life of anticipatory adaptation policies, whereas the adaptation cost will be incurred later in, or over the entire, project life for other types of policies. Some adaptive policies may fit more than one generic policy type. Sector-specific policies that correspond to the four generic types are listed in the attached sector guidelines.

#### **(1) Anticipatory adaptation.**

The priorities for anticipatory adaptation are:

- (a) modification of projects with long life spans (e.g. dams, bridges, forests). The Bank policy is to modify projects so that they can perform satisfactorily for the entire range of likely climate changes;
- (b) projects that bring benefits and achieve their development goals irrespective of occurrence of climate change (‘no

regrets' options). The Bank policy is to realize 'no regrets' options to the extent possible, e.g. improvement in the capability to adjust to existing climate variability;

- (c) projects for which adaptation to climate change is inexpensive. Where inexpensive opportunities exist, Bank projects should be modified so that they are able to perform satisfactorily for the entire range of likely climate changes, e.g. sewage systems may be modified inexpensively to prepare for future changes in ground water level;
- (d) projects that increase protection against extreme events (e.g. floods, storms, drought). Bank projects should reduce the vulnerability to extreme events when it can be achieved with no or few additional costs, e.g. by increasing drought early warning and preparedness;
- (e) projects which prevent irreversible impacts (e.g. preservation of biological diversity). Bank projects should help to preserve valuable biological resources, e.g. by protecting against sea-level rise threatening valuable coastal resources.

### *(2) Institutional and regulatory adaptation.*

The priorities for institutional and regulatory adaptation are:

- (a) projects that aim to correct developments that otherwise would increase vulnerability to climate change in the future (e.g. infrastructure, coastal-zone development, land use). By using regulatory measures, Bank projects aim to reduce future social and economic vulnerability to climate change, for example, by removing economic incentives that stimulate population increase in coastal areas endangered by rising sea-level, or adopting land-use regulations;
- (b) projects that correct institutions in order to reduce vulnerability (existing

institutions may produce 'perverse effects'). Bank policy should correct economic institutions and alter markets, investment and subsidy structures when they increase vulnerability to climate change, e.g. removing economic subsidies that create an economic disincentive for shifting to drought-resistant crops (e.g. from maize to millet).

### *(3) Research and education.*

The priorities for research and education are:

- (a) projects aimed at developing solutions when adaptive solutions currently are unavailable and time is needed for their development. When costs are modest, Bank projects might, for example, contribute to the development of drought-resistant crops and cultivars and support policy research;
- (b) projects that stimulate behavioral changes needed to accommodate to climate change. Bank projects might help to raise awareness of climate change and opportunities for adaptation, e.g. by supporting relevant activities of government agencies and NGOs in client countries.

### *(4) Development assistance for capacity building.*

The priorities for development assistance for capacity building are:

- (a) projects enhancing the productivity of sectors, especially natural resource sectors. Bank projects should aim to increase the productivity of sectors because this will increase wealth, resources and options available for adaptation purposes in client countries;
- (b) projects that strengthen the overall institutional capacity of client countries. Bank projects should aim to strengthen the institutional capacity of client countries because this increases their capabilities to develop and

- implement adaptive responses to adverse climate change effects;
- (c) projects that reduce pollution levels and improve environmental quality. By reducing non-climate environmental stresses, Bank projects contribute to making natural and socio-economic systems more robust and less vulnerable to climate-related stresses.

### **Project Preparation**

11. Opportunities for adaptation are often identified in NEAPs and other Bank documents. Climate change impacts are examined in Environmental Assessments and other Bank documents. Such documents should be used by project managers when assessing needs and opportunities for climate change adaptation. The Parties to the FCCC submit country communications which, in addition to GHG emission inventories and mitigation programs, contain vulnerability assessments and adaptation measures. These communications are important sources of information on impacts and adaptive requirements.

12. The needs and opportunities for adaptation to climate change should be recognized early in the project cycle and taken into account in project selection, siting, planning, and design. As it may be very costly and even impossible to modify a project in an adequate manner at a later stage, the needs and opportunities for climate change adaptation should be dealt with from the earliest stage of project preparation.

#### *Identification of adaptation needs:*

13. The needs for adaptation to climate change are best examined at the level of a specific sector. Bank staff should therefore consult the sector-specific guidelines attached as annexes.

14. The need for adaptation to climate change should be based on the most recent

information about the scale and potential adverse impact of climate change. The authoritative source of information on climate impacts is the United Nations Inter-governmental Panel on Climate Change (IPCC). In addition, a number of agencies – inside and outside the UN system – are involved in the scientific research of climate change and climate change impacts.

15. The benefits and costs of incorporating anticipatory adaptation measures into project designs should be assessed to the extent this is possible.

16. As part of the process of assessing climate change adaptation needs, it is necessary to identify relevant government agencies and scientific expertise, and their capability to carry out such assessments. The environmental assessment (EA) procedures in Bank lending operations may prove useful also for the assessment of climate change adaptation needs. Non-governmental organizations (NGOs) which may be useful sources of relevant knowledge and competence, could also contribute to such assessments. Moreover, NGOs may help to build indigenous capability for assessing needs for climate change adaptation.

#### *Review of adaptation options:*

17. Adaptation options should be closely examined and it is important to take several concerns into account. The task manager should attempt to identify the most effective and feasible adaptation options. Adaptation options that impose unfair burdens on some, or benefit some at the expense of others, should be avoided.

18. Inventories of adaptation strategies and options may be useful sources of information about concrete adaptation options. Information on adaptation options may be produced by the agencies – inside and outside the UN system – that are involved in scientific investigation and research of climate

change and climate change impacts. The IPCC may also be a useful source of information on adaptation options, and so may private and public research institutions, private sector actors, and NGOs. Relevant environmental agencies involved in the environmental assessment (EA) of Bank lending operations may prove useful also for the assessment of climate change adaptation opportunities.

19. The project task manager should explore the opportunities for adaptation policies at all possible levels. It is imperative to identify stakeholders who will or should be involved in key strategic decisions, and adaptive strategies should be tied to the stakeholders who will implement them. Due to the diversity of possible adaptive policies, adaptive policies could be pursued at the level of local communities, NGOs, specific sectors, governments, and regional and international organizations.

20. For adaptation purposes, some institutional arrangements may be more effective than others. By linking together or mixing adaptation options, it might be possible to increase effectiveness. Interlinkages and cross-sectoral effects of adaptation policies should be examined. It is essential that the total amount of resources available for adaptation purposes is used in such a manner that the optimal level of adaptation for a country, or a region is achieved. Overlap and duplication of adaptation options and strategies should be reduced and preferably avoided.

### Legal aspects

21. The objective of the United Nations Framework Convention on Climate Change (FCCC) is to protect the global climate system from negative anthropogenic interference caused by increasing accumulation of greenhouse gas concentrations in the atmosphere. The parties to the FCCC shall take precautionary measures to mitigate the adverse effects of climate change. Parties to the FCCC shall 'cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture, and for the protection and rehabilitation of areas, particularly in Africa, affected by drought and desertification, as well as floods' (Art. 4.1 (e))

22. In the future, agreements may be reached within the context of the FCCC, or other fora, that may be of consequence for the Bank's adaptation policy. The project task manager should therefore make sure that current relevant national and international policy developments regarding adaptation are taken into account in project planning and development. The World Bank has committed itself to an aggressive incorporation of environmental concerns into development strategies.

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**Annex A**  
**Climate Change Adaptation: Agriculture**

	Para. No.
Introduction.....	1-5
Policy Objectives.....	6-9
Stakeholders in the Agricultural Sector.....	10-14
Specific Adaptive Strategies.....	15-16
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## Annex A Climate Change Adaptation: Agriculture

### Introduction

1. Climate change will alter the present distribution of climatic resources in Africa and worldwide. Three effects are of primary importance in Africa: increased carbon dioxide concentrations, altered precipitation and soil moisture, and increased temperatures. CO<sub>2</sub> concentrations will increase, possibly to 450-550 ppmv by 2050, compared to about 350 at present. CO<sub>2</sub> enrichment in the atmosphere facilitates carbon uptake by plants, which promotes more rapid growth. It is also likely that CO<sub>2</sub> enrichment will reduce the rate at which plants transpire, resulting in an increase in water use efficiency - that is, the amount of water required during the growing season to produce biomass and yield will decrease.

2. The positive effects of CO<sub>2</sub> enrichment depend on moisture availability. Increased temperatures increase the atmospheric demand for water, both evaporation from soils and open water and transpiration from plants. The extent to which precipitation offsets the increased evapotranspiration demand is highly uncertain in Africa. It is likely that some regions will suffer significant decreases in moisture availability, even when the direct effects of CO<sub>2</sub> enrichment are included. The risk of drought is likely to increase in such regions as well.

3. Temperature increases may have direct impacts in some regions. A reduction in frost hazard and longer growing seasons will benefit agriculture in colder regions and high elevations. However, these regions are small in Africa. Heat stress may limit agriculture in some semi-arid regions.

4. The effects of climate change on agricultural potential, without effective adaptation, can affect household production

and consumption, regional agricultural and economic development, and national and international markets.

5. The guidelines presented in this annex on agriculture focus on cropping systems, food production and food security. Specific recommendations for livestock and pastoral systems, fisheries, aquaculture and forestry are not included.

### Policy Objectives

6. Bank policy for the agricultural sector should have the overall aim of making the best use of climate as a resource for agriculture, by enhancing the capabilities of agriculturalists, agribusiness and organizations to respond to climatic variations and climate change. Specific objectives are to promote sustainable agricultural development in Africa, reduce vulnerability to and increase capacity to respond to climatic hazards, and adapt to new climatic resources.

7. The fundamental requirement in Africa is to promote sustainable agricultural development. Sustainable development is already identified as a priority and many initiatives have been launched or proposed.<sup>1</sup> Closing the gap between experimental yields and farm yields, overcoming constraints in markets and providing rural infrastructure (credit, inputs, transport, etc.) will enhance the capacity of the agricultural sector to contribute to local and national economic development. Stronger, robust agricultural economies are more likely to have the resources to address the specific impacts of climate change. Thus, the Bank should explicitly connect the prospect of climate change with further investment in agriculture in Africa.

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<sup>1</sup> Reference to Bank documents: Nexus, etc.

8. Perhaps the clearest objective at present is to prepare for climatic hazards by reducing vulnerability, developing monitoring capabilities, and enhancing the responsiveness of the agricultural sector to forecasts of production variations and food crises. As for general development assistance, such activities are already justified by the present state of vulnerability to climatic hazards in Africa. However, climate change is likely to alter the distribution of climatic hazards, most notably drought, floods, heat waves, and frost. Other hazards, such as windstorms and tropical cyclones, are locally important, although the effect of climate change is uncertain. Enhanced preparedness is thus a direct response to climate change as well as contributing to current development objectives.

9. Adaptive strategies should mitigate the effects of adverse climate change. The Bank also seeks to take advantage of likely improvements in climate in some regions, although this has a lower priority than mitigating the adverse impacts. While regional projections of climate change and its impacts are highly uncertain, some responses in the agricultural sector are justified at present, others will become feasible as information on climate change improves.

### **Stakeholders in the Agricultural Sector**

10. Planning for climate change in the agricultural sector must be cognizant of the many interests and decision-makers involved in shaping policy, implementing decisions and coping with the consequences of changes in resources and hazards. The principal stakeholders range from vulnerable consumers to international organizations charged with research and relief (Table 1). Stakeholders will suffer the consequences of climate change to varying degrees and have primary concern for different types of adaptations. This is likely to influence their involvement in

planning and implementing adaptive responses.

11. Consumers are the ultimate stakeholders in adapting to climate change. For particularly vulnerable groups (such as resource-poor farmers, landless laborers, urban poor, the destitute and displaced or refugee populations), the outcome of strategies to adapt to climate change and climatic hazards may alter their livelihoods. Failure to cope with adverse change could lead to significant deprivation, social disruption and population displacement.

12. Producers have varying interests in climate change. Subsistence farmers are less likely to have the resources to consider anticipatory action than large-scale commercial farmers. Commercial farmers are more likely to be linked to national markets and international agribusinesses.

13. One of the key stakeholders in enacting forward-looking strategies is agribusiness: from local market traders to international commodity and research organizations. However, commodity traders are not likely to be affected directly by the consequences of climate change, as long as production is viable and trade required somewhere in the world. Incentives may be required to induce agribusiness to adopt a longer planning horizon and to develop and implement adaptive responses.

14. The bulk of responsibility at present for designing, evaluating and implementing strategic responses (anticipatory actions, planning institutional change and research/education) are national governments, national and international research centers, and aid organizations (particularly bilateral and multilateral, although some international NGOs may take an interest in adaptation policies).

### **Specific Adaptive Strategies**

15. Drawing upon the general guidelines of adaptation options, specific

strategies for agriculture are recommended (Table 2).

**(1) Anticipatory adaptation**

(a) These strategies are appropriate when long-term investment is being considered, or where valued resources are at-risk from climate change or adaptation to climate change. Examples of long-term investment are major irrigation schemes, particularly in regions where water supplies are uncertain. Valued resources that might be irreversibly lost due to climate change include coastal areas subject to inundation or salt water intrusion.

(b) The most certain aspect of climate change is increased CO<sub>2</sub> concentrations. Efforts to enhance the positive CO<sub>2</sub> responses in new cultivars may be worth the investment in plant breeding and agricultural technology, irrespective of changes in moisture availability. This research and development program would be undertaken by national or international research centers.

(c) Inexpensive adaptation includes establishing strategic food reserves to buffer potential increases in the variation of local and national production. This is only suitable at the national or international level. Connections to local grain banks are required, but increasing local reserves because of climate change may not be warranted at present.

(d) Protection against present and future extreme events should be a priority. Drought early warning and preparedness is urgent, building upon the considerable improvements that are already underway in many regions of Africa. Making better use of climate predictions is a key aspect of this adaptive strategy.

(e) Protection against irreversible impacts or losses of valued resources may be warranted in some situations. Thus, if coastal erosion and sea level rise threaten

valuable coastal resources, protection measures may be cost-effective. For example, ground water pumping may be required to lower the water table if saline intrusion affects agriculture in low-lying areas. It is unlikely that such projects are a priority in the near future. However, protection measures should be considered in the design of new developments. The cost of such developments would only be undertaken by commercial enterprises, with national or international backing.

**(2) Institutional and regulatory adaptation**

(a) Large-scale changes in resource allocations may require interventions in institutions and regulations. This is warranted particularly when land use changes increase vulnerability to climate change or where institutions constrain adoption of effective responses to climate change.

(b) The most significant land use change that increases vulnerability to climate change is development in semi-arid regions where climate change may be adverse. Water resources for irrigation may not be reliable, and salinization of soils may reduce agricultural potential. Planning for such development should at least evaluate the effect of climatic variations on project performance. Establishing priorities for development based on future land capabilities may be premature for most regions. Flexibility in development priorities should be retained, and new information taken into account.

(c) Regulation of resource allocation and development is deficient in much of Africa. The ability of community groups to manage rapid resource changes may warrant further support. Market structures often support crops with a high level of risk and fail to support markets for drought-tolerant crops. Regulations constraining free trade may increase the volatility of local markets and food supplies in response to climatic variations.

**(3) *Research and education***

(a) Research is required to develop responses to climate change that are not presently available. An example noted above is development of cultivars that optimize responses to CO<sub>2</sub> enrichment. More generally, development and testing of new cultivars suitable for a range of likely climatic conditions is required. Such research capacities are best undertaken at the national level, with support from international centers and commercial enterprises.

(b) Education on environmental issues is warranted, although it is probably too soon to undertake specific campaigns designed to adapt to climate change. For example, urging consumers to change their dietary preference in preparation for drier climates is not warranted. However, a broad capacity to address environmental issues and communicate understanding to stakeholders is urgently needed. This is even more critical in linking greenhouse gas abatement with sustainable development issues.

**(4) *Development assistance for capacity building***

(a) The highest priority for Bank assistance is to support sustainable agricultural development in Africa. Most of the strategies proposed to adapt to climate change fall into this category. Two strategies are appropriate:

(1) Encourage better use of climate information and resources to intensify production and cope with climatic risks.

(2) Reduce vulnerability through sustainable agricultural development, drought mitigation and preparedness, and integration of agriculture in regional economies.

These are ongoing development objectives, but further assistance is warranted in light of the risk of changes in climatic hazards.

(16) The inventory of specific adaptive mechanisms is well-documented in agricultural sector reviews and economic plans. In general terms, they focus on soil and water management, choice of crop varieties and land use, crop husbandry, planting and harvesting and economic adjustments at the farm, regional, national and international levels.

**Conclusion**

(17) A modest level of investment in adaptation to climate change in Africa should achieve the objectives stated above. If continued support at national and international levels for agricultural development is forthcoming, climate change need not cause enormous disruptions to agricultural production, at least for the next few decades. The key strategy for managing the risk of climate change in the near term is better drought preparedness and reduction of community vulnerability to fluctuations in local food production and economic conditions. Knowledge of costs and benefits of specific adaptive responses is at yet rudimentary but will improve in the future and will be important in project design, planning and evaluation.

**Table 1.** Stakeholders and adaptive interests in the agricultural sector

Stakeholders	Conseq.	Adaptive Responses			
		Antic.	Inst.	Res. & Edn.	Devt
Vulnerable consumers	✓				+
Subsistence producers	✓				+
Commercial producers		+		+	✓
Market traders	+				✓
National and intl food processing and trading				+	✓
National and international research		?		✓	+
Govt ministries, esp. Agriculture, health and water		+	+	+	✓
Aid and community development organizations		+	?	+	✓

**Notes:**

Conseq. refers to bearing the consequences of climate change impacts, that is those stakeholders who are directly affected by altered agricultural production. The adaptive strategies corresponding to the guidelines: Antic. is Anticipatory Adaptation and strategies targeted for coping with climate change; Inst. is Institutional and Regulatory Adaptation to prevent increased vulnerability; Res. & Edn. is Research and Education to develop and implement new solutions; and Devt is Development Assistance for Capacity Building that implements current options for sustainable agricultural development and reducing vulnerability to climatic hazards.

The ratings indicate the type of response likely to be of interest to each stakeholder:

- ✓ indicates primary interest in adapting to climate change.
- +
- ?

**Table 2.** Agricultural strategies to adapt to climate change in Africa

Type of Adaptation	Examples of Agricultural Strategies
<i>Anticipatory adaptation</i>	Enhance CO <sub>2</sub> responses in new cultivars Establish strategic reserves Early warning and preparedness Irrigation development in coastal regions subject to saline intrusion
<i>Institutional and regulatory adaptation</i>	
Land use	Development in marginal environments, e.g., where salinization limits productivity and water may not be available to flush soils
Regulatory	Community and participatory resource management; market development for drought-resistant crops (e.g., millet in southern Africa)
<i>Research and education</i>	Enhance research capacity to develop new crops and agricultural technologies Targeted interventions to reduce vulnerability, e.g., nutritional improvements through concerted education and health services; Change dietary preference or dependence
<i>Development assistance for capacity building</i>	Manage moisture through conservation, irrigation, soil drainage, mulching, fallowing Manage soil through mulching, tillage, crop rotation, drainage Change cultivars, crops and rotations Change area cropped or location Convert to or from cropping or pasture Change specialization, i.e., from cropping to livestock Alter timing of planting and harvest, planting depth, density Plant several varieties, including nitrogen-fixing crops and grasses Apply fertilizer, herbicides and pesticides Integrated pest management Invest in agricultural technology and machinery Store surplus food, or invest profits in good years Diversify farm income Cope with food shortages through off-farm purchases, donations, reduced consumption

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**Annex B**  
**Climate Change Adaptation: Water Supply**

	Para. No.
Introduction.....	1-4
Policy Objectives.....	5-8
Stakeholders in the Agricultural Sector.....	9-13
Specific Adaptive Strategies.....	14-15
Conclusion.....	16

### Introduction

1. Climate change will alter the present distribution of hydrological resources in Africa. Much of Africa suffers from both limited renewable water resources and high population growth rates. The issues of water supply and demand management thus dominate the problems of water pollution or water quality for many African water resource managers. As well as inherent water scarcity, implementation capacity is a critical issue, exacerbated by the frequency of prolonged droughts.

2. Four effects of global warming are of primary importance in Africa: changes in river runoff, changes in groundwater recharge, decreases in water availability, and rises in sea level. These changes depend on the effects of increased carbon dioxide concentrations, altered precipitation and soil moisture, and increased temperatures. CO<sub>2</sub> concentrations will increase, possibly to 450-550 ppmv by 2050, compared to about 350 at present. CO<sub>2</sub> enrichment in the atmosphere is likely to reduce the rate at which plants transpire, resulting to an increase in water use efficiency, although the extent to which this enhances catchment water yields is uncertain.

3. Increased temperatures increase the atmospheric demand for water, both evaporation from soils and open water and transpiration from plants. The extent to which precipitation offsets the increased evapotranspiration demand is highly uncertain in Africa. It is likely that some regions will suffer significant decreases in moisture availability, even when the direct effects of CO<sub>2</sub> enrichment are included. The risk of drought is likely to increase in such regions as well.

4. The guidelines presented in this annex on water focus on maintaining water resources to meet irrigation, domestic, municipal and industrial demand. Specific

recommendations for water quality, recreation and flood management are not included.

### Policy Objectives

5. Bank policy for the water sector should have the overall aim of making the best use of hydrological resources for multiple uses. The capabilities of water systems and water resource managers to respond to increasing demand in water supply, climatic variations and climate change must be enhanced.

6. Specific objectives are to:

1. Promote sustainable water resource management in Africa;
2. Maintain flexibility in responding to variations in water supply and demand.

7. The fundamental requirement in Africa is to promote sustainable water resource management. Sustainable development is already identified as a priority by the World Bank, in National Environmental Action Plans and national commitments witnessed at the UN Conference on Environment and Development in 1992.<sup>1</sup> While major dams may not be justified, improved institutions to manage the supply and delivery of water and conserve water use are essential.

8. The capacity to manage variations in water supply and demand is the clearest present objective with respect to climate change. Preparing for climatic hazards requires reducing vulnerability, improving the efficiency of water use, developing monitoring capabilities and contingency plans, and utilizing climatic forecasts. Such activities are already justified by present vulnerability of water resources in

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<sup>1</sup> See: World Bank (1993) *Water Resources Management: A World Bank Policy Paper*. Washington: World Bank and World Bank (1994) *A Guide to Formulation of Water Resources Strategy*. World Bank Technical Paper Number 263. Washington: World Bank.

Africa. To the extent that climate change alters the distribution of drought and floods, enhanced preparedness is a direct response to climate change as well as contributing to current environment and development objectives.

### **Stakeholders in the Water Resource Sector**

9. Planning for climate change in the water resource sector must be cognizant of the many interests and decision-makers involved in shaping policy, implementing decisions and coping with the consequences of changes in resources and hazards. The principal stakeholders range from local end-users to national water ministries and nongovernmental organizations (Table 1). Stakeholders will suffer the consequences of climate change to varying degrees and have primary concern for different types of adaptations. This is likely to influence their involvement in planning and implementing adaptive responses.

10. Consumers are the ultimate stakeholders in adapting to climate change. For particularly vulnerable groups, the outcome of strategies to adapt to climate change and climatic hazards may alter their livelihoods. Failure to cope with adverse change could lead to significant deprivation, social disruption and population displacement.

11. Large water users – irrigation schemes, energy producers and industry -- can manage their water use provided adequate information on future supplies and prices. Significant changes in irrigation efficiency or industrial processes, however, take several years to design and implement.

12. Water suppliers – private developers and traders and government boards – may take a longer term perspective on development, research and education, depending on the size of the

enterprise. Local traders who deliver water from boreholes are unlikely to evaluate the risk of climate change to the same extent as a river basin authority.

13. The bulk of responsibility at present for designing, evaluating and implementing strategic responses (anticipatory actions, planning institutional change and research/education) are national governments, possibly assisted by international research centers and aid organizations. Since the majority of water supplies in Africa are provided through direct access and public institutions, the role of private water companies is relatively less important than a national strategy and response capability.

### **Specific Adaptive Strategies**

14. Drawing upon the general guidelines of adaptation options, specific strategies for agriculture are recommended (Table 2).

#### **(1) Anticipatory adaptation**

Water managers typically deal with 90-99% levels of reliability as useful performance indicators to select “optimal” design criteria. At the project design stage the uncertainty in climatic conditions over the life of the project should be incorporated into the performance evaluation. To the extent that climate change may increase this uncertainty, anticipatory adaptation should be considered. This is most likely for long-term investments (over 30 years), such as major reservoir developments, particularly in regions where water supplies are uncertain. In some cases, critical water resources are at-risk from climate change or from policies to adapt to climate change. Critical resources that might be irreversibly lost due to climate change include groundwater in areas subject to salt water intrusion.

Undertaking anticipatory adaptation requires a national water strategy. The

IPCC recommends that the principles for sustainable water use in Agenda 21 and laid out by the World Bank can serve as a useful guide for developing flexible long-term water resource management strategies for nations, river basin authorities and water utilities. Adoption of such strategies should accommodate the hydrological effects of global warming, at least for the next few decades. While national strategies are justified by present and future water shortages in Africa, the threat of adverse climate change makes preparedness planning imperative.

### *(2) Institutional and regulatory adaptation*

Large-scale changes in resource allocations may require interventions in institutions and regulations. This is warranted particularly when land use changes increase vulnerability to climate change or where institutions constrain adoption of effective responses to climate change.

Managing water demand may require adjusting the institutions that price water and promote conservation. Analyzing the opportunity costs of water can identify cross-sectoral differences in water availability. The implementation of water pricing or other demand management tools (property rights, tradable permits, quotas) can encourage consumers to adopt more efficient practices.

### *(3) Research and education*

Research is required to develop responses to climate change that are not presently available. Development of national water strategies requires support from research centers, encompassing the regional distribution of water and its variability to technologies for efficient end uses. Such research capacities are best undertaken at the national level, with support from international centers and commercial enterprises.

Implementation of demand management will require targeted education. Although anticipatory adaptation to climate change need not be stressed among water users, promoting greater flexibility in water resource management requires a partnership between consumers, producers and managers. A broad capacity to address environmental issues and communicate understanding to stakeholders is urgently needed. This is even more critical in linking greenhouse gas abatement with sustainable development issues.

### *(4) Development assistance for capacity building*

The highest priority for Bank assistance is to support sustainable water resource management in Africa. Two strategies are appropriate: (1) Adopt “no regrets” strategies that maintain flexible responses to climatic variations. These are measures whose benefits exceed their costs to society, excluding the benefits of climate change mitigation. They improve the capability of the water sector to adjust to present and future climatic variability while remaining cost-efficient;

(2) Encourage better use of climate information to support continual adjustment in African water systems. The adaptation process involves new investments to expand capacity, operation of existing systems for optimal use, maintenance and rehabilitation of existing systems and modification of water demand.

15. Performance criteria include robustness, reliability, resiliency and vulnerability can be used to evaluate specific adaptive mechanisms, ranging from new reservoir and well construction, improved operating rules, more efficient delivery systems, and more efficient end uses (such as drip irrigation). Such mechanisms are well-documented in water sector reviews and economic plans.

These are ongoing development objectives, but further assistance is warranted in light of the risk of changes in climatic hazards.

### **Conclusion**

16. A modest level of investment in adaptation to climate change in Africa should achieve the objectives stated above. If continued support at national and

international levels for sustainable water management is forthcoming, climate change need not cause enormous disruptions to water users, at least for the next few decades. The key strategy for managing the risk of climate change in the near term is development of national water strategies, including drought preparedness and institutional development.



**Table 2.** Significant water resource strategies to adapt to climate change in Africa

Type of Adaptation	Examples of Water Resource Strategies
<i>Anticipatory adaptation</i>	National water strategies Marginal increases in water capacity Monitoring, warning and drought preparedness
<i>Institutional and regulatory adaptation</i>	Develop water markets that encourage conservation Community and participatory water resource management
Land use	
Regulatory	
<i>Research and education</i>	Enhance research capacity to develop water efficient technologies
<i>Development assistance for capacity building</i>	End-user education regarding water conservation Flexible water management systems
	Optimal water system operational rules
	Rehabilitation of existing systems
	New capacity and delivery systems
	Interregional transfers
	Demand management

## **PART TWO**

### **Climate Change Adaptation - Options and Constraints in Africa**

**Chapter 1: Climate Change Adaptation and Global Overlays**

**Chapter 2: Global Climate Models and Simulations of Climate Change in Africa**

**Chapter 3: Vulnerability and Adaptation**

**Chapter 4: Adaptation Strategy Formulation: Analytical Tools and Steps**

**Chapter 5: Climate Change and Agriculture in Africa**

**Chapter 6: Climate Change and Water Supply in Africa**

**Chapter 7: The Attention Given to Global Climate Change in the World Bank**

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## CHAPTER 1. CLIMATE CHANGE ADAPTATION AND GLOBAL OVERLAYS

### Introduction

This report is concerned with adaptation and policy responses to global climate change effects in Africa. The report explicitly addresses the issue of adapting to adverse climate change impacts and presents conceptual tools and methodologies relevant for adaptation to climate change. The report proposes three sets of climate change mitigation global overlays good practice guidelines for adaptation; one set of general guidelines for global climate change adaptation, and two sets of sector-specific guidelines for agriculture and water resources.<sup>1</sup> As a parallel effort, the World Bank has commissioned ICF Kaiser to develop global overlays guidelines for abatement of greenhouse gases.<sup>2</sup>

To date, the World Bank has not been actively involved in designing, promoting, or financing adaptation measures in client countries. In the future the World Bank's role in the area of adaptation could change, however, and the World Bank could play an important role in assisting client countries in their preparations for adverse effects of climate change. As discussed below, the United Nations Framework Convention on Climate Change (FCCC) explicitly expresses concerns about adverse climate change impacts in developing countries, particularly in Africa, and the World Bank might play a role in assisting client countries and the international community in observing and implementing this global environmental framework convention. This would mean a new and potentially significant role for the World Bank in the context of climate change and in regards to the protection of the national and global environment more generally.

This chapter presents the concept of global overlays and discusses this concept in relation to the concepts of mitigation and abatement as these have been defined by the Intergovernmental Panel on Climate Change (IPCC). The treatment of adaptation in the FCCC is summarized, and the chapter briefly discusses the involvement so far of the World Bank in adaptation to global climate change.

### 1.1 The concept of global overlays

The World Bank is presently in the process of developing and mainstreaming a new analytical tool called global overlays to 'integrate global environmental externalities into the World Bank's economic and sector work' (WB, 1995b: 1). Similar to a graphic overlay, which attaches a new layer to an already existing surface, the global overlays concept adds a global dimension to the sector studies that the World Bank regularly undertake. In addition to climate change, the concept of global overlays could be applicable with regard to other parts of the global environment such as the atmospheric ozone layer, international waters, biological diversity, and others.

The global overlays concept is concerned with global environmental externalities and, more generally, global environmental dimensions of economic and social activities at national

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<sup>1</sup> The term climate change mitigation 'global overlays' good practice guidelines is used in the Terms of Reference for this report.

<sup>2</sup> ICF Consulting Group, 'Guidelines for Climate Change Global Overlays'. ICF. Washington D.C, 1996.

level. Global overlays address the question of how sectoral strategies need to be modified when global externalities are taken into account. Because externalities in the climate change context are often understood to mean greenhouse gas (GHG) emissions (primarily carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O)), the costs of policies and measures that could reduce GHG emissions have so far received most of the analytical attention of the World Bank (Rosebrock, 1995). In the initial stage of the development of global overlays methodologies and conceptual tools, the emphasis has been on concern for GHG emissions reductions. The analytical attention has primarily been focused on the energy sector and, with respect to removing CO<sub>2</sub> emissions out of the Earth's atmosphere, on carbon sequestration in the forestry sector. However, as this report shows, in regards to adaptation to adverse climate change effects, it is relevant to examine a number of sectors in addition to energy and forestry.

The concept of global overlays reflects the World Bank's intention to integrate global concerns with national development strategies. The importance of global overlays is acknowledged in the United Nations Framework Convention on Climate Change (FCCC) which declares that its signatories should 'take climate change considerations into account, to the extent feasible, in their relevant social, economic, and environmental policies and actions' (Art. 4 (f)). An extension of the World Bank sector work is already called for by recent changes in its operational policy. The Bank's operational policy OP 10.04 of September 1994 notes that global externalities are 'normally identified in the Bank's sector work or in its environmental assessment process'. OP 10.04 requires that 'a project's global externalities [...] are considered in the economic analysis when (a) payments related to the project are made under an international agreement, or (b) projects or project components are financed by the Global Environment Facility. Otherwise, global externalities are fully assessed (to the extent tools are available) as part of the environment assessment process and taken into account in project design and selection'. Consequently, Bank sector work ideally should specify the global environmental implications of proposed sectoral development plans.

The World Bank's conceptualization of global overlays shows, however, that the concept could be applied in a different and broader meaning than GHG abatement policies and measures in the climate change context. Thus, in a recent World Bank Environment Department discussion note the concept of global overlays is understood as 'the dimension of economic and sector work that addresses global externalities and their mitigation through national policies and programs' (Vidaeus, 1995: 1). Although the discussion note is concerned with GHG emission reductions and GHG abatement, mitigation (and therefore the concept of global overlays) could also be understood to mean reduction of the *effects* of climate change, presumably through adaptation measures and policies reducing vulnerabilities of natural and managed sectors to adverse climate change impacts. It also seems possible to interpret the concept in this way as the discussion note explains further that 'the 'global overlay' initiative has as its overriding objective the internalization of global externalities into national environmental planning and the Bank's sector work, operations and dialogue with government and partners' (Vidaeus, 1995: 3). Mitigation would therefore refer to both internalization of the causes of global environmental externalities and to internalization of the effects of global environmental externalities.

As already pointed out, this report is explicitly concerned with adaptation and responses to climate change effects. While any comprehensive approach to climate change management will comprise both abatement components and adaptation components, as discussed in chapter 3, this report is not concerned with mitigation of GHG emissions or abatement.<sup>3</sup> This

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<sup>3</sup> Many abatement measures could also be part of an adaptation strategy, and *vice versa*. For a discussion of this issue in the context of Africa, see Hernes, Helga *et al.* (1995) *A Climate Strategy for*

report's use of the terms mitigation and adaptation is in accordance with the usage of the Intergovernmental Panel on Climate Change (IPCC) which suggests the following conceptual distinction:

*'Mitigation* or *'limitation* attempts to deal with the causes of climate change. It achieves this through actions that prevent or retard the increase of atmospheric greenhouse gas (GHG) concentrations, by limiting current and future emissions from sources of GHGs and enhancing potential sinks for GHGs...*Adaptation* is concerned with responses to both the adverse and positive effects of climate change. (Carter, T.R. *et al.*, 1994: ix).

To prevent misunderstandings, the World Bank could and perhaps ought to refrain from using the terms mitigation and abatement interchangeably; the term abatement should be used only when referring specifically to reduction of atmospheric gases causing global warming. Unfortunately, see Article 3.3 cited below, some of the confusion might stem from the FCCC itself which uses the term mitigation both in reference to limitation of GHG emissions, and in reference to limitation of adverse effects of climate change.

## 1.2 FCCC and Adaptation

The objective of the FCCC is to protect the global climate system from negative anthropogenic interference caused by increasing accumulation of GHG concentrations in the atmosphere. The FCCC is primarily concerned with GHG abatement and the stabilization of GHG emissions, but it nonetheless explicitly addresses the issue of adaptation to effects of climate change. Pursuant to Article 3.3 of the FCCC:

*'The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects...[P]olicies and measures should take into account different socio-economic contexts, be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors'*. (italics added)

Following Article 4.1 (b), all parties to the FCCC commit themselves to:

*'Formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing... measures to facilitate adequate adaptation to climate change'*.

And, more specifically, following Article 4.1 (e), all parties to the FCCC shall:

*'Cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture, and for the protection and rehabilitation of areas, particularly in Africa, affected by drought and desertification, as well as floods'*.

Pursuant to Article 4.4, moreover, the industrialized countries have a special obligation to assist developing countries that are particularly vulnerable to adverse climate effects:

‘The developed country Parties and other developed Parties included in Annex II shall also assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting the costs of adaptation to those adverse effects’.<sup>4</sup>

The first Conference of the Parties (COP-1), which took place in Berlin, in March-April 1995, endorsed a decision (Decision 10/3) made by the Intergovernmental Negotiating Committee (INC) with regard to stages in the adaptation process. According to this decision, adaptation will be structured as a three-stage process:

Stage I, which is a planning stage, includes studies of possible impacts of climate change in order to identify ‘particularly vulnerable countries or regions’ and ‘policy options for adaptation, and appropriate capacity building’;

In the medium and long-term, the following stages are envisaged for the particularly vulnerable countries or regions that are identified in Stage I:

Stage II, which focuses on preparation, includes ‘measures, including further capacity building, which may be taken to prepare for adaptation, as envisaged by Article 4.1 (e)’.

Stage III, which is the implementation phase, includes ‘measures to facilitate adequate adaptation, including insurance, and other adaptation measures as envisaged by Article 4.1 (b) and 4.4’.

### **1.3 The World Bank and adaptation assistance**

Prior to the COP-1 there were indications of various sorts that the World Bank in the future could be expected to perform important roles in the area of adaptation. As one World Bank Environment Department Paper observed, it appeared then that Parties to the FCCC ‘expect the bilaterals and multilaterals (especially the MDBs) to provide interim support by integrating climate change considerations into coastal zone management, and by incorporating climate change risk considerations into the agriculture and infrastructure investment planning of vulnerable client countries. Thus there is an expectation of a linkage between climate change vulnerability and risk analysis, adaptation planning, capacity building, and prudent investment’ (WB, 1995a: Annex I, 4).

The COP-1 agreed to fund the agreed full costs of Stage I measures in developing countries if undertaken in the context of formulating their national communications. Measures for Stages II and III are not yet eligible for funding. However, INC decision 10/3 states that ‘if it is decided...that it has become necessary to implement the measures envisaged in Stages II and III, the Annex II Parties [i.e. the developed countries] will provide funding... in accordance with their commitments contained in Articles 4.3. and 4.4 of the Convention’ (Fankhauser, 1995b:3).

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<sup>4</sup> The countries included in Annex II are: Australia, Austria, Belgium, Canada, Denmark, the European Economic Community, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom of Great Britain and Northern Ireland, and the United States of America.

**Figure 1: Climate Impacts in China: Results from a GEF sponsored project**

*China: Issues and Options in Greenhouse Gas Emissions Control* is a recent three-year comprehensive country study funded by the Global Environment Fund. The study's primary focus is on China's GHG emissions, but it nonetheless concludes that China probably would suffer from adverse impacts of climate change. Assuming a doubling of CO<sub>2</sub>, and using historical climate change data for different parts of China, four principal impacts from climate change are predicted: i) a general warming trend that would extend China's tropical and northern growing regions, ii) lower crop yields due to reduced availability of water caused by increased evaporation, iii) a greater threat to soil erosion, and iv) increased flooding of coastal areas and low-lying plains due to sea-level rise and more frequent and severe storms. The most affected economic sector, in both positive and negative ways, would be agriculture. Chinese researchers predict a decline in productivity for wheat, rice, and cotton, among others, and more scarce water would lead to a decline in the number of animals that could be supported on the same area of grassland. Despite some positive effects due to increases in temperature and rainfall, an overall decline in fisheries production is also predicted. Regarding terrestrial ecosystems, it would be most likely that wetlands, forests, and deserts would be negatively affected by a doubling of CO<sub>2</sub>. The study stresses that climate change impacts are likely to be more severe for China, because of its dependence on climate-sensitive sectors such as agriculture and the scarce resources available for adaptation, but it does not assess climate change damage costs, nor does it recommend a policy for China's adaptation to climate change. *China: Issues and Options in Greenhouse Gas Emissions Control* was conducted under a technical assistance project of the United Nations Development Program, executed by the World Bank and implemented by the Chinese Government.

Source: Todd M. Johnson et al. *China: Issues and Options in Greenhouse Gas Emissions Control*. World Bank Discussion Paper no. 330. The World Bank: Washington DC, 1996.

The World Bank Environment Department paper that was prepared for the first Conference of the Parties to the FCCC sets out the role of the World Bank with regard to the FCCC. It is suggested that the World Bank primarily will have a role to perform in the context of GHG emissions reduction and GHG mitigation. Nonetheless, the issue of adaptation to adverse effects of climate change receives some attention. Thus, in addition to helping in achieving GHG emissions reductions, 'the Bank also considers within its investment operations cost-effective mitigation measures that would greatly reduce the country's vulnerability to climate change, particularly in the infrastructure and agricultural sectors'. Furthermore, among the strategic elements of the Bank Group's assistance for mitigating climate change, it is suggested that the bank Group should 'support clients who are Parties in integrating climate change considerations (including both greenhouse abatement and climate change adaptation) into development policy and planning' (WB, 1995a: 5-6).

To date, the World Bank has been actively involved in two studies examining climate change impacts and adaptation issues, namely the study *China: Issues and Options in Greenhouse Gas Emissions Control* (Figure 1), which as one component includes an examination of climate change impacts in China. The second study, which is still in the initial phase, is *Caribbean: Planning for Adaptation to Global Climate Change* (Figure 2). It focuses on the Caribbean Community (CARICOM) countries which are parties to the FCCC, i.e. Antigua and Barbuda, Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, St. Kitts and Nevis, St. Lucia, and Trinidad and Tobago.

**Figure 2: Caribbean: Planning for Adaptation to Global Climate Change**

Initiated in 1995, *Planning for Adaptation to Global Climate Change* is a four-year project for the Caribbean funded by the Global Environment Facility. With the World Bank as the implementing agency, and the Organization of American States (OAS) as the executive agency, the project will support Caribbean Community (CARICOM) countries which are parties to the FCCC, i.e. Antigua and Barbuda, Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, St. Kitts and Nevis, St. Lucia, and Trinidad and Tobago. The project's overall aim is to support these countries in preparing to cope with the adverse effects of global climate change, especially sea-level rise, in coastal and marine areas. The project is designed to increase national and regional planning resources and skills for adaptation. This will include support to a broad range of enabling activities, including establishment of regional data systems to measure climate change effects, and national and regional vulnerability assessments. Caribbean countries are extremely vulnerable to the effects of sea-level rise caused by global warming; according to IPCC estimations, the costs of coping with a one-meter sea-level rise in the Caribbean could be more than US\$ 11 billion. Moreover, recent experiences with hurricanes have lead to concern over an increased frequency and severity of tropical storms as a consequence of global climate change.

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Source: 'Caribbean: Planning for Adaptation to Global Climate Change'. Brochure, July 1995.

The World Bank might in the future pay systematic attention to the issue of adaptation to climate change. There are already indications of this. For example, one recent strategy paper for the water sector in Africa, *African Water Resources: Challenges and Opportunities for Sustainable Development* (1996), in addition to the issue of climate variability, discusses the climate change issue in a generic sense and details some of the possible climate change impacts on water resources in East Africa.

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## CHAPTER 2. GLOBAL CLIMATE MODELS AND SIMULATIONS OF CLIMATE CHNAGE IN AFRICA

### Introduction

With hindsight, the prevailing twentieth century view of climate will be seen to have been one in which climate was regarded as a boundary condition, effectively stationary on time-scales relating to human decision-making and varying in any significant way only on geological time-scales. Only over the last quarter of the century - from the 1970s onwards - has this view been challenged, first by a few pioneering scientists, followed by the main body of climate scientists and, by the time of our present decade, by an increasing proportion of decision-makers. The prospect of significant global climate change induced by changing atmospheric composition - the enhanced greenhouse effect or so-called 'global warming' - has acted as the main agent in changing this view of climate. Within Africa, the prolonged sequence of dry years in the Sahel, commencing in the late 1960s and continuing into the 1990s, has acted as an equally effective agent in changing the conventional twentieth century view of climate. The view prevailing at the end of our century is one in which, i) climate can no longer be regarded as a stationary boundary condition; ii) climate is subject to change on a variety of time-scales many of which are very important for human decision-making and planning, and iii) humans themselves seem increasingly to be the cause of many of these changes in climate. New developments in weather and seasonal time-scale climate forecasting have provided an even greater impetus for organisations, charged with investment decisions and with future planning strategies, to include climate in their decision-making structures as a key variable rather than as a fixed boundary state.

This chapter reviews briefly what we know about future climate change as it will affect the world and Africa (section 2.1), including an assessment of the modelling tools that are available to explore such changes on both global and regional scales (section 2.2). We will describe the difference between climate predictions, forecasts, simulations and scenarios and illustrate for Africa some of the issues involved in constructing climate change scenarios (section 2.3). An entry-level scenario for Africa is described. Finally, we will argue that climate change is not an issue waiting to happen sometime during the twenty-first century, or only when CO<sub>2</sub> concentrations double in the atmosphere, but that we are actually living here and now under conditions of climate change<sup>1</sup>, albeit poorly defined and contentiously argued over (section 2.4).

### 2.1 The Global Context of Climate Change in Africa

#### *Is global climate changing?*

There is little doubt that on average the surface of the world is warmer than it was a hundred years ago. The global temperature record established from thousands of observing sites around the world and extending back to 1856 clearly indicates a warming trend of the order 0.5°C over this 140-year period. The trend has not been continuous over time and the warming has been concentrated in two periods: between about 1910 and 1940 and again since the 1970s. The reality of this surface warming has been robustly defended by the Inter-

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<sup>1</sup> Climate change in this chapter is taken to mean a sustained change in climate due either to human or natural factors. Climate variability describes the normal (natural) fluctuation in weather conditions from year to year and which is unrelated to human factors. Climate change may, of course, lead to a change in climate variability.

governmental Panel on Climate Change (IPCC) in their 1990, 1992 and 1996 reports. These reports indicate that the uncertainty in the warming trend due to measurement error or bias amounts to about  $\pm 0.15^{\circ}\text{C}^2$ . This global warming has been reflected over Africa, with a continental average 20th century warming of about  $0.53^{\circ}\text{C}$  (Jones & Briffa, 1992). African warming also has not been continuous over time and shows some seasonal variation (Figure 2.1). The Sahel has warmed least and southern Africa the most.

### *Why is global climate changing?*

There are three broad categories of explanations for the changes in global climate which have been observed over the historic period: 'attributed' natural variability; 'unattributed' natural variability; and anthropogenic causes. These three categories of explanation are not, of course, exclusive and it is likely that all three have contributed to some extent to the observed warming.

'Attributed' natural variability includes factors such as volcanic eruptions, variations in solar activity and changes in the orbital parameters of the Earth. The first of these factors effects climate only on very short time-scales, typically from six months to five years (Robock & Mao, 1995), and the eruption of Mt. Pinatubo in June 1991 is a good example of such an effect. The second factor may influence climate on a variety of time-scales ranging from the 11-year sunspot cycle through to 80- or 400-year cycles in solar activity which have been proposed (Lean, 1991). The third factor is only relevant on very long time-scales - multi-millennial - and cannot really be invoked to explain observed changes over the last 140 years (Ledley, 1995). None of these attributed causes of natural variability appear capable of explaining all or even a substantial part of the observed warming trend of  $0.5^{\circ}\text{C}$  since the 1850s.

'Unattributed' natural variability supposes that natural changes in the interaction between the atmosphere, oceans and cryosphere lead to variations in global climate which might persist for decades or centuries. The causes of such changes are hard to specify, but may lie in natural resonances or oscillations in the coupled ocean-atmosphere system. The ENSO phenomenon is a type of unattributed natural variability, although one which operates on the sub-decadal time-scale and which is quite well understood. Results from experiments using different types of climate models suggest that this type of internal climate variability is unlikely to account for a century-long warming trend of more than about  $0.2^{\circ}$  to  $0.3^{\circ}\text{C}$ , i.e., about half the observed warming (Wigley & Raper, 1990).

If natural variability of whatever kind is insufficient to explain all of the observed global warming, then invoking anthropogenic causes is a convincing response to this attribution dilemma. This certainly has been the conclusion of the latest IPCC report (IPCC, 1996) which states that, '... *the balance of evidence suggests a discernible human influence on global climate.*' This represents a much more positive attribution of global warming to human causation than was possible in either the 1990 or 1992 IPCC reports and is a result of progress in identifying in the historic records the expected spatial signature of surface temperature change which would result from the combination of increases in greenhouse gas and sulphate aerosol concentrations in the atmosphere (Santer *et al.*, 1995). Whilst much

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<sup>2</sup> The satellite record of free tropospheric temperatures over the last 16 years, by contrast, shows little warming trend (Hansen *et al.*, 1995). The reasons for this difference are threefold: i) the satellite microwave sounding unit (MSU) retrieves atmospheric temperatures from between about 2km and 8km above the Earth's surface - with the strongest contribution originating at about 4km; ii) this part of the atmosphere responds differently than does surface climate to confounding factors such as volcanic eruptions and El Niño/Southern Oscillation events (ENSOs; Jones, 1994); and iii) the period of satellite record from 1979 to 1995 has, as a whole, been warm compared to the earlier part of the century; this period also shows relatively little warming trend in the surface record.

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**Figure 2.1:** Time series of annual and seasonal temperature departures (degrees Celsius) from the 1951-80 average for continental Africa from 1897 to 1993. Data from P.D.Jones, pers. comm.

remains to be done in terms of refining this assessment, and in further disentangling natural from human-induced climate change, the scientific consensus clearly places the onus of proof on those who do *not* believe that human activities are contributing to climate change rather than on those who do.

### *How much will global climate change in the future?*

The answer to this question is largely dependent on the answer to the previous one. Ensuring consistency with the recent reports of the IPCC in 1995 and 1996 (IPCC, 1995; 1996), the range of possibilities for future global temperature change can be presented in the following way. There are four key factors underlying projections of future global warming: i) future greenhouse gas and sulphur dioxide emissions scenarios; ii) how those emissions translate into atmospheric gas and aerosol concentrations; iii) how sensitive the climate system is to such changes in atmospheric concentration (i.e., the 'climate sensitivity'<sup>3</sup>); and, iv) the role natural variability will play in the future climate.

We illustrate the importance of the first and third of these factors in Figure 2.2 using a simple climate model (MAGICC; Wigley & Raper, 1992; Hulme *et al.*, 1995) used by IPCC in their 1990, 1992 and 1996 reports. In the upper plot, three global warming projections are shown which reflect the range of emissions scenarios published by IPCC in 1992 (Leggett *et al.*, 1992) and updated in 1996 (Kattenburg *et al.*, 1996). These projections assume a 'best guess' value for the climate sensitivity (2.5°C) and include the cooling effects of sulphate aerosols<sup>4</sup>. The effect on future warming of different emissions scenarios is relatively small by 2050 (e.g. the warming range is only 0.2°C), but increases substantially during the later decades of next century so that the difference in warming between the highest and the lowest scenarios by 2100 is 1.1°C. Whichever emissions scenario is pursued therefore, or whatever emissions abatement measures are put into practise, at least 1°C of global warming is likely to be experienced during the next century at a rate of between 0.1° and 0.2°C per decade. This highlights the importance of paying careful attention to adaptation options, alongside efforts to reduce greenhouse gas emissions.

The lower plot shows the effect of different values of the climate sensitivity on warming projections. These curves all assume the IS95a emissions scenario, but adopt values for the climate sensitivity of 1.5° (low), 2.5° (best guess) and 4.5°C (high). The divergence of these warming curves in the early decades is greater than the divergence due to the range of emissions scenarios, but by 2100 the range due to these two uncertainties is broadly similar.

The other two key factors dictating the rate of future warming mentioned above are the conversion of gas emissions into concentrations and the role of natural variability. The uncertainty over how gas emissions will convert to atmospheric concentrations revolves largely around the so-called 'missing carbon' problem and the modelling of the global carbon cycle. This uncertainty is due in part to the lack of knowledge about the strength of various carbon sinks (e.g. oceans, boreal forests, tropical grasslands), which in turn is partly due to uncertainty about the effects of carbon and nitrogen fertilisation on ecosystems. There is about a ±10% uncertainty in the conversion of CO<sub>2</sub> emissions into CO<sub>2</sub> concentrations (IPCC, 1995).

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<sup>3</sup> The 'climate sensitivity' is defined as the eventual warming of the average surface temperature of the Earth following a doubling of atmospheric CO<sub>2</sub> concentration. It's value is commonly believed to lie between 1.5° and 4.5°C.

<sup>4</sup> Sulphate aerosols, generated from emissions of sulphur dioxide, act as cooling agents in the atmosphere. They may act directly (by scattering incoming solar radiation) or indirectly (by increasing cloud reflectivities) to lower surface air temperature. Unlike greenhouse gases, aerosols are quickly washed out of the atmosphere by precipitation, thus their cooling influence will be greatest in the regions where the sulphur dioxide is emitted, i.e., the heavily industrialised regions.

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**Figure 2.2:** Global-mean temperature anomalies (with respect to the 1961-90 average) for 1856 to 1995 (observed; histogram) and from 1976 to 2100 (modelled; dashed lines) for three different emissions scenarios and a climate sensitivity of 2.5°C (top panel) and for one emissions scenario (IS95a) and three different values of the climate sensitivity (bottom panel). Sulphate aerosol effects *are* included. Model results from MAGICC (July 1995 version).

In the above illustration of future temperature change (Figure 2.2), no allowance is made for natural variability due to any cause - volcanoes, solar variations or internal ocean-atmosphere variability. These factors will undoubtedly influence global climate over the next 100 years, although in ways impossible to quantify at present. There will, therefore, be substantial variation around the warming curves shown in Figure 2.2, both from year-to-year and from decade-to-decade (this type of variation is illustrated in the observed curve shown in Figure 2.2). Nevertheless, warming due to increased greenhouse gas concentrations - partly offset by aerosol cooling - seems likely to dominate the global climate of the 21st century (IPCC, 1996).

### *Is this global climate change important?*

The above summary of the climate change question has focused on a range of projections of global temperature. Whilst global temperature is a useful and convenient indicator of the behaviour of the climate system, by itself it tells us little about how societies and ecosystems will actually experience climate change. Whether or not the proposed magnitudes of warming are important depends on a number of other factors which fall into two broad categories: i) the regional and temporal nature of the climate change; and ii) the ability of different socio-economic and environmental systems to withstand, adapt to or exploit the change in climate.

Global warming will have a wide diversity of regional manifestations. Some regions will warm more rapidly than others, some regions will experience increases in rainfall and others decreases, and sea-level increases will not be uniform around the world, but will reflect local and regional geological and atmospheric conditions. Global warming by itself also tells us nothing about the likely changes in the frequencies of extreme events, such as tropical cyclones, drought sequences, or intense rainfall events. Many, if not most, climate change impacts will arise through changes in the frequency and magnitude of such extreme events. Finally, the above projections of global warming dismiss the possibility of extreme or catastrophic changes in the climate system which may result once certain biogeophysical thresholds are breached; they assume a fairly gradual and linear change in global climate. For example, the possibility that changes in ocean circulation or large bio-climatic feedbacks may be triggered by climate change cannot be dismissed (e.g. Manabe & Stouffer, 1995). How likely such 'surprises' are is difficult to say, but any assessment of climate change and its importance for a particular region cannot ignore such outcomes.

The other set of factors which will determine how important climate change is for society and environment, revolve around the adaptability of these systems to change. Both in the managed and natural environment there is a huge diversity of such adaptive capacity. A change in climate, however, alters a key boundary condition and at a rate and potentially to a magnitude not before experienced by cultured *homo sapiens*, i.e., since the end of the last glaciation 14,000 years ago. That this change will occur at a time of rapid population growth is clearly a cause for concern. The concurrent increase in the rate of technological change may either help or inhibit human adaptation. Some of the issues surrounding the notion of a 'dangerous climate change' - as defined in the UN Framework Convention on Climate Change - are explored by Parry *et al.* (1996).

## **2.2 The Modelling of Climate and Climate Change**

Investment in the further development of climate models seems the most promising route for increasing understanding about the operation of the climate system and about its sensitivity to various forcing factors, including human pollution. There are a range of climate models which have been used in modelling global climate change and one categorisation of these models is described below.

### *One-dimensional Climate Models*

Such models are typically referred to as upwelling-diffusion energy balance models and describe the basic operations of the coupled ocean-atmosphere system through a small number of simple equations. They are one-dimensional models in that there is no specific representation of latitude or longitude (although there are usually land and ocean and Northern and Southern hemisphere boxes). The output from such models is typically a global-mean temperature and sea-level value. These models are easy to run on a desktop computer, are generally transportable between machines and can be used for multiple sensitivity experiments. The results shown in section 2.1 derive from one such model.

### *Global Climate Models (GCMs)<sup>5</sup>*

GCMs represent the most sophisticated attempt to simulate climate on a global-scale. These are fully three-dimensional representations of the Earth's atmosphere (and increasingly the oceans too), but are CPU-intensive and are generally not readily transportable. GCMs are continually being updated in terms of their parameterisation schemes. No GCMs are operated in Africa. GCMs are in many ways similar to numerical weather forecast models, but they are used to simulate the climate system over years and decades rather than days and weeks. The history of global climate change experiments using GCMs can be condensed as follows.

1st generation experiments. First generation GCMs characterised climate modelling until about 1990 and form the basis for the discussion about climate modelling in IPCC (1990). These models contain a three-dimensional atmospheric component, but only a 'slab' (or single layer) ocean. Because the dynamics of the ocean system are not modelled, climate change experiments using these GCMs can only reproduce equilibrium climates, typically a climate representative of 'now' and a climate representing some future condition - usually an atmosphere in which CO<sub>2</sub> concentrations have been doubled. Because these modelled climates represent a hypothetical steady-state system, results from such experiments cannot be interpreted in calendar years. They are, strictly speaking, sensitivity experiments. Many (indeed most) climate change impact studies have used results from these first generation experiments. For example the US Country Studies Programme, funded by USAID and operating in several dozen countries worldwide, use results from three such experiments.

2nd generation experiments. Second generation GCMs include a dynamic ocean model attached to the three-dimensional atmosphere. This model configuration allows transient climate change experiments to be performed and a number of such experiments were completed in the early 1990s and are reported in IPCC (1992; 1996). A typical experimental design for these models would enable, say, 100 years of current climate to be simulated at which point greenhouse gas (GHG) concentrations would start incrementing yearly at a pre-defined rate, say 1% per annum, for a further 100 years. Although year-by-year changes in climate are simulated, it is still difficult to interpret the results in calendar year terms because of the 'cold-start' problem<sup>6</sup>. Because of this problem such experiments should strictly be termed quasi-simulation experiments. A few impact studies have now used results from second generation experiments.

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<sup>5</sup> GCM has traditionally been an acronym for General Circulation Model. This nomenclature dates back to the origins of climate models as numerical weather prediction models which contained a representation of the atmosphere alone. As climate models have developed to include oceans, the cryosphere and biosphere, it seems less defensible to describe them as models of the general circulation of the atmosphere. The term 'global climate model' (GCM) is therefore preferred here.

<sup>6</sup> The 'cold-start' refers to the fact that in these experiments increases in GHG concentrations start increasing from a time representing 'now', whereas in the real climate system GHG concentrations have been rising for several decades and have already introduced an element of warming into the system. In cold-start experiments there is an unrealistic delay of a decade or two after GHG concentrations start to increase before the model climate begins to warm.

3rd generation experiments. Over the last two years a small number of transient experiments have been completed using coupled ocean-atmosphere GCMs, but with a different experimental design to second generation experiments. The two main changes are, i) the inclusion of the effects on climate of sulphate aerosols in addition to GHGs, and ii) the simulation of climate over the recent historic period with real historic forcing (so-called 'warm start' experiments), in addition to a simulation of 21st century climate using emissions scenarios. These two changes enable results to be interpreted more realistically in calendar year terms and have also enabled GCMs to achieve a more realistic simulation of global temperature over the last 100 years than has before been possible. Results from one such experiment performed by the UK Hadley Centre are shown in Figure 2.3. These experiments have been reported in IPCC (1996) and some results are now appearing in the scientific literature (e.g. Mitchell *et al.*, 1995), although no impact studies have yet used these results. These experiments can justifiably be called simulation experiments.

#### *Regional climate models (RCMs)*

An increasing number of climate modelling centres have now established a regional climate modelling capacity. Regional models have quite similar physical representations of atmospheric processes as GCMs, but operate at a much finer spatial resolution - typically 50kms - over limited domains. These regional models still need to be driven at their boundaries by the results from the coarser scale GCMs, but within their high resolution domain RCMs generate a more detailed representation of surface climate. Some climate change experiments using RCMs nested within GCM results have been completed for North America, Europe and Australia (e.g. Jones *et al.*, 1995), and over the next year or so similar experiments may be completed over other regions in the developing world (e.g. India, southern Africa, south-east Asia; Hadley Centre communication, February 1996).

#### *Prospects for future model development*

There are a number of directions in which climate model development will be pursued over the next few years. There is still much fundamental work to be done in improving basic model physics, especially in the representation of cloud dynamics and ocean heat transport. The next generation of GCM experiments may for the first time discriminate explicitly between different greenhouse gases (until now, CO<sub>2</sub> has been used as a surrogate for all GHGs), with explicit models of atmospheric chemistry possibly being included. This would allow climate-ozone feedbacks to be represented in the experiment. A further major development will be the inclusion of dynamic vegetation models in the GCM, allowing climate-vegetation feedbacks to be represented (until now, land cover and surface properties remain static for the duration of the experiment). Higher resolution GCMs and RCMs may also be established in the future, although how quickly this can sensibly be achieved depends on developments in computing technology and resources.

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**Figure 2.3:** Global-mean annual temperature anomalies (with respect to the 1961-90 average) from 1856 to 1995 (observed; bold histogram) and from 1860 to 2100 (modelled; faint histograms). Model results derive from the HADCM2 GCM climate change experiment reported in Mitchell *et al.*, 1995; the continuous histogram includes the effects of *both* greenhouse gases and sulphate aerosols, while the dotted histogram includes *only* the effects of greenhouse gases. HADCM2 uses observed forcing changes until 1990 and the IS92a forcing scenario after 1990. Data from J.Murphy, pers. comm.

### 2.3 Constructing Climate Change Scenarios for Africa

Before commencing on a discussion of climate change scenarios and Africa, it is important to be clear about the terms being used (see Annex 2.1). Although climate change scenarios have on occasions been defined using historical analogues (e.g. warm periods in the past as analogues for warming in the future) or constructed using fairly arbitrary assumptions about the magnitude of future climate change, the discussion here is limited to scenarios constructed using some form of process model.

Direct results from Global Climate Models or Regional Climate Models are not particularly appropriate for the purposes of scenario construction or for the assessment of climate change impacts. This is so for a number of reasons. As mentioned above, GCM results cannot usually be associated with specific calendar years; linking GCM results with output from simpler models may be necessary to achieve this. GCM results refer to only one emissions scenario. In many impacts assessments a range of emissions scenarios may need to be considered. The spatial resolution of the GCM results is very coarse for regional applications. Typically, the current generation of GCMs operate on a scale of only 300-400kms, thus climatic features on scales smaller than this are not reproduced by the model. Regional Climate Models - operating a scales between 25-100kms - provide one means of generating such local detail, although so far no climate change experiments have been performed for the African region using RCMs.

For these reasons, a number of different approaches to model-based scenario construction have been employed in recent years, in which results from GCMs are used in conjunction with results from simpler models and/or with observational data. Some of the main techniques are summarised below. Although all aspects of climate change are uncertain to some degree, some aspects are more uncertain than others. Table 2.1 lists a number of the more important variables in a hierarchy of increasing uncertainty. Thus, for example, we can be very sure about future increases in atmospheric CO<sub>2</sub> concentrations, and relatively confident about the range of projections of global-mean temperature and sea level, but very uncertain about regional patterns of precipitation and soil moisture and largely ignorant about changes in the frequencies of extreme events.

Variable	Category
CO <sub>2</sub> concentration	Certain
Global-mean temperature	Confident
Global-mean sea level	Confident
Patterns of regional temperature	Likely
Patterns of regional rainfall and other variables	Possible
Soil moisture	Possible
Interannual variability	Largely unknown
Extreme events	Largely unknown

**Table 2.1:** Categorisation of uncertainty surrounding future changes in a selection of climate-related variables.

#### *Linking Model Results*

Since a GCM experiment provides only one realisation of future climate forced by only one emissions scenario, it is sometimes helpful to couple GCM results with global warming projections from a one-dimensional model. In this case the *pattern* of climate change is derived from the GCM, but this pattern is then scaled by the *magnitude* of global warming derived from the one-dimensional model. Thus Figures 2.4 and 2.5 show four patterns of

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**Figure 2.4:** Change in mean annual temperature (degrees Celsius) over Africa associated with 1°C of global warming from four climate change experiments performed with successive versions of the UK Met. Office/Hadley Centre GCM: UKLO (1st generation, 1987), UKHI (1st generation, 1989), UKTR (2nd generation, 1992) and HADCM2 (3rd generation, 1995). All patterns show greenhouse gas only forcing.

**Figure 2.5:** Percent change in mean annual rainfall over Africa associated with 1°C of global warming from four climate change experiments performed with successive versions of the UK Met. Office/Hadley Centre GCM: UKLO (1st generation, 1987), UKHI (1st generation, 1989), UKTR (2nd generation, 1992) and HADCM2 (3rd generation, 1995). All patterns show greenhouse gas only forcing.

change in, respectively, annual temperature and rainfall over Africa derived from four different climate change experiments performed by the UK Met. Office/Hadley Centre over a period of nearly ten years. In each case, the model is forced by changes in greenhouse gases alone. These patterns of change represent results from first, second and third generation GCM experiments, each pattern having been standardised by the global warming of the respective experiment. These temperature and rainfall changes are therefore each associated with 1°C of global warming enabling a direct comparison of patterns to be made.

Climate sensitivity	IS95a		IS95c		IS95e	
	Plus SO <sub>2</sub>	No SO <sub>2</sub>	Plus SO <sub>2</sub>	No SO <sub>2</sub>	Plus SO <sub>2</sub>	No SO <sub>2</sub>
Low	2069	2048	>2100	>2100	2066	2041
Mid	2049	2029	2058	2039	2048	2025
High	2033	2015	2035	2018	2033	2013

**Table 2.2:** Estimated date by which 1°C of global warming (with respect to the average of 1961-90) will have been reached as a function of emissions scenario and climate sensitivity. Results from MAGICC (July 1995 version). The two sets of results refer to whether or not the cooling effect of sulphate aerosols due to SO<sub>2</sub> emissions is included. The shaded cells show the ‘best’ estimate, with and without aerosol effects.

Using a one-dimensional climate model a range of calendar dates can be applied to the realisation of these patterns of change, the range of dates relating to different assumptions about greenhouse gas and aerosol precursor emissions scenarios and about the value of the climate sensitivity. We use one such climate model - MAGICC<sup>7</sup> - to present a typical range of dates associated with 1°C of global warming with respect to 1961-90 (Table 2.2) and with 30cm of global sea level rise (Table 2.3). Anticipated atmospheric CO<sub>2</sub> concentrations are shown in Table 2.4. A ‘best guess’ choice of parameters and emissions scenario would see a 1°C global warming occur by 2029, or delayed until 2049 if sulphate aerosol cooling is included. This is a rate of warming of between 0.15° and 0.2°C per decade. Already, 0.2°C of this global warming has been observed by the decade 1986-1995. The increase in CO<sub>2</sub> concentration from the average 1961-90 level (~ 334ppmv) associated with this 1°C warming would be 33% (to 444ppmv by 2029) without aerosol effects, or 50% (to 505ppmv by 2049) including aerosol effects. Already, by the decade 1986-95, an increase of 7% in CO<sub>2</sub> concentrations has been observed. A 30cm sea level rise would occur by 2033, or by 2069 with aerosol effects.

<sup>7</sup> MAGICC - Model for the Assessment of Greenhouse gas Induced Climate Change (Wigley & Raper, 1992; Hulme *et al.*, 1995) - was developed by Tom Wigley and Sarah Raper of the Climatic Research Unit, UEA, Norwich, UK and has been used in the successive IPCC assessments of 1990, 1992 and 1996.

Climate sensitivity	IS95a		IS95c		IS95e	
	Plus SO <sub>2</sub>	No SO <sub>2</sub>	Plus SO <sub>2</sub>	No SO <sub>2</sub>	Plus SO <sub>2</sub>	No SO <sub>2</sub>
Low	2088	2063	>2100	2078	2082	2058
Mid	2069	2044	2079	2050	2066	2041
High	2054	2030	2058	2032	2053	2028

**Table 2.3:** Estimated date by which 30cm of global sea level rise (with respect to the average of 1961-90) will have been reached as a function of emissions scenario and climate sensitivity. Results from MAGICC (July 1995 version). The two sets of results refer to whether or not the cooling effect of sulphate aerosols due to SO<sub>2</sub> emissions is included. The shaded cells show the 'best' estimate, with and without aerosol effects.

Climate sensitivity	IS95a		IS95c		IS95e	
	Plus SO <sub>2</sub>	No SO <sub>2</sub>	Plus SO <sub>2</sub>	No SO <sub>2</sub>	Plus SO <sub>2</sub>	No SO <sub>2</sub>
Low	572	502	>468	>468	654	517
Mid	505	444	452	432	551	450
High	456	405	427	398	482	408

**Table 2.4:** Estimated CO<sub>2</sub> concentration by the time 1°C warming is reached as a function of emissions scenario and climate sensitivity. Results from MAGICC (July 1995 version). The two sets of results refer to whether or not the cooling effect of sulphate aerosols due to SO<sub>2</sub> emissions is included. The shaded cells show the 'best' estimate, with and without aerosol effects.

### *Using Baseline Climatologies*

GCMs can only portray surface climate at coarse space-scales and even at these scales their representation of current climate is not always very good. Joubert (1995), for example, evaluated the control simulations of a sample of first generation GCM climate change experiments for southern Africa and found large differences in model performance. For these reasons, it is quite common for future climate scenarios to be constructed from a baseline climatology existing at a high resolution and based on observations (e.g. 0.5° latitude/longitude), with the coarse-scale climate change fields (e.g. those shown in Figures 2.4 and 2.5) from a GCM experiment superimposed on this baseline. This approach requires the appropriate baseline climatologies to exist, but does have the advantage that the more detailed structure of surface climate is derived from observations, while the GCMs are used only to define the *changes* in climate.

### *Downscaling and Weather Generators*

More sophisticated statistical techniques can be used to overcome the scale mis-match between GCMs and many applications of climate scenarios for impacts assessment. These fall into two main groups: i) downscaling techniques, and ii) stochastic weather generators. Downscaling techniques generally attempt to relate large-scale climate patterns with local or site specific climates and then use the coarse-scale output from the GCM experiments to infer local or site specific information on the basis of the previously established relationships. Stochastic weather generators (SWGs) are statistical models which can simulate daily weather sequences on the basis of a small set of parameters derived from observations. Once calibrated, SWGs can generate very long sequences of synthetic weather for a site or region and can be perturbed using results from GCM experiments to simulate weather sequences

under conditions of climate change. Both these two groups of techniques are very demanding of observational data for calibration purposes and although there are many examples of these techniques being employed in impacts assessments in developed countries, apart from South Africa they have not yet been used in Africa.

### *Using Multiple GCM Results*

As shown above in Figures 2.4 and 2.5 different GCM experiments can yield very different patterns of climate change at the continental scale. This is because different models operate at different resolutions, represent atmospheric processes in different ways and are subject to different forcing scenarios. As the number of climate models has grown and the number of reported experiments has increased, it becomes difficult to know how to present the results from such a plethora of experiments for impacts or policy purposes. There are various options.

The simplest option is to use results from just one GCM experiment, where this experiment may be chosen because it is somehow defined as the 'best' model or is the 'latest' experiment. Figure 2.6 shows temperature and rainfall changes over Africa, equivalent to those shown in Figure 2.4 and 2.5, defined in this way. These results are from the combined greenhouse gas and aerosol transient experiment performed by the Hadley Centre in 1995 (HADCM2; cf. Figure 2.3), an experiment that certainly qualifies as being the 'latest' and which might also be defined as using one of the 'best' models. While this approach keeps the scenario straightforward it avoids addressing inter-model uncertainties and it is not always easy to argue that any one GCM necessarily yields a more reliable result than any other.

A second option is to use a large number GCM experiments in an impacts assessment or policy evaluation, thus capturing a range of different results. This approach certainly has the advantage that one looks at a wide range of possible outcomes, but can be impractical if large numbers of GCM results are involved. Climate change experiments have been performed using GCMs in more than 20 modelling centres, thus the total population of first, second and third generation experiments is now quite substantial.

A third option is to reduce the sample of GCM results by some form of compositing technique. One such approach has been used by the Climatic Research Unit over a number of years for regional impacts assessments in Europe, Asia and Africa (e.g. Hulme, 1994; Rotmans *et al.*, 1994). Figure 2.7 presents some examples of changes in temperature and rainfall, again standardised to 1°C global warming, from the resulting scenario. The 'low' and the 'high' composite changes derive from treating results from 11 different GCM experiments (both first and second generation experiments) as a randomly drawn sample from a larger population and establishing the 90% confidence limits of this sample. In a simple way, therefore, one is attaching probabilities to these composite scenarios. This subsample of 11 experiments spans the range of results from the full sample of GCM climate change experiments which probably amounts to more than 30. This compositing approach stresses the uncertainty inherent in GCM results by quantifying the extremes of the 80% confidence band in the temperature and rainfall changes. This band spans changes in rainfall of up to  $\pm 15\%$  in some regions. The equivalent uncertainty band for temperature is less substantial.

**Figure 2.6:** Change in mean annual temperature (left; degrees Celsius) and rainfall (right; percent) over Africa associated with 1°C of global warming from the combined greenhouse gas and sulphate aerosol experiment using HADCM2 (see text for further explanation). Note: the patterns of change are quite different from the greenhouse gas only experiment using HADCM2 shown in Figures 2.4 and 2.5.

**Figure 2.7:** Change in degrees Celsius in mean annual temperature (top) and percent change in mean annual rainfall (bottom) over Africa associated with 1°C of global warming using the 'low' (left) and the 'high' (right) composite scenarios based on a sample of 11 GCM experiments (see text for further explanation).

### *Limitations*

A correct understanding of the term ‘scenario’ will make it quite clear that there are serious limitations to climate change scenarios as accurate ‘predictions’ of future climate. As stated above, scenarios are conditional estimates of future climate; conditional upon, i) the assumptions governing future emissions of greenhouse gas and other pollutants, and ii) which processes and feedback mechanisms are incorporated in the climate models which generate the results. While there are procedures which can be used to address the former set of uncertainties (e.g., use a range of emissions scenarios spanning the plausible range of outcomes), the latter set of conditions are determined by the climate model design and are therefore harder to quantify. With regard to African climate change scenarios, the major model limitations would include the following:

- the ability of the GCM to simulate ENSO events. Since some regional rainfall regimes in Africa are highly sensitive to ENSO (e.g. southeastern Africa, coastal East Africa, parts of north-east Africa), whether or not the GCM is simulating realistic ENSO events will be important for evaluating the credibility of the scenario. There is some evidence that successive generations of GCM experiments have consistently improved their simulation of ENSO (e.g. Tett, 1995), although this does not mean that there is a consensus about whether ENSOs are likely to change substantially in character as a result of climate change (see Knutson & Manabe, 1995).
- the ability of the GCM to simulate the observed interannual and interdecadal variability of African rainfall (i.e., the correct frequency spectrum). For example, the prolonged desiccation of the Sahel during the 1970s and 1980s and into the 1990s has not always been well reproduced by climate models.
- the representation of land cover/climate interactions over Africa. Sensitivity experiments with climate models has shown that changes in land cover characteristics (e.g., deforestation) *can* have major impacts on continental climate if the perturbations are large enough (Xue & Shukla, 1993). Since GCMs used for climate change experiments do not yet allow land cover characteristics to change - either due to climate change or due to human disturbance - there must be some caution applied when interpreting the results of GCM scenarios for Africa.
- representation of precipitation, cloud cover and radiation changes because of uncertainties in the cloud and tropical convection parameterisation schemes.

### *An Entry-level Scenario for Africa*

Given the above discussion about what climate models can and cannot show, and indeed the limits to prediction, is it possible to say anything useful about how future climate in Africa may change? Indeed it is, and this section summarises one such climate change scenario (refer Annex 2.1 for definition) for Africa using the linked model approach described earlier. This scenario assumes little direct policy intervention globally to restrict greenhouse gas emissions and assumes mid-range estimates of population and economic growth from the World Bank. In other words it follows IPCC scenario IS95a. The other assumptions that are made below include mid-range settings for all model parameters and the use of the latest climate change experiment from the Hadley Centre (HADCM2; Mitchell *et al.*, 1995) to establish the patterns of climate change. The statements below refer to the climate of the years around 2050 and the changes are expressed relative to the average climate of the period 1961-90. They should be read in conjunction with Table 2.1 about levels of certainty.

Atmospheric CO<sub>2</sub> concentration: about 500ppmv, a rise of about 50% compared to 1961-90 climate.

Sea-level: about a 25cm rise in global sea-level. There will be regional and local differences in this rise around the coast of Africa depending on ocean currents, atmospheric pressure and natural land movements, but 25cm gives a general figure.

Temperatures: the world will be about 1°C warmer than the 1961-90 average. Over Africa, land areas will have warmed by more than this amount, up to 1.6°C over the Sahara and semi-arid parts of southern Africa. The Equatorial countries of Cameroon, Uganda and Kenya, for example, will be about 1.4°C warmer. This represents a rate of warming to 2050 of about 0.2°C per decade. Sea surface temperatures in the open tropical oceans off Africa will have risen by less than the global average (i.e., about 0.6° to 0.8°C) and the coastal regions of the continent will therefore warm the least of any Africa land region, between 1°C and 1.2°C warming (see Figure 2.6, left, for a visual depiction of this scenario).

Precipitation: rainfall changes will be relatively modest compared to the large year to year variability of rainfall in most parts of Africa. In general, rainfall will increase over the continent, the exceptions most likely being southern Africa and parts of the Horn of Africa. Here, rainfall declines by about 10%. Parts of the Sahel see rainfall increases of up to 15% compared to the 1961-90 average. Equatorial Africa experiences a small - 5% - increase in rainfall (see Figure 2.6, right, for a visual depiction of this scenario). These rainfall results are not very robust in the sense that different climate models, or different simulations with the same model, may yield quite different patterns.

Other variables: the increased temperatures will likely lead to increased open water and soil/plant evaporation. Exactly how large this increased evaporative loss will be depends on factors such as physiological changes in plant biology, atmospheric circulation and land use patterns. As a rough estimate potential evaporation over Africa may increase by between 5% and 10%. Little can yet be said about changes in variability or extreme events in Africa. Rainfall may well become more intense, but whether there will be more tropical cyclones or a changed frequency of El Niño events is largely in the realms of speculation.

## **2.4 Linking the Future with the Present**

Climate change scenarios usually describe possible climate conditions several decades into the future. The assessment of climate change impacts typically follows this methodology and evaluates how those changed climate conditions might impact on a range of social and environmental processes (e.g. the IPCC guidelines; Carter *et al.*, 1995). This approach has the *advantage* that the magnitude of the climate change considered is perhaps large enough to provoke a noticeable effect on the sector considered - whether water, crops or vector-borne disease. The *disadvantage* of this methodology is that climate change is (implicitly) considered to be a problem for the future and that it deflects attention away from how we get from where we are now to where we will be in a generations time. It underplays the importance of living and making decisions under the more ambiguous conditions of climate change in the present.

There is mounting evidence that global climate is already changing and that these changes are related to human pollution of the atmosphere. The characteristics of this climate change vary from region to region and may be more or less discernible from the background variability of climate. The changes might manifest themselves in a diversity of ways: changes in average temperature (*cf.* Figure 1); changes in the frequency of droughts (perhaps relevant for the

Sahel or for parts of southern Africa); changes in the nature of El Niño events in the Pacific (the prolonged ENSO of 1991-95 is unprecedented in the historic record and has been calculated to have a return period of 1-in-2000; Trenberth & Hoar, 1996); or changes in sensitive environmental indicators (for example, the appearance of malarial transmission at higher altitudes in eastern Africa<sup>8</sup>).

There are a number of consequences which flow from the realisation that we are now living under a changing climate and that climate change cannot simply be reserved for several decades into the future when a new equilibrium climate will prevail. The transient (or incremental) nature of climate change and the transient nature of the responses to climate change are most important.

#### *What climate statistics to use for planning purposes?*

The literature continues to contain examples of where agroclimatic (and sometimes hydrological) statistics for Africa are calculated without reference to the time period to which the data used refer (e.g., Booth (1991); Legates & Willmott (1990); Leemans & Cramer (1991); Le Houérou *et al.* (1993)). Whenever this occurs, the implicit assumption is being made that climate (or at least rainfall supply) has been stable over the duration of the 20th century and will continue to be so in the future and that the period from which ones data are sampled is therefore largely irrelevant. The sensitivity of rainfall averages to the choice of time period has been illustrated before (e.g., Todorov, 1985; Farmer, 1989; Hulme 1994), yet failure to appreciate fully this sensitivity continues to plague published agroclimatic studies. A classic example of where rainfall (and also in this case hydrological) statistics, based on too restrictive a time period, were used to ill effect was the South Chad Irrigation Project (Kolawole, 1987). This project, planned in the late 1960s and executed in the 1970s, suffered from a 3m drop in the level of Lake Chad between 1973 and 1984 because of rainfall decline and crop yield performance has remained very far short of planned production.

The importance of this issue is demonstrated in Figure 2.8. Here we show the same rainfall time series for the Sahel region in tropical North Africa, but using two different reference periods to define the average (or two different expectations of what is 'normal'). Depending on which of the two perspectives is adopted, or which set of statistics are used in the planning activity, a very different view of likely rainfall over the next 10 years is obtained. With the prospect of future climate change the situation becomes even more delicate. Does one use existing historic statistics for African rainfall and temperature as the guide to the future or, if one recognises that human-induced climate change will occur, how does one build this prospect of change into the planning statistics? Although the scenarios of temperature change all point in the same direction, as we have seen above the situation for rainfall is much less clear. Probably the only safe option at this time is to plan for a wider range of rainfall futures than has historically been the case (e.g. by adding  $\pm 10\%$  to the rainfall statistics and allowing for greater variability) and therefore planning greater resiliency into water, agriculture, urban, etc. schemes. Conway *et al.* (1996) provide an example of the sort of approach which could be taken in their study of Nile water management.

#### *The continuity between seasonal forecasts and climate change scenarios*

The twin objectives of improved seasonal forecasting and improved climate 'prediction' are part of the same basic scientific enterprise which is to understand and model the global climate system (see Table 2.5). As mentioned earlier the basic numerical models used to work towards these two objectives are fundamentally the same, although the experimental design is different in each case. Recent developments in seasonal forecasting, especially for the Tropics (e.g. Chen *et al.*, 1995), have drawn attention to the need for appropriating such

<sup>8</sup> A WHO meeting on climate change and malaria in Africa was held in Ethiopia in May of this year.

forecast information into drought management systems and other natural resource operations (e.g. Gibbard *et al.*, 1995). Africa, or at least regions within Africa, is one of the potential beneficiaries of such improved forecasts as has been shown in southern Africa over the last few years. The strength of the relationship between rainfall in this region and ENSO has enabled for several seasons now robust seasonal forecasts to be issued before the commencement of the rainy season. This relationship has also been shown to extend to maize yields in Zimbabwe (Cane *et al.*, 1994) and the promise exists for irrigation management and hydro-electric energy generation also to benefit from such a capability.

	Operational status depending on region			
	Untried	Experimental	Pre-operational	Operational
<b>Multi-year (Climate)</b>	most areas	global/hemispheric scale	-	-
<b>Seasonal</b>	some equatorial and high latitude areas	many areas	certain promising areas including southern Africa	parts of the USA, Australia and a few other suitable areas
<b>Within season</b>	-	many areas including southern Africa	some developed economies	certain well researched areas (USA, Europe)

**Table 2.5:** Qualitative assessment of current status of long-lead climate 'forecasts'. [Source: Gibbard *et al.*, 1995].

Such seasonal forecasting should be able to continue under conditions of climate change, as long as the forecasts are model-based rather than merely statistical, and as long as the forecast models are continuously revised in the light of improved understanding of the long-term response of the climate system to changing atmospheric composition. Since climate change is incremental only on multi-year timescales - indeed, climate change is not detectable at the interannual scale - building planning and management response systems which react to forecast information about interannual climate variability is a surrogate method for building resiliency to climate change into planning systems.

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**Figure 2.8:** Annual rainfall departures in the Sahel from 1900 to 1995 with respect to the 1931-60 average (top) and the 1961-90 average (bottom). The smooth line is the result of a 10-year low-pass filter. The choice of reference period alters the perception of the recent desiccation in the Sahel and what may be anticipated in the near future.

*Implications for future research*

One of the most pressing scientific needs related to research on African climate is the maintenance and (if possible) enhancement of the surface climate observing network. This is important for at least three main reasons:

- for the detection of long-term climate change, stable and continuous observing sites are necessary. This is as true in Africa as in other regions of the world and is why the WMO has a programme to designate and maintain key sites as Reference Climate Stations. This programme needs additional recognition and funding;
- for the calibration of new satellite-based methods of observing the climate. Satellite monitoring of climate possesses a number of advantages over conventional measurements, but the continuous calibration and re-calibration of the satellite algorithms with surface observed data will remain necessary well into the future;
- for the monitoring of climate. Satellite-based methods will not be able to replace in entirety the suite of climate variables measured at the surface. Near real-time monitoring of climate will continue to rely upon both surface and satellite-based observations.

The potential for further improvements to seasonal rainfall forecasting in Africa needs to be realised. This will involve the continuation of research both using global climate models for such forecasts (e.g. as undertaken at present in the Hadley Centre, UK, and at NOAA, USA) and using statistical methods which can be undertaken in a much wider range of research centres including many African National Meteorological Agencies.

The role of land cover changes within Africa on regional climate needs to be better defined. This will require the establishment of high resolution historical datasets on land cover changes within the continent (from either historical analyses or from satellite observations) and also more detailed field experiments (such as HAPEX-Sahel) into how local moisture and energy budgets are affected by land cover changes.

A continual need to explore the results of GCM experiments which simulate greenhouse gas and aerosol induced climate change to seek to identify the likely regional response within Africa to global-mean warming. This will be only one part of the much larger effort underway worldwide to narrow the uncertainties surrounding the predictions of greenhouse gas induced climate change. Resolving whether the recent desiccation in the Sahel is associated in some way with global air pollution, however, is of great importance.

There is an important need for information about climate change and variability to penetrate more fully into national government organisations and into international donor agencies. This is necessary to ensure that what *is* known about past and present climate variability is properly accommodated into national economic and environmental planning. Such sensitisation of the policy process to climate variability also ensures that as knowledge about future climate change improves, it too can be sensibly used to guide drought/climate-related economic policy.

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### Annex 2.1: Definitions of Terms

‘Prediction’, ‘forecast’, ‘simulation’ and ‘scenario’ are all terms that are used in a variety of contexts when discussing future weather and/or climate. There is no commonly accepted definition of these terms as they apply to climate change modelling, so specific definitions will be adopted here.

- **prediction**: the result of a single model integration where the relevant input forcing factors are well-known can be termed a *prediction*. This is an appropriate term to use in relation to short-term (less than one month) weather modelling and, to a lesser extent, for seasonal (less than one year) time-scale climate modelling, but is inappropriate to use in relation to long-term (>10 years) climate modelling because here the input forcing factors are not well-known.
- **forecast**: as a result of integrating a model several times, each time with the same input forcing factors but slightly different initial conditions, it is possible to build up a series (or ensemble) of predictions. Using this ensemble (maybe 5, 10 or 20 individual predictions) it is possible to derive a *forecast* which would contain some statement of probability. This technique is now routinely employed in weather forecasting, is increasingly common in seasonal time-scale forecasting and is being experimented with in climate forecasting (Palmer, 1993).
- **simulation**: because the relevant input forcing factors (e.g., greenhouse gas concentrations in the future, volcanic eruptions, solar variability) in long-term (>10 year) climate change experiments cannot be well defined, one has to make a set of assumptions about these factors. In this case, *simulation* is a more appropriate term to use than prediction; the latter is in danger of implying that we can ‘predict’ future greenhouse gas emissions (and hence population, energy technology, etc.) or natural phenomena (such as volcanic eruptions). It is clear that we cannot.
- **scenario**: the result from one or more long-term climate simulations should be termed a *scenario* - a conditional estimate - where one has been forced to make some explicit assumptions about future global demography and economy. A scenario might be derived from one climate simulation, several climate simulations using different models or forcing factors, or from an ensemble of simulations using the same model and forcing factors, but different initial conditions (e.g. Cubasch *et al.*, 1994).



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## CHAPTER 3. VULNERABILITY AND ADAPTATION

### Introduction

This chapter defines the concept of adaptation and examines stakeholders in responding to climate change. It is argued that adaptation to adverse effects of climate change is needed under some conditions and that developing countries will be particularly vulnerable to global climate change. Four main types of adaptation responses to climate change are identified; anticipatory adaptation, institutional and regulatory adaptation, research and education, and development assistance for capacity building. The first two types of responses should be given immediate priority attention. It is emphasized that adaptation responses should achieve net benefits that are greater than costs, increase flexibility, and increase robustness.

### 3.1 Need for adaptation to climate change

It seems very likely that global atmospheric concentrations of GHG will be increasing during most of the 21<sup>st</sup> century.<sup>1</sup> Many experts and analysts therefore would agree with the experts of the United States Country Studies Program when they recommend that 'nations (...) need to assess options for adapting to climate change because it is unlikely that climate change can be completely averted' (CSMT, 1994:7-1).

Adaptation to climate change would be warranted even in the unlikely event that GHG emissions soon would be stabilized or reduced. This is because of the long lifetime of greenhouse gases after their emission into the atmosphere and the time needed for the climate system to return to its original state. Thus, the IPCC estimates that an increase in temperature from 0.1 to 0.7 °C will occur after 1990 because of carbon dioxide emissions prior to 1990 (IPCC 1995:10). The impacts of already emitted GHGs will be felt for several generations. The issue of how best to adapt to climate change is therefore urgent.

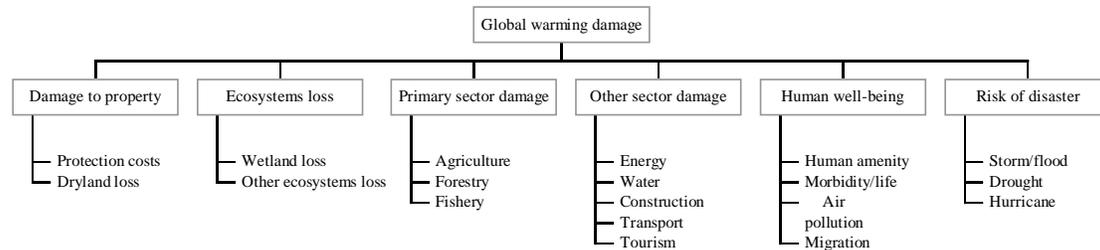
The severity of the effects of climate change will vary. All climate change impacts will not constitute damages, and environmental sectors will to varying degree be sufficiently robust and resistant to climate impacts, at least in the short run. Environmental sectors will have some adaptive mechanisms and absorptive capacity for climate impacts. Other, more severe,

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<sup>1</sup> The *IPCC Second Assessment* predicts: 'If global CO<sub>2</sub> emissions were maintained at near 1994 levels, they would lead to a nearly constant rate of increase in atmospheric concentrations for at least two centuries, approaching twice the pre-industrial concentration by the end of the 21<sup>st</sup> century'. According to several projections of future energy use and emissions, a stabilization of emissions at 1994 levels is not likely. The U.S. Department of Energy's *Annual Energy Outlook 1996 (AEO96)* projects energy trends to the year 2015: 'Carbon emissions from energy use are projected to increase by 1.1 percent a year through 2010, reaching 1,660 million metric tons.' The *AEO96* predicts a shift from renewable energy to fossil fuels, particularly for electricity generation. 'Beyond 2010, with slower demand growth, emissions grow at a slower rate, reaching 1,735 million metric tons in 2015.' The European Environment Agency predicts, in its 1996 report *Climate Change in the European Union*, 'an expected increase in emissions (compared to 1990 levels) of 5% in 2000, 13% in 2010 and 16% in 2020. Stabilization would only be within reach if the maximum potential of the estimated effects of abatement measures is actually realized. The main causes for the expected increase are: continuous transport growth, continuing low energy prices, the slow improvement of energy efficiency and the fact that many of the measures in National Programs will not be completed before 2000.' In IEA's *World Energy Outlook-1996 (WEO-96)* world energy demand is projected 'to increase by between 34 and 46 per cent between 1993 and 2010. This increase in demand will be met primarily by fossil fuels. Energy consumption outside the OECD, Eastern Europe and the countries of the former Soviet Union could more than double by 2010. OECD energy consumption could represent less than one half of world energy consumption in 2010'. As rising fossil fuel consumption implies increasing greenhouse gas emission, *WEO-96* predicts that 'by 2010, world carbon emissions could be between 36 and 49 per cent above their 1990 level. The majority of this increase will come from non-OECD countries. The increase in China alone could be of a similar order to the increase in the OECD as a whole'.

impacts will result in significant damages on environmental sectors, however. Moreover, the rate of warming and climate change is an important factor and could exceed the adaptive capacity of natural and managed systems. One study, for example, concludes that ‘current evidence indicates that the speed at which plant species can disperse is slow compared to the rate of climate change...only some animals are adapted to moving long distances quickly and to thrive in disturbed environments’ (Graves and Reavey, 1996: 133). As Figure 3.1 shows, climate change could potentially inflict damage on a large number of natural and socioeconomic sectors (e.g. agriculture, forestry, water resources, and fisheries).

**Figure 3.1.** Overview of sectors potentially vulnerable to climate change effects.



Source: Fankhauser (1995a: 16).

To develop appropriate adaptation policies, it is necessary to examine the potential future effects of climate change and single natural and socioeconomic systems’ potential for adaptation. Unfortunately, no comprehensive and systematic vulnerability assessment exists for developing countries. Table 3.1 gives an assessment of climate change effects and potentials for adaptation in the case of the United States. The analysts draw the following conclusion with respect to potentials for adaptation:

‘It is our judgment that on the whole, the potential effects of climate change will be more severe for natural ecosystems than for societal systems...It does not seem likely that society would be able to ameliorate the negative effects of climate change on natural ecosystems. In contrast, the effects of climate change on societal systems could lead to expensive adaptations, such as building coastal defenses, new energy plants, or new resources of water supplies. Given the long time period over which climate change may happen, it seems likely that the United States will be able to afford to make these investments’ (Smith and Mueller-Vollmer: 10-11).

**Table 3.1.** Summary of climate change impacts and possibilities for adaptation for various natural and socioeconomic systems.

Systems	Potential Impacts	Adaptation Potential
Forests/ Terrestrial Vegetation	Migration of vegetation. Reduction in inhabited range. Altered ecosystem composition.	Low potential for natural adaptation. Minimal potential for anthropogenic assistance.
Species Diversity	Loss of diversity Migration of species. Invasion of new species.	Very low potential for natural adaptation. Anthropogenic intervention may save select species.
Coastal Wetlands	Inundation of wetlands. Migration of wetlands.	Low potential for natural adaptation. Removing barriers to migration will offset some losses.
Aquatic Ecosystems	Loss of habitat. Migration to new habitats. Invasion of new species.	Moderate potential if in open waters, many uncertainties. Low potential if in enclosed waters.
Societal Coastal Resources	Inundation of coastal development. Increased risk of flooding.	High potential for adaptation through coastal defenses and relocation of structures at significant cost.
Societal Water Resources	Changes in supplies. Changes in drought and floods. Changes in water quality and hydropower production.	High potential for adaptation of managed systems to provide water supplies, flood protection, and hydropower at significant costs.
Agriculture	Changes in crop yields. Shifts in relative productivity and production.	Very high potential for adaptation, with potential for reductions of agriculture output in marginal areas.
Human Health	Shifts in range of infectious diseases. Changes in heat stress and cold weather afflictions.	High potential for adaptation through pest management, behavioral and infrastructure changes.
Energy	Increase in cooling demand. Decrease in heating demand. Changes in hydropower.	High potential for adaptation through increased power production at increased cost.
Transportation	Fewer disruptions of winter transportation. Increased risk for summer inland navigation. Risks to coastal roads.	Very high potential for adaptation through adjustment of modes of transportation and seasonal patterns.

Source: J. B. Smith and J. Mueller-Vollmer, *Setting Priorities for Adapting to Climate Change*, 4. RCG/Hagler, Bailly, 1993.

This conclusion regarding adaptation potential of natural and socioeconomic systems in the United States is evidently based upon the analysts' assessment of the kinds and amounts of economic, technical and other resources that are available for adaptation purposes in the United States and, in addition, the ability and willingness of the American political-institutional system to adapt to climate change. Similar to this, the potential for climate change adaptation of natural and socioeconomic systems should be understood in the context of single countries and their resources, including resources provided through the international system, available for adaptation purposes. The potentials for adaptation in similar natural systems, however, do not vary significantly from one country to the other.

### 3.2 Adaptation Defined

Adaptation refers to adjustment to altered environmental conditions (Smit, 1993). Adaptation could be a biological, technical, institutional, regulatory, behavioral or economic response (OTA, 1993:2). Many adaptation options for climate change could become available. Among these are coastal protection, while others include adjustment in management practices in forestry and agriculture, establishing early warning systems for extreme weather events, creating migration corridors for migratory species (both flora and fauna), and others. Adaptation measures and policies will also include infrastructure development, environmental planning, education and raising awareness, land use planning, water resources management, and urban development.

**Table 3.1.** Strategies for responding to adverse environmental impacts

<p>In the earliest literature on impact assessment, mitigation was understood to include the following objectives and actions:</p> <ul style="list-style-type: none"> <li>• to avoid an adverse impact altogether by not taking a certain action,</li> <li>• to minimize adverse impacts by limiting the degree or magnitude of the action,</li> <li>• to rectify an adverse impact by repairing, rehabilitating, or restoring the affected environment,</li> <li>• to reduce or eliminate an adverse impact over time by appropriate techniques of maintenance or preservation, and</li> <li>• to compensate for an adverse impact by replacing or providing substitute resources or environments</li> </ul> <p><i>Source:</i> Paul A. Erickson, <i>A Practical Guide to Environmental Impact Assessment</i> (San Diego: Academic Press, 1994), 240-51.</p>
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Adaptive measures are commonly divided into two groups (Titus, 1990; Smith *et al.*, 1995; Smith and Lenhart, 1996). The first group of measures are reactive adaptations. Reactive adaptations are ex post responses made after climate change has occurred. One group of this main type of measures and policies would be concerned with adaptation during extreme events. Climate events such as drought has resulted in short term relief actions to alleviate the social consequences of drought. For example, in the Northeast of Brazil one response focused on maintaining the income level of the unemployed rural population through massive Keynesian unemployment programs to construct public works. A second response focused on distribution of water to the rural population and cities in need of water (Magelhães: 49).

The second group consists of anticipatory adaptation measures which are taken in advance of climate change. They aim to reduce the effects of climate change. According to one study, 'the goal of anticipatory measures is to minimize the impact of climate change by reducing vulnerability (e.g., sensitivity) to its effects or by enabling reactive adaptation to happen more efficiently (faster or at lower costs). The former is robustness (ability to absorb surprises), while the latter is resiliency (ability to recover from failure)' (Smith and Mueller-Vollmer:11). This type of adaptation is concerned with increasing the long-term and permanent capacity to adapt to the adverse effects of climate change. In the case of the Northeast Brazil, for example, the main component of a long-term response to droughts has been to increase the capacity to store water during the dry period by building hundreds of dams where billions of cubic meters of water were accumulated in strategic points of the Northeast Brazil. Other important adaptation measures are transportation infrastructure and irrigation projects. The region has moreover benefited from climate research by using relevant information about occurrence of drought in the formulation of government agriculture policy (Magelhães: 49-50).

### 3.3 Why Adapt to Climate Change?

Some have concluded that it is better to delay adaptation to climate change until later (Ausubel, 1991a; Ausubel, 1991b; Ausubel, 1995). It has been emphasized that many key factors are uncertain, better and cheaper technology will be available in the future, and future generations will have greater wealth that can be used for adaptive purposes. In the extreme version of this argumentation, there is no need for an adaptation policy response to climate change. However, it seems very doubtful that purely market-based approaches to adaptation will alone be sufficient and much less be optimal, especially in the case of developing countries.

Arguments for postponement of adaptation to climate change are often based on the assumption that climate change is likely to happen gradually. However, in 1990 the IPCC concluded that the rate of future climate change was uncertain. Evidence indicates that the climate in earlier times has changed considerably within decades (Dansgaard *et al.*, 1993;

Overpeck, 1995). The 1996 IPCC Second Assessment Report also emphasizes the occurrence of non-gradual changes: 'Future unexpected, large and rapid climate system changes (as have occurred in the past) are, by their nature, difficult to predict. This implies that future climate changes may also involve 'surprises'. In particular these arise from the non-linear nature of the climate system. When rapidly forced, non-linear systems are especially subject to unexpected behavior' (Houghton *et al.*, 1996: 7).

Adaptation is not advisable in all cases, however, and the need for adaptation is best assessed in each single case and at the sectoral level. Whether adaptation is advisable is generally dependent upon the constraints on and opportunities for adaptation and, as discussed below, the cost and benefits associated with an adaptive response. Moreover, climate impacts on regional and national levels presently cannot be predicted with accuracy. However, despite the current uncertainties of climate change, it is clearly preferable to develop and implement anticipatory adaptation policies in some cases (Smit, 1993; Burton, 1995). One U.S. Office of Technology Assessment Report in particular points to the costs of possible climate impacts, cases where there exist a need to react well in advance of any climate change, and when anticipation today is less expensive or more successful compared to a response made at a later stage. As the report concludes:

'Waiting to react to climate change may be unsatisfactory if it is possible that climate change impacts will be very costly. Of greatest concern may be those systems where there is the possibility of surprise - of facing the potential for high costs without time to react - or where the climate impacts will be irreversible. Such impacts seem more likely if long-lived structures or slow-to-adapt natural systems are affected, if adaptive measures require time to device or implement, or if current trends and actions make adaptation less likely to succeed or more costly in the future. In these cases, anticipating climate change by taking steps now to smooth the path of adaptation may be appropriate' (OTA, 1993: 4).<sup>2</sup>

These are all important reasons why it would be advisable to react earlier rather than later. In some cases and situations there might be several such reasons for deciding not to postpone adaptation to climate change. First, it seems justified to react at an early stage when the costs of climate change impacts potentially are very high, but could be avoided, or at least reduced, by anticipatory adaptation. Climate change causing storms and floods could result in loss of human lives and property, but costs and losses could be reduced through improved contingency planning. In general, it is necessary to take into account varying lead times of human interventions and the lead time of ecological and socioeconomic systems when examining the need for anticipatory adaptation. Some species may be unable to migrate to a more favorable location before the climate changes, for example, and government intervention to make markets favor more climate-robust products may take years and even decades to accomplish.

Decisions of a long-term nature made today may be affected by future climate change. For example, some types of trees that are planted today may not survive under altered climate conditions that increase temperatures and change precipitation patterns. Similarly, the design of long-lived structures, such as bridges and dams, should take into account possible climate change, and many examples of marginal changes and inexpensive adjustments options exist (Smith and Lenhart, 1996). Another example, coastal-zone development in climate-sensitive areas in Africa may contribute to future losses due to climate changes if no adjustments to climate change are made.<sup>3</sup> Moreover, in some cases reacting to climate change may already

<sup>2</sup> Examples of irreversible changes are loss of species or loss of valuable ecosystems.

<sup>3</sup> A recent Bank report identifies global warming and vulnerability of sea-level rise as an important area for regional cooperation deserving GEF support. World Bank, 'A Framework for Integrated Coastal Zone Management in Sub-Saharan Africa' (1995)

be warranted. Adaptation is therefore advisable in areas (e.g. floods and droughts) where action already is needed but has not yet been taken. Such anticipatory adaptation would bring benefits even in the absence of climate change, and they should be considered being examples of so-called 'no regrets' options.

Action should be taken in situations such as those just described. However, there is no need for immediate adaptation when adequate technologies and responses to climate change already exist and can readily be implemented. Some adaptation responses may have short lead times and could easily be implemented by existing institutions. They could therefore be implemented as the effects of global warming unfold. For example, as pointed out in chapter 5, it might be relatively easy to switch to heat-tolerant crops as warming increases. Moreover, by postponing adaptation until later, it is possible to increase knowledge of the magnitude and severity of impacts and accordingly respond in a more adequate manner. Also important, although feasible and effective adaptation responses may be available today, inexpensive and more effective responses may become available in the future. If adaptive responses and policies are implemented prematurely, future opportunities for inexpensive and effective adaptations could be lost.

As will be discussed below, while developing countries are more vulnerable than industrialized countries to adverse effects of climate change developing countries generally lack the capacity and resources needed to protect themselves. Industrialized countries might in some cases already have the technology, wealth, know-how and institutional capacity necessary to protect themselves when climate changes, but such capabilities and resources are lacking or insufficiently available in most developing countries today. High priority should therefore be given to enhancement of sustainable economic growth in developing countries because this will increase wealth, resources and options available for adaptation purposes in those countries (see, e.g., Goklany, 1995). It should in this respect be noted that the U.N. Framework Convention on Climate Change stresses that the achievement of sustainable social and economic development and eradication of poverty are priority goals for the developing countries. Moreover, this underlines the importance of integrating adaptation with other immediate, medium and long-term goals and with broader societal goals of the developing countries. Additionally, the threat of climate change is yet another significant environmental issue which should justify that further development of indigenous institutional capacity to protect the environmental and ecological resources of developing countries is undertaken. Finally, solutions to adapt to climate change may presently be unavailable or unknown. It will therefore be necessary to develop solutions, and society must engage in research in order to improve the capacity to adapt.

Table 3.3 shows the four types of adaptation responses to climate change that are relevant to examine in the case of Africa. These represent four generic types of climate change adaptive policies. They are not listed according to priority, urgency or cost. It seems that adaptation cost often will be incurred at the early stage of anticipatory adaptation policies, whereas for other types of policies the adaptation cost will be incurred later or over the entire life of a project or a policy. Some adaptive policies may fit more than one generic policy type. The first two types of measures should be given immediate attention. It will be important to identify those policies and measures that better are taken soon, otherwise opportunities for inexpensive adaptation options will be missed. Sector-specific policies for agriculture and water resources that correspond to the four generic types are presented in chapters 5 and 6, respectively.

**Table 3.3.** Four generic types of adaptation response to climate change in Africa**(1) Anticipatory adaptation.**

Included in this group of adaptation policies are:

- a. modifications of projects with long life spans (e.g. dams, bridges, forests). The policy is to modify projects so that they can perform satisfactorily for the entire range of likely climate changes;
- b. projects that bring benefits and achieve their development goals irrespective of occurrence of climate change ('no regrets' options). The policy is to realize 'no regrets' options to the extent possible, e.g. improvement in the capability to adjust to existing climate variability;
- c. projects for which adaptation to climate change is inexpensive. Where inexpensive opportunities exist, projects should be modified so that they are able to perform satisfactorily for the entire range of likely climate changes, e.g. sewage systems may be modified inexpensively to prepare for future changes in ground water level;
- d. projects that increase protection against extreme events (e.g. floods, storms, drought). Projects should reduce the vulnerability to extreme events when it can be achieved with no or few additional costs, e.g. by increasing drought early warning and preparedness;
- e. projects which prevent irreversible impacts (e.g. preservation of biological diversity). Projects should help to preserve valuable biological resources, e.g. by protecting against sea-level rise threatening valuable coastal resources.

**(2) Institutional and regulatory adaptation.**

Included in this group of adaptation policies are:

- a. projects that aim to correct developments that otherwise would increase vulnerability to climate change in the future (e.g. infrastructure, coastal-zone development, land use). By using regulatory measures, projects aim to reduce future social and economic vulnerability to climate change, for example, by removing economic incentives that stimulate population increase in coastal areas in Africa that are endangered by rising sea-level, or adopting land-use regulations;
- b. projects that correct institutions in order to reduce vulnerability (existing institutions may produce 'perverse effects'). Policy should correct economic institutions when they increase vulnerability to climate change, e.g. removing economic subsidies that create an economic disincentive for shifting to drought-resistant crops (e.g. from maize to millet).

**(3) Research and education.**

Included in this group of adaptation policies are:

- a. projects aiming at developing solutions when adaptive solutions currently are unavailable and time is needed for their development. When costs are modest, projects might, for example, contribute to the development of drought-resistant crops and cultivars;
- b. projects that stimulate behavioral changes needed to accommodate to climate change. Projects might help to raise awareness of climate change and opportunities for adaptation, e.g. by supporting relevant activities of government agencies and NGOs in countries in Africa.

**(4) Development assistance for capacity building.**

Included in this group of adaptation policies are:

- a. projects enhancing the productivity of sectors, especially natural resource sectors. Projects should aim to increase the productivity of sectors because this will increase wealth, resources and options available for adaptation purposes in African countries;
- b. projects that strengthen the overall institutional capacity of countries in Africa. Projects should aim to strengthen the institutional capacity of African countries because this increases their capabilities to develop and implement adaptive responses to adverse climate change effects;
- c. projects that reduce pollution levels and improve environmental quality. By reducing non-climate environmental stresses, projects contribute to making natural and socio-economic systems more robust and less vulnerable to climate-related stresses.

It must be strongly emphasized that adaptation should not be looked upon as an alternative to responding to climate change by mitigating GHG emissions. Both should be part of a comprehensive policy response to the global climate change issue. As a defensive response to a given amount of global warming, however, adaptation is a necessary and wise step to reduce possible adverse climate change impacts. If it turns out that the damages inflicted by climate change are rather insignificant and acceptable, adaptation measures still could be justified as long as they are inexpensive and effective. Due to the involved uncertainties, there is a considerable need for precaution, and global action has so far quite appropriately focused primarily on GHG mitigation. Precaution should also be taken into account when designing adaptation policies. Moreover, because of differences in vulnerability, wealth,

capacity and other factors, the costs of damages and adaptation will be unevenly distributed across countries. To achieve equitable responses to the climate change issue, such issues should be taken into account, together with the range of issues relevant to mitigation of greenhouse gases.

### 3.4 Stakeholders in Responding to Climate Change

#### Identification of decision makers and vulnerable groups

Who are the stakeholders in responding to climate change? Obviously, everyone will be affected, at least by the knowledge that the climate system has changed. For the next decade of planning adaptive responses, it is imperative to identify stakeholders who will or should be involved in key strategic decisions.

The first step in identifying and evaluating adaptive responses is to identify the actors and publics who will be affected by climate change - who alter social, economic and political vulnerability, and who will implement climate policy, both for limiting greenhouse gas emissions and mitigating impacts. Adaptive strategies must be tied to the stakeholders who will implement them. The diverse nature of climate change requires that project analysts recognize the diversity of impacts and responses.

The actors, resource managers or stakeholders can be grouped in various ways. The terminology and characterization of stakeholders vary between disciplines, regions and potential climatic changes. Common typologies may include:

- Stakeholders in different sectors: farmers; agribusiness; consumers; research and consultancy groups; government
- Resource managers in different levels of institutions: individuals; local, national, international governments; nongovernmental or private voluntary organizations; professional or trade groups; commerce and industry
- Vulnerable groups that will experience the most adverse consequences of climate change; smallholder agriculturalists

#### Who are the stakeholders?

A first step is to identify the requirements for information on climate change and climate change impacts, say by 2000. While much fundamental research on the climate system will remain, by 2000 limited area models nested in high resolution, coupled ocean-atmosphere general circulation models with realistic land cover should be available for regional impact assessment in Europe (and most of the developed world). These improvements should provide realistic scenarios of sub-national climate change for a wide range of climatic variables, transient time series, and changes in climatic variability. However, such scenarios may not constitute probabilistic predictions for specific years in the future. It remains to be seen whether research over the next few years reduces the current disparity in scenarios of potential climate changes for specific regions.

Even with these improvements, by 2000 it is probably not realistic to expect individual firms to include climate change impacts in their business plans. For example, farmers, construction projects, and households are unlikely to be concerned with adapting to the small increments in mean climate expected within their planning cycle, generally one to five years. In contrast, resource and sectoral organizations responsible for more strategic planning should be involved in integrated climate change assessments.

An initial list of groups of stakeholders that may be important in developing countries is shown in Table 3.4. The focus is on sectors and organizations that are likely to have strategic interests in climate change impacts. The most prominent are planning groups concerned with

water resources, agricultural commodities, forestry, coastal settlements, energy supplies, and insurance/finance.

**Table 3.4.** Examples of stakeholders for climate change impact assessment

Sector	Organizations
<b>Natural Resources</b>	
<i>Agriculture</i>	
Research, regulation, advice	Ministry of Agriculture
Commercial	Marketing boards
<i>Forestry</i>	
Research, regulation, advice	Forestry Departments
Commercial	Timber companies
<i>Water resources</i>	
Research, regulation, advice	Ministry of Water, Basin development agencies
Commercial	Private utilities
<i>Conservation and land use</i>	
Research, regulation, advice	Wildlife and Conservation departments
Commercial/public	International and local NGOs
<i>Coastal Zone</i>	
Research, regulation, advice	Planning authorities
Commercial/public	Recreation and tourism developments
<b>Socio-economic Sectors</b>	
<i>Insurance and Finance</i>	
Research, regulation, advice	Ministry of Finance, National banks
Commercial	Insurance companies, Banks
<i>Energy</i>	
Research, regulation, advice	Ministry of Energy
Commercial	Utilities, especially for hydropower
<i>Commerce and Industry</i>	
Research, regulation, advice	Development agencies, Agribusiness
<i>Transport</i>	
Research, regulation, advice	Ministry of Transport
Commercial	Port authorities
<i>Household Consumers</i>	Consumer groups
<b>Government and Research</b>	
<i>National Government</i>	Department of Environment, Implementing agencies for the Framework Convention on Climate Change, sectoral ministries
<i>Local Government</i>	District governments
<i>National Research Centres</i>	Meteorological offices, Agriculture and livestock research centres
<i>University and Regional Research Centres</i>	National and regional centres

Among stakeholders, four interests in climate change are salient:

- *Understanding climate change.* As individuals and communities, institutions and corporations, the many publics should have access to the best available information about climate change, its potential impacts, and efforts to reduce greenhouse gas emissions. Regardless of specific decisions, such public education provides broad support for further action.
- *Adapting to climate change.* Some sectors, with strategic decisions taken over the course of decades, should begin to adapt to the threat of climate change. A simple typology of adaptive options is presented below.
- *Adapting to climatic variations.* Regional climate change assessments may provide useful information on sensitivity to current climatic perturbations, such as subsidence and water shortages induced by drought. Indeed, the connection between current issues and the future is almost an essential basis of climate change impact modeling. It certainly is a major concern for many users.
- *Reducing greenhouse gas emissions.* Already some OECD countries have adopted targets for reduction of greenhouse gas emissions; developing countries will be expected to do so at a later point. These targets will need to be allocated between sectors and regions. Many stakeholders are

likely to be more concerned with GHG reduction in the next few years than with climate change impacts in the next half century. Making the connection between the two is important.

In addition to stakeholders, one may consider special populations that are vulnerable due to resource constraints, social and political structures and economic conditions. Within Africa, a common catalogue of vulnerable groups includes:

- *Rural smallholder agriculturalists* may be resource-poor due to shortages of land and labour, subject to fluctuations in production (e.g. caused by drought and pests) and affected by market failures (e.g., inflation). Their empowerment in the political economy varies widely, often along ethnic lines.
- *Pastoralists* occupy ecologies that are sensitive to climatic fluctuations. Their vulnerability is dominated by the encroachment of higher potential lands and integration into market and political economies.
- *Rural wage labourers* depend on the market, often with few savings to buffer times of recession and hyper-inflation.
- *Urban poor* have similar entitlements as the rural wage labourers, but have greater access to the political economy or wider sources of income.
- *Refugees and forced migrants* may command food through voluntary, national or international assistance, but are inherently dependent on the political economy.
- *Destitute groups* are no longer able to sustain production (either agriculture or labour exchanges). They require external assistance for survival, and to re-enter the productive economy.
- For example, four vulnerable groups have been identified in Zimbabwe (Table 3.5). The urban poor total some 6% of the population, and are relatively insensitive to fluctuations in agricultural production, as long as urban prices are not inflated and food aid is available (see below). In rural areas, vulnerability among smallholders (occupying present or former communal lands) varies between agroecological zone. Fewer people are vulnerable in the wetter areas (zones I through III) than in the semi-arid zones (IV and V), due to the conjuncture of better agricultural conditions, improved infrastructure and access to markets. In all zones, vulnerability is higher in years of drought or poor production, but the increase in vulnerability is largest in the semi-arid zones. For all of Zimbabwe, some 28% of the population is characterized as vulnerable on average, increasing to almost half of the population in poor years.

**Table 3.5.** Vulnerable groups in Zimbabwe

GROUP	AVERAGE YEAR		POOR YEAR	
	No. H/holds	% of Popn	No. H/holds	% of Popn
<i>Urban</i>				
Unemployed	72,000	3.7	72,000	3.7
Informal workers	53,000	2.7	53,000	2.7
Urban total	125,000	6.4	125,000	6.4
<i>Rural</i>				
Communal farmers				
Zones I and II	20,000	1.0	39,000	2.0
Zone III	22,500	1.0	98,000	5.0
Zones IV and V	137,000	7.0	450,500	23.0
Landless & unemployed	210,000	12.5	210,000	12.5
Rural total	389,500	21.5	797,500	42.5
<i>Total</i>	514,500	27.9	922,500	48.9

Source: Christensen and Stack, 1992

These vulnerable populations at present may not be engaged in policy on climate change; they are certainly among the first to suffer the adverse consequences.

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**What are stakeholder decision-making processes?**

Each group of stakeholders has different requirements for information, different ways of processing information to make decisions, and different objectives and constraints. The nature of stakeholder decision making should be evaluated at the same time as specific adaptive responses are evaluated.

Major differences are likely to be goals, objectives and constraints. Commercial farmers tend to maximise profits while subsistence or partially commoditized producers also seek to maintain food supplies for household consumption. Credit and debt are differentially available and constrain investment. Risk taking or aversion differs between individuals, farming systems and regions.

Information needs, sources and processing range from rapid to ancillary, international to local and technological to traditional. For example, a commercial farmer may well use global networks to forecast weather and markets in order to plan each season. In contrast, traditional farming systems are more conservative relying on local sources with a longer lag between new information and changes in farming practices. Such issues are well documented in the farming systems, institutional and development literature.

A key characteristic of importance for responding to climate change is the planning horizon. National economic planners rarely look beyond a five year development plan, although they may be concerned with longer-term trends in population and technological development. Trade-offs between current investment in climate change adaptation that will only have benefits in the next fifty years may be difficult to implement. In contrast, environmental institutions promoting sustainable development may take a longer term view and seek to mobilize funds and public support for resilient development strategies even at the expense of some present investment or consumption.

**Adaptation to Specific Rates and Magnitudes of Climate Change**

While many typologies of strategies for coping with climatic hazards exist, relatively few for longer term responses to climate change have been suggested. It seems useful to relate the nature of climate change to different levels of investment in adaptive responses. Figure 3.2 relates the rate of climate change and its expected magnitude to four types of strategies.

Small changes can be accommodated in the normal course of development. These would entail relatively little cost and would be incorporated into existing planning mechanisms without major institutional development. Examples include adjusting set-aside quotas and breeding new crops to take advantage of, or adapt to, new climates. As long as climate changes slowly, such changes would be accommodated within recurrent agricultural research and policy planning.

Planned resilience aims to provide flexibility to mitigate adverse changes or take advantage of new climates through strategies that are beneficial for both existing resource development and coping with climate change. It may involve some expenditure, but the investment is deemed worthwhile since it reaps benefits for present resource use. For example, increasing insurance coverage of climatic hazards, maintaining adequate re-insurance funds and developing international mechanisms to share the financial burdens of climatic hazards would be a beneficial response to present climatic hazards, and would reduce the risk of undue climate change impacts in vulnerable regions.

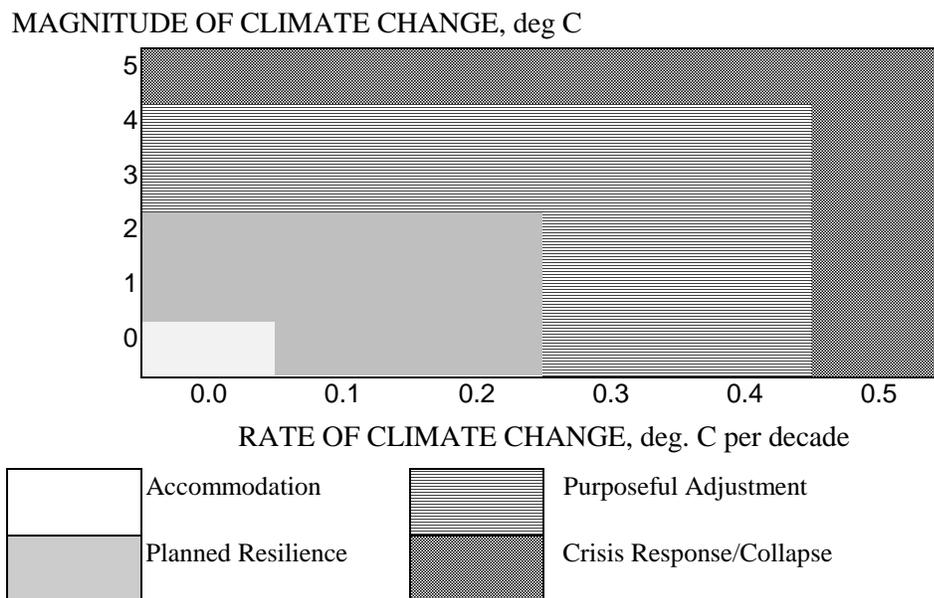
With accurate forecasts, purposeful adjustments can be incorporated in sectoral activities and planned responses. This class of responses would involve considerable investment for which there would be little benefit in the immediate future, and little benefit if climate change does

not occur. The timing of such adjustments is critical, as is the need for reliable regional forecasts of climate change. Examples are be higher sea walls and larger reservoirs to cope with sea level rise and the risk of droughts and floods. Both have negative environmental consequences, so they would only be justified if the impacts of climate change are likely to be serious. Some aspects of climate change are more predictable than others (as noted in chapter 2) - enhancing the CO2 fertilization effect and heat tolerance in new crop varieties is probably warranted with present information.

The aim of adaptation is to avoid crises. However, if present strategies to handle climatic hazards are insufficient, further disaster preparedness is warranted and may be justified in part for as a means to reduce the risk of large-scale impacts from climate change. A climate change catastrophe scenario would mean the collapse of major regional ecosystems, such as fishing grounds, coastal settlements, and semi-arid agriculture. It is likely that planned resilience and purposeful adaptation would be less costly than coping with such large-scale effects. In any case, coping with crises often fails to mitigate future disasters and has a high opportunity cost.

This explicit typology can be mapped against the relevant types of adaptive responses (Table 3.3). Change that can be accommodated does not require further consideration. *Anticipatory adaptation* corresponds to the broad strategy of planned resiliency. It also includes measures to reduce climatic risks and inexpensive responses that require explicit information about climate change. *Planning changes for adaptation* seeks to reduce vulnerability and develop institutions that can carry out further planned adjustments when required. *Research and education* seek to enhance the capacity to generate, evaluate and implement appropriate strategies. In most cases in Africa, it is premature to undertake costly responses to cope with specific impacts—the upper end of purposeful adaptation.

**Figure 3.2.** Adaptive responses classified by the rate and magnitude of climate change



**Criteria for Evaluating Adaptive Responses**

To provide a consistent basis for screening adaptive responses, a common set of criteria should be adopted.

**Stakeholder analysis**

Adaptive responses are specific to or most appropriate for certain stakeholders. This should be recognized in the evaluation.

**Priority stakeholder**

Is there a stakeholder or vulnerable group that should be given priority for targeting adaptive strategies? Priority may be either due to stakeholder involvement in decision making or due to the vulnerability of specific groups.

**Resource conflicts**

Are there conflicts over resource use between or among different stakeholders? Would such conflicts affect the ability to design and implement specific adaptive strategies?

**Resilience and purposeful adaptation**

For most regions, the most effective adaptive responses are those which build upon present capabilities to enhance resilience to climatic variations. Beyond this level of response, purposeful adaptation may be justified in some sectors and for some projects. Key criteria are:

**Multiple benefits**

Does the adaptation have benefits for a number of objectives and stakeholders? For example, farm-level water conservation reduces soil erosion which benefits downstream water users.

**Specificity to predicted climate change**

Conversely, does the adaptation only have benefits if climate changes in the expected direction? Is there a critical threshold for adopting the adaptation? For example, breeding plants resilient to high temperatures is unnecessary if such high temperatures do not occur.

**Effectiveness**

How effective is the adaptation in coping with the expected climate change? Is there a critical threshold beyond which the response will not be effective. Clearly, the definition of effectiveness varies, depending on the resource objectives of the concerned stakeholders.

**Strategic**

Related to enhancing resilience is the strategic role of specific adaptations. For example, some activities might have little direct benefit, but have an important role in developing institutional capacity or in planning future responses. Two specific aspects are:

**Facilitating adaptation**

Many of the most cost-effective adaptive responses have yet to be identified. In such cases, fundamental research and stimulation of innovation may be warranted. For example, plant biology research might identify genetic mechanisms that control high temperature stress. Or, innovation in energy efficiency in agricultural systems is required to limit greenhouse gas emissions (a separate topic from coping with climate impacts).

**Development pathways**

More broadly, the role of adaptation in shaping future development needs to be assessed. Costly responses now may limit investment and constrain development. This is a general issue, but may apply for specific projects and activities. A common example in land use planning is the effect on protection schemes (sea walls and dikes, for instance) on subsequent development. The perceived protection is used as a rationale for further development, increasing the potential for catastrophic losses. A positive example would be contribution to sustainable development. For example, including climate change in national environmental action plans may reinforce the need for sustainable agricultural development.

**Timing**

There is a gap between the implementation of adaptation strategies and the realization of their benefits.

**Matching planning horizon**

What is the planning horizon required to design and implement the adaptation? For how long is the adaptation useful? Some responses, such as switches in cultivars, can be implemented with a few years. Others, such as large reservoirs, require decades to design and build, but may last for decades as well.

**Irreversible impacts**

Matching the timing of an adaptive response and its benefits may need to consider the possibility of irreversible impacts and option values. For example, building dikes to protect agricultural land from flooding may alter the natural cycle of siltation and soil replenishment.

**Cost benefit**

Economic evaluation of projects is well-defined, although contentious issues of discount rates, valuing environmental quality, and equity remain. Obviously, proposed adaptations should have positive returns or be cost-effective. However, full cost-benefit analyses may be difficult and expensive to carry out. Three aspects concern climate change impacts specifically:

**Initial investment by stakeholders**

The initial investment may be a constraint, either because of poverty and lack of credit among some stakeholders or because the expected return is low compared to other economic investments. The difference between public and private objectives and economic decision making may be important in such cases. While most guidelines recommend 'low cost' adaptations, the definition of low cost depends on each stakeholder and their opportunity costs.

**Timing of benefits**

The return on investment depends on the timing of the benefits. Most of the strategies suggested under a resilient development scenario would have fairly immediate benefits. Those that depend on long term climate change would have a stream of future benefits that might be very low in the near future. Both social and market discounting tend to reduce the present value of future benefits.

**Realization of benefits**

The benefits may not accrue to the stakeholders that make the investment. The beneficiaries are future generations, or other present social and economic groups. This is a common problem of equity in public interventions in resource management. It is readily apparent in greenhouse gas abatement. A common issue in coping with climatic hazards is public liability and financing (through taxation) of vulnerable populations. For example, drought taxes are often levied in Zimbabwe, and the public cost of recent natural disasters in the US exceeded several billion dollars.

**Constraints for adoption**

Adaptions will only be effective if they are widely adopted, with relatively efficient means of dissemination and maintenance. Three sorts of constraints are common in adopting agricultural innovations:

**Information**

Information about the strategy, its utility and means of implementing it may be lacking. Also, available information may not be communicated effectively.

**Technical development**

The adaptation may not be technically reliable, or it may require a level of technical development that is not available for all stakeholders.

**Social, cultural and political barriers**

Many of the most significant barriers to innovation are institutional, encompassing the social norms of behaviour, cultural means of communication and decision making, and political processes of empowerment and participation. Of course, these same characteristics are resources for social, economic and political development.

**3.5 Developing countries and climate damage costs**

It is a long-held view that developing countries are more vulnerable than developed countries to climate change and that developing countries lack the capacity to face serious environmental threats. For example, at the workshop 'On Assessing Winners and Losers in the Context of Global Warming', participants noted that 'though there will be winners in both developed and developing countries, there will tend to be more losers than winners among the developing countries, because of their lesser adaptation capability. Developing countries will also be losers in relation to the strategic responses to limit climate change, because these necessary strategies will impose restrictions on development goals and will require technology transformation and investments that are not available to most developing countries' (Glantz, 1992: 9).

The 1996 IPCC Second Assessment Report also notes that the vulnerability of human health and socioeconomic systems depends on economic circumstances and institutional infrastructure. According to the report, this 'implies that systems typically are more vulnerable in developing countries where economic and institutional circumstances are less favorable' (Watson, R.B. *et al.*, 1996: 24). Developing countries' social, environmental, and economic vulnerability multiplies the effects of droughts and other climate events. In general, overpopulation, poverty and land degradation threaten to undermine their capacity to deal with environmental crisis.

While emphasizing that aggregate estimates for damages from climate change are subject to considerable uncertainty, the IPCC concludes, in its Second Assessment Report, that developing countries probably will suffer more from adverse climate change effects than developed countries: 'The aggregate estimates tend to be a few percent of world GDP, with, in general, considerably higher estimates of damage to developing countries as a share of their GDP' (Bruce *et al.*, 1996: 10). Based on a review of leading climate impact cost studies, it has been concluded that climate-related 'damage (relative to GNP) to developing countries may be about 60 per cent higher than the OECD average' (Table 3.6) (Fankhauser, 1995a: 20). According to the IPCC, the aggregate damages for 2xCO<sub>2</sub> for developing countries could be from 2 to 9 per cent of national GDP (Bruce *et al.*, 1996: 218) - an atmospheric CO<sub>2</sub> concentration twice the preindustrial level (commonly referred to as 2xCO<sub>2</sub>) is commonly used to compare estimates of global warming.<sup>4</sup> Although data are weaker in the case of non-OECD countries, one study concludes that 'it seems fair to say that global warming will have its worst impacts in the developing world, with a damage of *at least 2 per cent* of GNP for 2xCO<sub>2</sub>' (Fankhauser, 1995a: 56). In comparison, a global freeze on carbon emissions has been estimated to cost about 1 1/2 per cent to 2 1/2 per cent of the world GNP in the first half of the 21st century and about 3 per cent of GNP in the second half (Cline, 1992: 191).

**Table 3.6.** 2xCO<sub>2</sub> damage for different regions (present scale economy)

	<i>bn \$ (1988)</i>	<i>% GNP (1988)</i>
European Union	63.6	1.4
United States	61.0	1.3
Other OECD	55.8	1.4
Former Soviet Union	18.2	0.7
China	16.7	4.7
Rest of the World	54.2	2.0
OECD	180.4	1.3
NON OECD	89.1	1.6
World	269.5	1.4

Source: Fankhauser, 1995a: 55.

It should be expected that relatively more severe damages will occur in developing countries. 'One would intuitively expect impacts to be more severe in developing countries, where the dependence on climate-related sectors is considerably higher than in the first world' (Fankhauser, 1995a: 20). In Africa, agriculture contributes 34 percent of the total GDP - in many countries its contribution is well over 50 percent - and employs about 60 per cent of the population (Hernes *et al.*, 1995). Many analysts, also those who are more optimistic as to the severity of possible future adverse climate change impacts and the possibilities for

<sup>4</sup> According to the IPCC, atmospheric CO<sub>2</sub> concentrations have increased from about 280 ppmv in pre-industrial times to 358 ppmv in 1994. Ppmv (parts per million by volume) is an unit for mixing ratio (or concentration) that gives the number of molecules of a gas per million molecules of air.

satisfactory responses (Ausubel, 1991a: 218-19; Schelling, 1992: 6), agree that developing countries are considerably more vulnerable to adverse climate effects than developed countries.<sup>5</sup>

In addition to the severity of climate damages themselves, the total cost from climate damages for developing countries will depend upon the adaptive responses in developing countries and whether or not they will be sufficient and satisfactory. Unfortunately, due to lack of resources, a failure to adapt is a likely possibility: 'The situation for LDCs could be further aggravated by a failure to implement the cost efficient [cost effective] adaptation responses (e.g. coastal protection), something which is quite likely to happen if the necessary funds are not made available' (Fankhauser, 1995a: 20). The IPCC similarly emphasizes that the amount of adaptation is crucially dependent upon the availability of appropriate means, measures and policies. This is illustrated in the case of agriculture where, according to the IPCC,

'adaptation - such as changes in crops and crop varieties, improved water-management and irrigation systems, and changes in planting schedules and tillage practices - will be important in limiting negative effects and taking advantage of beneficial changes in climate. The extent of adaptation depends on the affordability of such measures, particularly in developing countries; access to know-how and technology; the rate of climate change; and biophysical constraints such as water availability, soil characteristics, and crop genetics. The incremental costs of adaptation strategies could create a serious burden for developing countries; some adaptation strategies may result in cost savings for some countries' (Watson, R.B. *et al.*, 1996: 24).

Developing countries' high vulnerability to environmental crisis is not only a result of the severity of environmental threats *per se*. The vulnerability should rather be understood in the socio-economic context characteristic of developing countries. For example, the effects of droughts are enhanced in developing countries because they are poorly equipped to deal with severe environmental problems; already degraded marginal lands may become totally unproductive due to a reduction in precipitation. These countries often have little ability to prepare for an environmental crisis, also when they are well-aware of predictions of crisis, or recurrent crisis.

Useful technologies for adaptation to climate change could become available in the future, as emphasized by some, but it is uncertain whether developing countries will be able to afford such technologies. Moreover, developing countries might seldom have the societal resources and infrastructure that will be necessary to take advantage of such adaptation technologies. Relocating a forest type, for example, to a more climate-benign location could appear to be an attractive adaptation response but might fail as such because of developing countries' inability to provide necessary supportive services in the new location. A number of social, technical, economic, planning and political factors may act as constraints on adaptation projects in developing countries.

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<sup>5</sup> Michael Grubb writes that 'it is almost impossible to pin a credible value on the damages that may be associated with climate change', but he finds that 'there are many indications that climate change may impact more seriously on people in poor countries'. More generally, Grubb argues, 'the definitive political issue in climate change is that emissions in each country are likely to inflict damage (or at least risk of damage) on others. Specifically again, in aggregate the richer countries are probably inflicting risk and damage on the poorer ones'. Grubb, 1995: 86-87.

### 3.6 Recommendations

It seems beyond doubt that atmospheric concentrations of GHG will increase during most of the 21<sup>st</sup> century. Marking a significant turning point, the IPCC recently concluded, in its Second Assessment Report, that ‘the balance of evidence suggests a discernible human influence on global climate’ (Houghton *et al.*, 1996: 4). Some global climate change will occur as a result of the increase in atmospheric concentrations of GHGs and countries should take steps to minimize adverse climate change effects. Developing countries in particular will be vulnerable to climate change, and adaptive response options in developing countries should be examined. Effective solutions need to be developed.

A range of natural and socioeconomic sectors in Africa could potentially suffer due to the adverse impacts of climate change. It is necessary to identify good criteria for identifying, assessing and selecting adaptation measures. The scarcity of resources and political and organizational attention to global environmental issues with uncertain national consequences and very long lead-times underline the importance of identification of good criteria for selection of adaptation measures. The criteria for identification, assessment and selection of adaptation measures should be developed in the context of Africa’s need to adapt to climate change and, equally important, take into account Africa’s potential for climate change adaptation. The three broad criteria flexibility, robustness and economic justification are most relevant. Policies satisfying all or most of these criteria should be adopted (Table 3.3).

#### *Achieving net benefits greater than costs*

Adaptation responses should maximize net benefits. At least, they should achieve benefits greater than costs: ‘Further adaptation is warranted as long as the additional costs are lower than the additional benefits from reduced damage levels’ (Fankhauser, 1995b: 8). The avoided damage from climate change is the key benefit of adaptation. Adaptation projects should minimize the combined costs of adaptation and climate damages.

To determine the optimal level of adaptation at a global level, the aim is to find the amount of adaptation that minimizes the costs of a given climate change, namely the combined costs of abatement, costs of adaptation, and damage costs (and residual damages). It is therefore necessary to calculate and compare costs of adverse climate change effects and costs of adaptation measures and policies. By comparing the abatement costs, the adaptation costs and the damage costs it is, in principle, possible to determine the appropriate and economically justified level of adaptation.<sup>6</sup> From the perspective of individual nations, the aim is to find the amount of adaptation that minimizes the costs of climate change.<sup>7</sup> Where there is insufficient or under-investment in adaptation, avoidable and therefore unnecessary damage costs are incurred. Or, in the reverse case, where there is excessive or over-investment in adaptation, avoidable and therefore unnecessary adaptation costs are incurred.

Adaptive responses and measures might be relevant for more than one sector in a country or a region. Although individual sectors might want to achieve maximum adaptation to adverse climate change impacts, climate change may simultaneously inflict damages on a number of sectors, and local, regional and national government and international agencies should in

<sup>6</sup> ‘Real world’ comparisons of climate policy costs and benefits will be somewhat hampered by the lack of full knowledge about the costs of climate damages. Abatement costs will be known with more precision. An optimal climate policy is achieved when adaptation and abatement is done until the marginal costs of adaptation equal the marginal costs of abatement and the marginal costs of remaining damages.

<sup>7</sup> The most cost-effective national mix of abatement and adaptation strategies depends on a range of issues, including the contribution of greenhouse gases of the individual countries. Africa contributes less than 7 per cent of global total greenhouse gases (Okoth-Ogendo, H.W.O. *et al.* 1995:30). Given the global emissions of greenhouse gases, and expected abatement level due to the FCCC, the rational choice of a country is to undertake adaptive measures as long as the marginal cost is lower than the residual damages for the country.

such circumstances compare impacts and develop appropriate multi-sectoral adaptation responses. Interlinkages and cross-sectoral effects of adaptation strategies should be examined. It is essential that the total amount of resources available for adaptation purposes is used in such a manner that the optimal level of adaptation for a part of a country, a country, or a region is achieved.

Steps should be taken to prepare for expected future climate change impacts when costs are modest. There may in some cases exist inexpensive opportunities today to prepare for future climate changes, whereas it may be very costly later to adjust to climate change. This is relevant for infrastructure constructions with long lifetimes (e.g. dams and bridges). Moreover, adaptation is necessary in those cases where climate change can inflict irreversible damage (e.g. loss of species or loss of valuable ecosystems). In addition, “unfavorable trends” may contribute to complicate possible future adjustment to climate change and increase costs of climate change.<sup>8</sup> For example, coastal development in climate-sensitive areas may contribute to future losses due to rising sea-level. Opportunities for adaptation therefore may be lost if possible climate change impacts are not taken into account today.

Non-climate change-related benefits from climate change adaptation might be significant and could make adaptation more attractive in an economic sense. Examples of ‘no regrets’ adaptation projects are early warning systems for extreme weather events, which also might help to detect types of weather events that are not climate change caused but cause considerable damages to property and result in loss of human lives, and improved irrigation systems.<sup>9</sup> Those ‘no regrets’ opportunities are basically concerned with development of needed capacity to deal with present climatic variability. Moreover, although the benefits of adaptation projects might be mostly local, some adaptation projects might have positive global side-effects, such as preservation of biological diversity, and would therefore bring global environmental benefits. In general, the overall benefits of adaptation projects, also benefits that are unrelated to climate change, should be included in the examination of adaptation options.

### *Increasing flexibility*

It is important not to select adaptation options which under different climate conditions might prove undesirable but cannot be adjusted if needed. The need for flexible adaptation measures and policies is accentuated by the current uncertainties with regard to climate change and climate impacts.

According to one study: ‘Flexible systems and polices are those that allow self-adjustments or midcourse corrections as needed without major economic or social disruption’ (OTA, 1993: 16). Ideally it would be possible to modify measures and policies to reap benefits but avoid unnecessary or undesirable costs due to inflexibility. Because climate in the future is uncertain, an adaptation policy should perform successfully ‘under a wide range of climate conditions, such as hot and dry, hot and wet, more intense rain storms, etc.’ (Smith and Mueller-Vollmer: 19). For example, instead of building an expensive dam it might be preferable to improve systems for water conservation and water collection because if it with more information becomes evident that the dam will not be needed, improving water conservation and water collection is a more flexible strategy (OTA, 1993: 16).

There are indeed many other examples of flexible policies and measures. To mention one, developing agricultural crops that are able to grow despite changes in climate variables such

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<sup>8</sup> For a discussion of “unfavorable trends”, see Smith and Lenhart, 1996.

<sup>9</sup> Similar to ‘no regrets’ projects discussed in the context of GHG abatement, it could be asked why climate change adaptation projects, that seemingly make economic sense in themselves, are not being undertaken and why they should be the object of policy.

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as temperature and precipitation would increase flexibility. In general, scientific research might increase knowledge of options and therefore hopefully increase flexibility. But flexibility is not achieved simply by developing a wider range of options; social institutions and policies may act as barriers and limit flexibility. For example, it is important to correct imperfections so that the market is sufficiently flexible to allow farmers to change to more climate resistant crops, or that government subsidies do not, implicitly or explicitly, increase vulnerability to climate change by unwisely encouraging expansions in coastal zones. It will also be important to increase knowledge of and access to relevant technologies.

### *Increasing Robustness*

By decreasing vulnerability to adverse effects from climate change, policies can reduce the risks of climate change and make systems more robust to climate changes. Enhancement of robustness can be achieved in many ways. Developing and planting crops that could withstand even considerable changes in climate would increase robustness. By applying a variety of strategies against losses it may be possible to reduce losses. For example, a strategy based on a mix of management strategies for forests could help to reduce losses and thereby increase robustness (OTA, 1993: 17).

Preparations today for future unknown climate changes can also be seen as an improvement on the robustness of a system. Similar to an insurance, by investing a small amount today it might be possible to prevent severe losses in the future. For example, establishing gene banks or learning more about how to restore ecosystems could be part of an climate change insurance or investment strategy (OTA, 1993: 16). Moreover, since climate change represents an important additional stress, enhancement of robustness would be achieved by decreasing the existing vulnerability of systems. By reducing non-climate stresses, natural and socioeconomic systems would become more robust and less vulnerable to climate-related stresses. For example, introducing more environmentally sound agricultural practices in Africa will increase the robustness to climate change.

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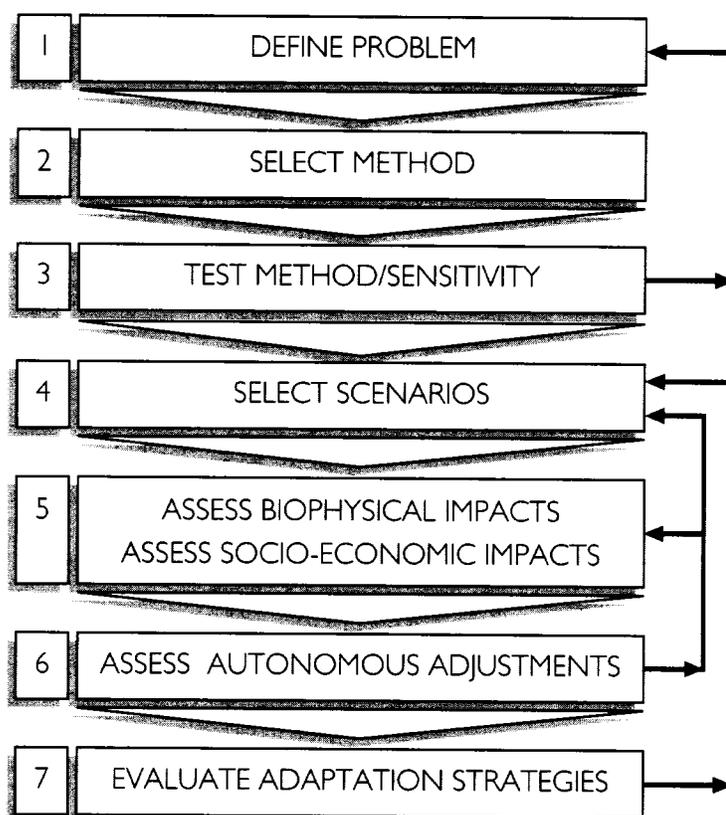
## CHAPTER 4. ADAPTATION STRATEGY FORMULATION: ANALYTICAL TOOLS AND STEPS

This chapter presents methodology and concepts that are relevant for analysis of adaptive responses to climate change. While some of these concepts and methodology already are discussed more thoroughly in chapter 3, this chapter shows two ways in which these have been brought together with the explicit aim of developing concrete and justified adaptive measures to climate change. Some of the concepts are also applied in chapters 5 and 6 in this report. This chapter examines in more detail the proposals for analysis and development of adaptive policy strategies that have been made by the Intergovernmental Panel on Climate Change (IPCC) and the U.S. Country Studies Program, respectively. Both suggest a generic and rigorous methodology for adaptation studies, and there are some similarities between these two methodologies.

### 4.1 The Intergovernmental Panel on Climate Change (IPCC)

The most comprehensive attempt to produce guidelines for identification and comparison of climate adaptation strategies has been made by the IPCC (Figure 4.1). The purpose of the guidelines has been to help conducting estimations of impacts and adaptations which will make it possible to compare assessments made for different regions, geographical areas, sectors and countries.

**Figure 4.1.** Seven steps of climate impact assessment.



Source. Carter *et al.*, 1994: 5.

According to the IPCC, climate impact and adaptation assessments should involve the following seven steps:

- Definition of the problem
- Selection of the methods
- Testing the method
- Selection of scenarios
- Assessment of biophysical and socio-economic impacts
- Assessment of autonomous adjustments
- Evaluation of adaptation strategies

The tasks which adaptation analysts face at the various steps of the climate impact assessment can be summarized as follows (Carter *et al.*, 1994).

- (1) *Definition of the problem* includes identification of the specific goals of the individual assessment, the ecosystem(s), economic sector(s) and geographical are(s) of interest, the time horizon(s) of the study, the data needs and the wider context of the work. The goals of assessments vary, and it is important to identify the precise goal of the individual study and assessment. The exposure unit (i.e. the impacted object) vary from study to study. Studies focus on a single sector (e.g. agriculture, forestry, or energy production), several studies in parallel but separately, or several sectors interactively. The selection of time frame vary depending, among others, on the sector to be studied and assessed. For example studies in industrial impacts might chose a time frame of 5-10 years, whereas studies of the forestry sector might use a 100-year perspective. Data needs vary from one study to another, and might impose limitations on a study. It is useful for policy makers who will evaluate the wider significance of a study and an assessment that it is presented in the context of similar studies as well as in the context of the political, economic and social system of the region.
- (2) *Selection of the method* depends upon the resources that are available, models and data. Impact assessment methods can be qualitative and descriptive and, in other cases, quantitative and prognostic. Single impact assessment may contain elements of more than one of these methods. Four general methods stand out: experimentation, impact projections, empirical analogue studies and expert judgment. Because of the impossibility of simulating a large-scale system such as the climate, experimentation is relevant only where the important variables are manageable (e.g. gas enrichment experiments with plants). Biophysical models, economic models, and integrated systems models are used in impact projections. Knowledge of the climate-society interactions in a region can be used to anticipate future climate impacts. Among such analogy studies four types can be identified: historical event analogies, historical trend analogies, regional analogies of present climate and regional analogies of future climate. Expert judgment in a given field can be solicited through literature review and identification of comparable studies.
- (3) *Testing the method*. It is important that the methods are tested in preparation for the main evaluation tasks. Feasibility studies, data acquisition and compilation and model testing may all be of value in testing the method.
- (4) *Selection of the scenarios*. This requires, first, a projection of environmental and socio-economic conditions expected to exist in the study period in the absence of climate change and, second, a projection of environmental and socio-economic conditions expected to exist with climate change.

Establishing the present situation; To assess the impact of possible future climate change, three baselines must be specified: the climatological, environmental and socio-economic baselines. The time frame of projections is also an important consideration. Three factors

can influence the time horizon selected: the limits of predictability, the compatibility of projections and whether the assessment is continuous or considers discrete points in time. Projecting future climate; In order to predict future climate and establish climate scenarios (i.e. a number of plausible future climates), three basic types of scenarios can be used: synthetic scenarios, analogue scenarios and scenarios from general circulation models. It is likewise necessary to project environmental trends with climate change and project socio-economic trends with climate change.

(5) *Assessment of impacts.* This involves estimating the differences in environmental and socio-economic conditions projected to occur with and without climate change. For sectors or area(s) of interest, impacts are estimated as the differences between projected conditions without and projected conditions with climate change. Assessment may include: qualitative description, indicators of change, compliance to standards, costs and benefits, geographical analysis, and dealing with uncertainty.

(6) and (7). *Assessment of autonomous adjustments, and evaluation of adaptation strategies.* The seven steps in the IPCC framework for evaluating climate adaptation strategies are:

- Define the objectives.
- Specify the climate impacts of importance.
- Identify the adaptation options.
- Examine the constraints.
- Quantify measures and formulate alternative strategies.
- Weight objectives and evaluate trade-offs.
- Recommend adaptation measures.

*Defining the objectives.* Analysis of adaptation need some agreed overall goals and evaluation principles. Among goals enjoying widespread acceptance are sustainable development and reduction of vulnerability. More precise and concrete objectives will often be defined in government programs, legislation, environmental treaties, or through a interpretation of goals such as those mentioned above.

*Specifying the climatic impacts of importance.* This involves an assessment using methods described above of the possible climate impacts. In order to develop adequate adaptation strategies, expected possible climate impacts should be described as precisely as possible.

*Identifying the adaptation options.* The main purpose of assessment is to produce lists of options fitting to the climate impacts to which adaptation is considered to be necessary. Six types of adaptation strategies for climate change have been identified:

- *Prevention of loss*, involving anticipatory actions to reduce the susceptibility of an expose unit to climate impacts.
- *Tolerating loss*, where adverse impacts are tolerated because the exposure unit has some adaptive mechanisms and absorptive capacity for climate impacts in the short term.
- *Spreading or sharing loss*, impacts are tolerated but the burden of impacts is carried not only by those affected by climate impacts but is distributed over a larger region or population.
- *Changing use or activity*, involving a switch of activity or resource use to adjust to the adverse climate effects.
- *Changing location*, where preservation of an activity is considered more important than its location, and migration occurs to areas which are more suitable under the changed climate.
- *Restoration*, which aims to restore a system to its original condition following damage or modification because of climate.

IPCC acknowledges that there exist numerous ways to classify adaptation measures, but, no matter the sector of concern (e.g. forestry, agriculture, waster resources), a list will include among other management measures:

- Legal
- Financial
- Economic
- Technological
- Public education
- Research and training

The importance of closely examining relevant constraints on adaptation measures is underlined by the IPCC. The effectiveness of different measures should also be tested. The key evaluation step consists of weighing objectives and evaluating trade-offs. It might be relevant to examine adaptation measures in terms of: (i) national economic development; (ii) environmental quality; (iii) regional economic development; and (iv) other social effects. The final step is recommending adaptation measures by providing policy advisers and decision makers with information on the best available adaptation measures and adaptation strategy. Recommendations should also address relevant assumptions and uncertainties.

#### **4.2 The U.S. Country Studies Program**

The U.S. Country Studies Program has recently prepared the manual '*Guidance for Vulnerability and Adaptation Assessments*'. The manual defines the two key terms vulnerability and adaptation as follows:

‘An assessment of a country’s *vulnerability* to climate change is an evaluation of how changes in climate may affect segments of the natural environment, elements of the national economy, and human health and welfare. Key natural resource sectors that might be susceptible to changes in climate include agricultural crops, livestock, forests, water resources, coastal resources, fisheries, and wildlife’ (CSMT, 1994: p. 2-1).

The U.S. Country Studies Program’s manual makes clear that other sectors that might be affected by climate changes are human health, energy, infrastructure, and human settlements.

Regarding assessment of vulnerability, the U.S. Country Studies Program defines vulnerability assessment in the following way:

‘a *vulnerability* assessment consists of an analysis of the scope and severity of the potential effects of climate change. For example, a rise in temperature and an increase in rainfall may effectively lower (or raise) the yield of a country’s agricultural crops, which, in turn, may reduce (or increase) a country’s gross national product (GNP) and its economic well-being’ (CSMT, 1994: p. 2-1).

The U.S. Country Studies Program advances the following definition of adaptation:

‘An assessment of a country’s *adaptation* to climate change is an identification and evaluation of changes in technologies, practices, and policies that can be taken to prepare for climate change. For example, agricultural crops may be changed and planting cycles modified to adjust to changes in temperature and rainfall patterns’ (CSMT, 1994: p. 2-1).

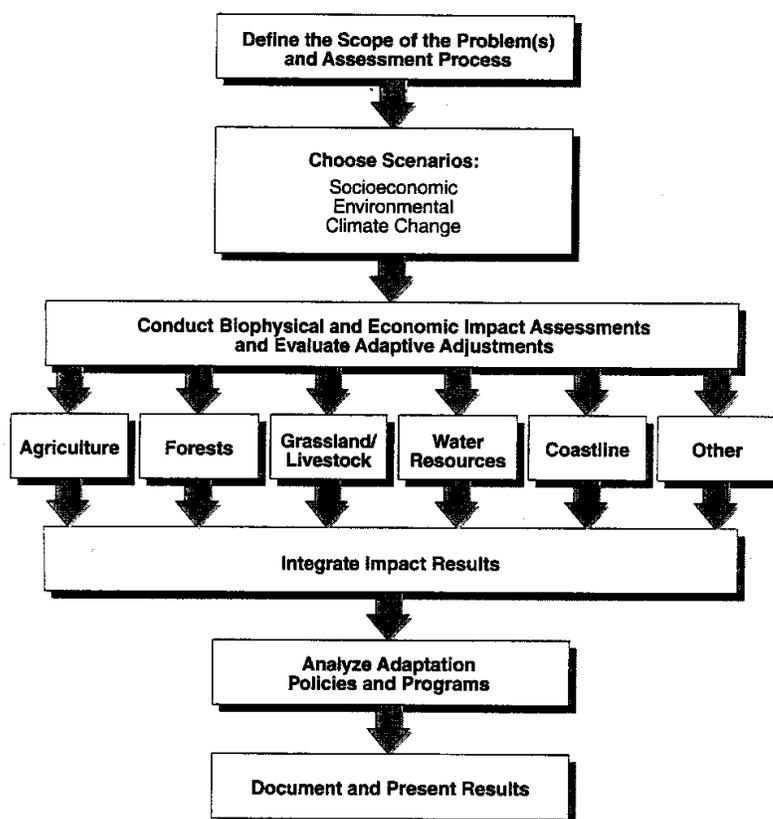
Approximately 100 scientists, engineers and policy analysts met in St. Petersburg, Russian Federation, from May 22-25, 1995, at the International Conference on Climate Change Adaptation Assessments. They agreed to a definition of adaptation to climate change as follows:

'Adaptation to climate change includes all adjustments in behavior or economic structure that reduce the vulnerability of society to changes in the climate system' (CSMT, 1995: 3).

### The climate change vulnerability and adaptation process

The U.S. Country Studies Program suggests a step-wise climate change vulnerability and adaptation analytical process (Figure 4.2) (CSMT, 1994: 2-4/2-6).

**Figure 4.2.** The Climate Change Vulnerability and Adaptation Process.



Source: CSMT, 1994: 2-5.

In the first step, which is identical with the IPCC, the scope of the problem and assessment process is defined. This step includes defining terminology, identifying the issues to be addressed, and selecting sectors to be studied, and defining the geographical study area and time frame for the assessment. It consists of following steps:

- Identify assessment goals,
- Define sectors to be studied,
- Select the study region,
- Select the time frame,
- Determine data needs,

- Develop the context for assessment, and
- Develop a schedule.

The CSMT supports the overall goals of a climate change vulnerability and adaptation assessment as defined by the IPCC. The CSMT adds, in addition, that more detailed, country-specific goals also need to be identified. CSMT stresses that it is important to identify who will use the results of the assessment, determine what information should be generated for the assessment, and determine what level of detail is necessary.

In the second step, the sectors which are most vulnerable to the effects of climate change and will have the greatest impact on the population and the economy are identified. In order to determine whether a country should include a particular sector in its study, the CSMT proposes to examine issues as the following: Is the sector a major element of the national system?; Do any current conditions indicate that the sector is especially sensitive to changes in climate?; Would a disruption in the sector because of climate change have a major impact on human populations or economic activity?; Is there a foreseeable benefit to taking some actions to deal with climate impacts on the sector in the short or medium time horizon? To the extent these questions can be affirmed, it will be relevant to consider including the issue in a vulnerability and adaptation assessment.

Building on the IPCC, the CSMT suggest the following candidate study regions: administrative units; geographical or physiographic units; ecological zone; climatic zone; and sensitive zone.

Often the time frame for vulnerability and adaptation studies are long because climate impacts are mostly expected to become evident in the medium of long term. However, some adaptation measures may need to be implemented in the short term in order to deal effectively with a long-term problem.

Data availability and data need in particular vulnerability and adaptation assessments vary. If data are insufficient to the needs of a particular analytical methodology, it is preferable instead to chose a different analytical methodology.

To develop the context for assessment, the CSMT attaches special importance to identification of stakeholders - e.g. policy makers, climate researchers, government officials, educational leaders, non-governmental organisations, and the general public - in the outcome of the assessment. Development of ways to include the input of stakeholders in an assessment and ways to convey the assessment results to stakeholders is also considered important (CSMT, 1994: 3-5). Finally, the CSMT proposes a schedule for organizing and completing individual countries' vulnerability and assessment process (CSMT, 1994: 3-6).

The second step of the CSMT climate change vulnerability and adaptation process is the selection of scenarios to be used in assessing climate change effects, including defining and describing the scenarios underlying the assessment. Similar to the IPCC, comparisons between 'nonclimate', or baseline, scenarios and climate change scenarios are used in assessing vulnerability of sectors to climate change. The CSMT finds that climate change scenarios are useful in (i) helping determine whether particular sectors are potentially vulnerable to climate change, (ii) identifying thresholds at which impacts become negative or severe, and (iii) identifying the relative vulnerability among sectors and regions. According to CSMT, climate scenarios are always uncertain since future developments cannot be predicted with certainty or accuracy. But scenarios are useful in identifying how changes in baseline conditions (most importantly, in population, income, or technology) increase or decrease particular sectors' sensibility to climate change.

The CSMT recommend using at least two baseline scenarios. In addition, a scenario with no-changes in current conditions should be included as it often is useful in illustrating changes in baseline conditions. It is also by comparison between the 'no-change' scenario and baseline scenario that baseline variables with significant effect on climate sensitivity

might be identified. Thus, such a comparison can be of essential help in formulating adaptation policies.

Similar to the IPCC, the CSMT includes estimates of climate, socioeconomic and environmental conditions in baseline scenarios. Predictions about development of baseline conditions should be based on best available sources, be internally consistent, and be guided by expert judgment. It is repeatedly pointed out by CSMT that the purpose of constructing climate scenarios is not to predict the future but to assess the sensibility of sectors to climate changes.

When developing climate scenarios, CSMT recommends that these are based on output from GCMs and so-called incremental scenarios (CSMT, 1994; 4-6/4-10). While GCMs are the best source of information on how an increase in concentration of greenhouse gases will change climate, they need to be supplemented by more reliable information on changes in regional climate variables.

The third step of the CSMT climate change vulnerability and adaptation process involves determining the biophysical impacts from examining the effect of the baseline, climate, and environmental scenarios on sectors (e.g. agriculture, forestry, water resources, and coastline resources). This step includes an evaluation of alternative practices and technologies for adapting to impacts, including economic considerations.

The biophysical assessment outlined by the CSMT contains two parts. The first part is an impact assessment of climate effects on a particular sector using the scenarios described above. The aim is to understand the direct effects of climate change (e.g., changes in crop yields). The CSMT recommends using either an empirical-statistical or a simulation approach to develop projections of the biological and physical effects. The second part of the assessment recalculates those effects by including effects of steps taken to adapt to the changes (e.g., changing crop planting cycles). Termed 'technical adaptation', this recalculation assumes that the steps taken do not have any major impact on the scope and extent of climate change. In other words, technical adaptation measures does not include attempts to reduce emissions of greenhouse gases.

The aim of step four and five of the CSMT climate change vulnerability and adaptation process is to integrate the results of each sector impacts and to analyze adaptation policies and programs. The intention is to produce concise information about a country's sensitivity to climate change and adaptation options that will be useful to decision-makers.

The CSMT presents different ways to integrate the results of the biophysical impact assessments: (i) integration across sectors is intended to deal with interactions across sectors; integration in common metrics is done in order to produce tangible comparisons of impacts across and can be done by integration (ii) cost to a sector of climate impacts, (iii) by determining the number of people affected by future climate change, which might be of crucial significance when deciding how to react to climate change, and (iv) by determining quantity of land and land-use affected by climate change may be an useful way to integrate impact results. Other ways to integrate the results include (v) integration with mitigation analysis, and (vi) integration with other government programs.

According to the CSMT, the goal of the adaptation policy assessment is to analyze anticipatory climate change options. While technical adaptation, or reactive adaptation, might be able to remedy some of the effects of climate change, climate change may in some cases result in unacceptable impacts, for example loss of human life or species diversity, and missed opportunities to anticipate adverse climate impacts by acting before climate changes occur. The CSMT recommends to analyze the effectiveness of current policies in coping with climate change, analyze the costs and benefits of alternative policies to anticipate the effects of climate change, identify which policies are most in need of immediate implementation, and involve policy makers in the assessment.

The primary approach developed by the CSMT consists of the following steps: (i) analyze vulnerability and technical adaptation. The most to be used for this purpose are described above; (ii) in the second step, the scope of the adaptation policy assessment is defined. The CSMT recommends to focus on the most vulnerable regions within sectors; (iii) as the third step, the sensitivity of current policies should be analyzed. Current policies on resources that are vulnerable to climate should be examined, and inventoried. All policies of consequences for the management of a particular resource should be identified, and the objectives of the policies should then be identified.

After the relative effectiveness of policies under climate change scenarios has been examined, the next step is to analyze alternative policies that might be better in adapting to climate change. The CSMT finds that the most important criteria are flexibility ('can policies meet their objectives under a variety of climate situations?'), and efficiency ('are the benefits larger than the costs?'). Among policies satisfying those criteria of flexibility and efficiency, it should then be assessed whether they could address climate effects that cause irreversible or catastrophic impact, would affect long-term projects, and result in unfavorable trends (CSMT, 1994: p. 7-5). In the sixth step, results are documented and presented.

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## CHAPTER 5. CLIMATE CHANGE AND AGRICULTURE IN AFRICA

### Introduction

The case study of agriculture illustrates some of the impacts of climate change and evaluates suggested adaptation strategies in Africa, following the categories proposed in the guidelines (Chap. 3). The case study does not attempt to provide a detailed inventory of adaptive responses, nor does it suggest the best mix of strategies for all of Africa or for specific regions. By illustrating how adaptive responses can be evaluated, the case studies provide examples of issues and methods for project officers to consider.

This chapter begins with a review of the effect of climate change on agricultural environments. The case study then focuses on three scales of the agricultural sector: field/household production, national food balances and international trade. The three levels of concern are matched by identifying the stakeholders who would be involved in responding to climate change and coping with its consequences. Finally, adaptive responses for different types of stakeholder are reviewed.

Case study material is taken from the available and emerging literature. Of particular interest are: international reviews of climate change issues that contributed to the IPCC (Strzepek and Smith 1995; Downing 1996; Hulme *et al.* 1995; Ominde and Juma 1991); the regional review of southern Africa coordinated by the Climatic Research Unit for the WWF (Hulme *et al.* 1996); country studies conducted for the U.S. (Lenhart *et al.* 1996), Environmental Protection Agency (Downing 1992), Food and Agriculture Organization and others; the IPCC documents themselves (Houghton *et al.* 1996; Watson *et al.* 1996, Bruce *et al.* 1996); and the volumes of related material on climatic variability, drought and agricultural development.

Agriculture is highly sensitive to climatic fluctuations, with a low intensity of cultivation, little irrigation, low yields and stagnant or declining food production. There is no accepted estimate of the economic impact of climate change in Africa. Common estimates are up to 10% of GDP, although the direct costs to agriculture are relatively modest, perhaps less than 1% of GDP (Pearce *et al.* 1996). However, the greatest concern is over the threat to regional sustainability and vulnerable livelihoods, values that cannot be readily calculated in monetary terms.

Agriculture accounts for over 30% of GDP in most of Africa. Most production is dryland, with irrigation on about 5% of the cropped area. About half of human food consumption is from cereals (maize, wheat, rice, millet and sorghum) a fifth from cassava, while livestock accounts for less than 10% of consumption. Other significant commodities are sugar cane, pulses, groundnuts, cotton, tobacco, coffee and tea. In semi-arid areas pastoralism dominates: this report does not explicitly discuss impacts on livestock economies although the general guidelines are still relevant.

While GNP per capita is low, and dependent on agriculture, African economies have been growing. Investment in agriculture, however, is low. Most importantly, household expenditure on food is high and human development is inadequate (high infant mortality and low female literacy), indicators of high socio-economic vulnerability. Dependence on food aid and high numbers of refugees highlight potential economic and political instability. Against this backdrop of underdeveloped resources, sensitivity to climatic fluctuations and enduring socio-economic vulnerability, the impact of climate change in Africa could be significant (Table 5.1).

**Table 5.1.** Agricultural sensitivity, capacity and vulnerability in Africa

## (a) Sensitivity to agricultural impacts of climate change

Region	Population Density	Population Growth	Crop Land % of total	Irrigated Land % of total	Average Yield of Cereals kg/ha	Food Production Index 1970=100
Northern	226	2.25	5%	27	1,973	115
Sudano-Sahelian	106	2.72	4%	7	727	90
Gulf of Guinea	891	2.83	21%	2	892	100
Central	145	2.70	4%	1	923	87
Eastern	541	2.88	10%	2	1,363	92
Indian Ocean	262	1.96	5%	23	1,988	98
Southern	208	2.56	6%	7	929	76
Total	253	2.65	6%	8	1,098	92
Bangladesh	9,853	2.18	72%	31	2,572	96
Thailand	1141	0.92	45%	19	2,052	109
Mexico	491	1.55	13%	21	2,430	100
Greece	795	0.07	30%	31	3,700	101
United Kingdom	2404	0.19	28%	2	6,332	112

## (b) Capacity to adapt to agricultural impacts of climate change

Region	GNP per capita \$	GDP in agriculture %	GDP Growth Rate %/yr	Fertilizer use kg/yr	Public agricultural investment \$
Northern	1,285	17	3.60	94	25
Sudano-Sahelian	860	34	2.36	5	7
Gulf of Guinea	760	39	1.87	6	15
Central	760	22	2.15	2	5
Eastern	593	47	3.05	12	13
Indian Ocean	280	22	3.85	140	6
Southern	333	21	3.38	27	7
Total	355	30	2.75	25	11
Bangladesh	205	37	4.20	101	68
Thailand	1,697	13	7.80	39	78
Mexico	2,971	8	1.50	69	129
Greece	6,530	17	1.60	172	25
United Kingdom	33,850	2	2.80	350	347

## (c) Vulnerability to food crises

Region	Expenditure on food	Food aid	Refugees	Female literacy	Infant mortality
Northern	42	18	221,450	45	59
Sudano-Sahelian	42	13	974,800	17	119
Gulf of Guinea	39	6	819,750	28	109
Central	39	3	480,500	41	97
Eastern	37	4	1,408,150	43	102
Indian Ocean	57	12	0	73	66
Southern	57	15	1,793,800	53	85
Total	57	10	5,698,450	35	97
Bangladesh	59	12	245,300	22	108
Thailand	30	2	255,000	90	26
Mexico	35	3	47,300	85	35
Greece	30	-1	1,900	89	8
United Kingdom	12	-3	24,600	0	7

Source: World Resources Institute (1994)

## Impacts on the agricultural environment

Chapter 2 reviews projections of climate change. The most important elements of climate change for Africa are CO<sub>2</sub> enrichment, changes in precipitation and changes in extreme events. Unfortunately, only changes in CO<sub>2</sub> concentrations are reasonably sure. Current projections of changes in precipitation are not reliable in Africa. Scenarios of extreme events are only beginning to emerge from the climate modelling community.

It is clear from research around the world that climate change will have mixed impacts. Sectors in some regions may benefit, while the same sector in other regions or other sectors in the same region may suffer. Within specific sectors, the impacts (positive and negative) may not be evenly distributed among the stakeholders or population-at-risk. The purpose of adaptation, therefore, is to maximise the utility of available climatic resources - a balance between taking advantage of new resources and preparing to limit the adverse impacts of detrimental changes.

The direct effects of carbon dioxide enrichment on plants tend to increase yields and reduce water use. Increased CO<sub>2</sub> concentrations increases the rate of photosynthesis and increases water use efficiency - the amount of water required to produce a unit of biomass or yield. The direct effects are strongest for plants with a C4 pathway, such as wheat, millet and sorghum, compared to C3 plants, such as maize and sugar cane (and most grasses). Of course, the effect is also true for weeds, many of which are C4 plants. According to the IPCC (Watson *et al.* 1996), the effect of a doubling in CO<sub>2</sub> concentrations (from the present) varies from a 10% to almost three-fold increase in biomass (Table 5.2). The IPCC did not report a consensus estimate of the range of increases in water use efficiency: they are likely to be in the same range, i.e., at least 10% to perhaps a doubling of water use efficiency.

**Table 5.2.** Biomass responses of C3 and C4 weeds and crops to a doubling of CO<sub>2</sub>

Category	Biomass Response
C3 Crops	1.10 to 2.43
C4 Crops	0.98 to 1.24
C3 Weeds	0.95 to 2.72
C4 Weeds	0.56 to 1.61

Source: Watson *et al.* (1996), based on a literature survey by Patterson (1993)

The CO<sub>2</sub> enrichment effect must be included in any assessment of climate change. CO<sub>2</sub> concentrations are almost certain to increase. While a doubling in CO<sub>2</sub> is not expected until 2100 or later, even with strong controls on GHG emissions, carbon dioxide concentrations are expected to be in the range of 450 - 550 ppmv by 2050, compared to about 350 ppmv at present (See Chap. 2). This range of projections is reasonably likely, and the beneficial effects of CO<sub>2</sub> will off-set at least some of the impacts of higher temperatures and reduced moisture.

It is very likely that local temperatures in Africa will increase, probably at around the global average. Warmer climates will alter the distribution of agroecological zones. Highlands may become more suitable for annual cropping due to increased temperatures (and radiation) and reduced frost hazards. This expansion of agriculture is important in the East Africa highlands. For example, agroecological suitability in the highlands of Kenya would increase by perhaps 20% with warming of 2.5 ° C based on an index in potential food production (Downing 1992). In contrast, semi-arid areas are likely to be worse off. In eastern Kenya, 2.5 ° C of warming results in a 20% decrease in calorie production.

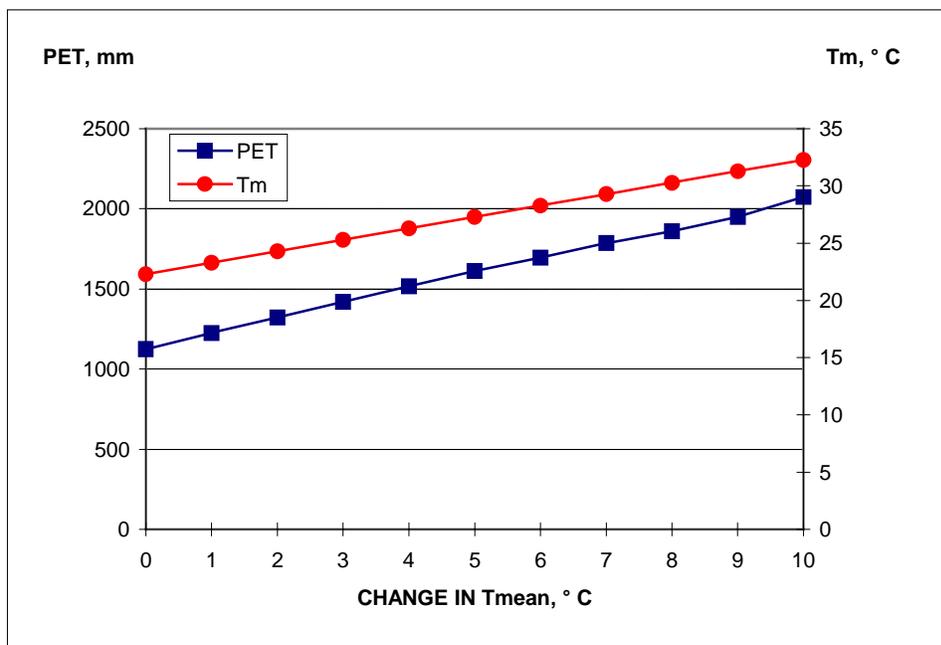
In some lowlands high temperature events may affect some crops. Growth is hindered by high temperatures and plant metabolism begins to break down for many cereal crops above 40° C. The effects of stress are related to the growth stage, flowering is often the most sensitive period.

Warming tends to accelerate plant growth, reducing the length of the growing season. If growth is accelerated during the period in which the grain is filling, the quality of yields may decrease. The effect of a shorter growing period is often the most significant impact of climate change, although it may be possible to develop cultivars that respond more slowly to accumulated temperatures.

Based on a scenario of warming (without changing precipitation) climate change would affect maize production in South Africa (Schulze *et al.* 1996). A regional hydrological model was coupled with CERES-Maize, a widely-used mechanistic model of cereal productivity. Where mean annual precipitation exceeds 600mm, along the east coast and north-eastern highlands, and for nitrogen-unlimited conditions, present yields average between 4 and 8 t/ha. In contrast, yields for subsistence farmers, where nitrogen is a limiting factor, are two-thirds less, exceeding 2 t/ha in only a few parts of the country.

Warming of some 2 °C and increased carbon dioxide concentrations (to 555 ppmv) increases potential yields in relatively wet regions (over 600mm) while the direct CO<sub>2</sub> effect counterbalances the temperature changes in drier regions. Nitrogen stress affects the absolute changes but has little effect on the impact of climate change. This example illustrates that the balance between temperature changes and water use efficiency, related to CO<sub>2</sub>, can be beneficial. Clearly, one conclusion from this assessment is that reducing the gap between subsistence producers (less than 2t/ha) and the top commercial farms (over 8t/ha) may be a higher priority than mitigating the impact of climate change *per se*.

Since low temperatures are not a major constraint in Africa, the dominant effect of climate change will be in altered water balances, especially in tropical and subtropical regions. Higher temperatures increase the atmospheric demand for moisture, or potential evapotranspiration (PET). The changes in PET per degree of warming are on the order of 100 mm in climates typical of semi-arid Africa (Figure 5.1). Where soils are deep and changes are modest, some amelioration of the impacts can be expected. In shallow, sandy soils reduced precipitation will lead to soil water stress more quickly. Shorter growing seasons or dry periods in the middle of the season will constrain the types of crops that can be grown and the reliability of yields.



**Figure 5.1.** Relationship between temperature change and potential evapotranspiration. Thornthwaite's estimate of annual PET was calculated for mean temperatures for semi-arid Zimbabwe and a latitude of 20 ° S. PET increases by 100mm for each 1 ° C increase in mean temperature. This indicates the amount of precipitation required to compensate for higher temperatures.

The sensitivity of current cropping systems to rainfall fluctuations has been highlighted throughout Africa. For example, Sivakumar (1991) related crop performance to the timing of rainfall events. Akong'a *et al.* (1988) constructed scenarios of maize yields based on historical distributions: the driest 10% of years resulted in maize yields varying from 30-70% of average between different agroecological zones. National crop forecasting models similarly related rainfall to crop performance, and have been used to assess potential impacts of climate change (Downing 1992). Maize, one of the principal crops, clearly varies in its response to good and bad years (Figure 5.2).

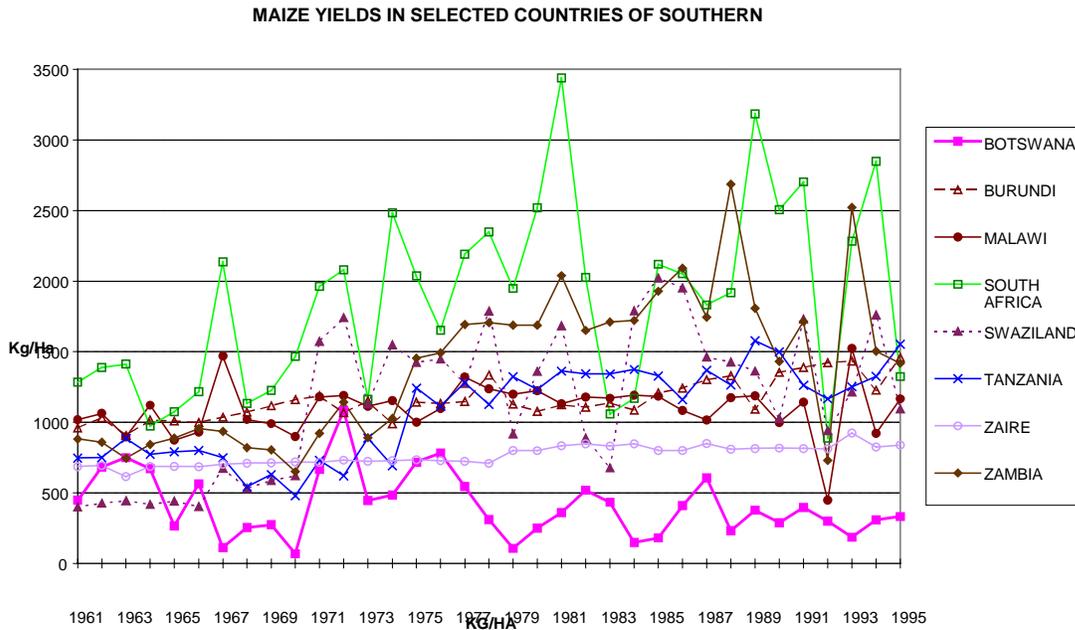


Figure 5.2. Maize yields in southern Africa. Source: FAO data.

At the local scale, dynamic crop-climate models have been used to evaluate the full range of potential crop responses to climatic variations. An example from Zimbabwe illustrates the methods and range of results. The current situation is simulated, using a crop-climate model and best practice for the present climate (Table 5.3). In this case, the CERES-Maize model was used (Muchena 1994). The *impact* of climate change is measured by the difference between the present and a scenario of future climate change with the present agronomic practices in place. Current yields, simulated for a research station (that is with a high level of management), average 3-5 t/ha. With warming of 2 ° C, potential yields would decrease to by up to 15%, and by up to 25% with warming of 4 ° C. Changes in precipitation might offset the temperature changes or cause even greater losses. The *ceteris paribus* impact of climate change in Zimbabwe might range between a 50% decrease to yield to potential yield being maintained or even improving somewhat in some regions.

Table 5.3. Sensitivity of maize yields to climatic variations in Zimbabwe

Agroecological zone	Unit	Banket Highlands	Gweru Middle zone, sub-humid	Chisumbanje Lowlands, semi-arid
Baseline yield	t/ha	4.7	3.7	2.9
Climate sensitivity				
+2 ° C	% of base	95	92	86
+4 ° C	% of base	80	76	73

Source: After Downing (1992), see also Muchena (1994)

Despite the adverse impact of climate change in Zimbabwe illustrated above, there is some scope for adaptive responses at the farm level. Table 5.4 shows results using the CERES maize model for Masvingo, a semi-arid site in central Zimbabwe. Without adaptation, potential yields are under 3 t/ha. With the Canadian Climate Centre scenario of climate change, crop failure would be common. However, planting a month earlier results in potential yields that are a third larger than at present. Yields could be three times the present level with full irrigation. Such adaptive strategies—planting early, using a short-season variety, and at least partial irrigation—can be effective at relatively modest cost.

**Table 5.4.** Potential maize yields with scenarios of climate change and agronomic adaptation for Masvingo, Zimbabwe

Agriculture	Climate	Yield, t/ha	Impact, % of baseline
No adaptation	Baseline	2.59	
	CCCM 2xCO2	0.06	2
With early planting and short-season variety	Baseline	3.00	116
	CCCM 2xCO2	3.49	135
Irrigated	Baseline	9.14	353
	CCCM 2xCO2	9.75	376

Source: Matarira *et al.* (1996).

The impact of changes in variability and extreme events is a major concern for African agriculture. Already many regions are risky - agricultural production has low returns and recurrent deficits. A shift toward greater risk might lead to reduced investment and to abandonment of some regions. The means to cope with drought have increased throughout the continent, but are quite short of providing long-term livelihood security for vulnerable populations.

The effect of climate change includes spatial shifts in agricultural potential, yields and comparative advantage. Mapping shifts in agricultural potential is readily accomplished for relatively simple agroecological indicators. A monthly crop-climate model, based on the Food and Agriculture Organization's (FAO) water requirements satisfaction index (WRSI) (FAO 1986), illustrates the approach (Hulme 1996).

The input data are monthly values. The maize crop (a typical tropical variety) is characterised by its typical growing seasons (days required for each phase of development) and the crop-water requirements for each phase (Kc values). With climate change, the growing season is assumed to be shorter. A length of growing season factor was included to adjust season length in the climate change conditions. Based on the site results in Zimbabwe seasons could be 10 to 25% shorter (or in some cases longer) for scenarios of climate change in (about) 2075. In this study, a 10% reduction was assumed, scaled to 2050. To accommodate the variability in seasons, the model was run for seasons starting in September to January. The maximum WRSI from the five potential start months was used. This both captures some of the spatial variability in planting and allows the start of the season to adjust with climate change. The water balance is calculated as the accumulated balance for the growing season of monthly precipitation and potential evapotranspiration. Available soil water is included, but as a single reservoir. The effect of carbon dioxide on water use efficiency is included. The direct effect of elevated concentrations of atmospheric carbon dioxide on the transpiration rate of maize was incorporated in the WRSI model through an adjustment factor applied to the crop coefficients.

At the regional scale, the maize WRSI model tests sensitivity to moisture deficits in spring/summer rainfall areas where planting would occur between September and January. For the baseline climatology (the 1961-90 period mean), almost all of southern Africa north of Namibia and Botswana is suitable for maize in the present climate - at least the water requirements are satisfied (WRSI=100) (Figure 5.3). In the Kalahari desert, drier conditions limit the suitability of maize. The most suitable season starts in September in the tropics and November in much of the SADC region.

**Figure 5.3.** Southern Africa Maize Water Balance, Baseline. Maximum water requirements satisfaction index (WRSI) for planting between September and January for a 130-day maize variety.

With the three scenarios of climate change superimposed on the baseline climatology, maize suitability remains high throughout most of southern Africa (Figure 5.4 to Figure 5.6). Small areas of decreased suitability remain in the semi-arid regions of Namibia, Botswana, South Africa, Zimbabwe and East Africa. The effects of the relatively modest scenarios of temperature and precipitation are apparent. In addition, increased water use efficiency overcomes the effects of higher temperatures and reduced precipitation in some of the semi-arid regions. Analysis of the more extreme scenario (ECHAM1TR) would likely show more drastic reductions in maize yields over a considerable area.

**Figure 5.4.** Southern Africa Maize Water Balance, Difference between the Baseline and CCC Scenario. Maximum water requirements satisfaction index (WRSI) for planting between September and January, for the CCC GCM scenario for the 2050s and the middle estimate of global temperature change for the IS92a scenario of global emissions.

**Figure 5.5.** Southern Africa Maize Water Balance, Difference between the Baseline and UKTR Scenario. Maximum water requirements satisfaction index (WRSI) for planting between September and January.

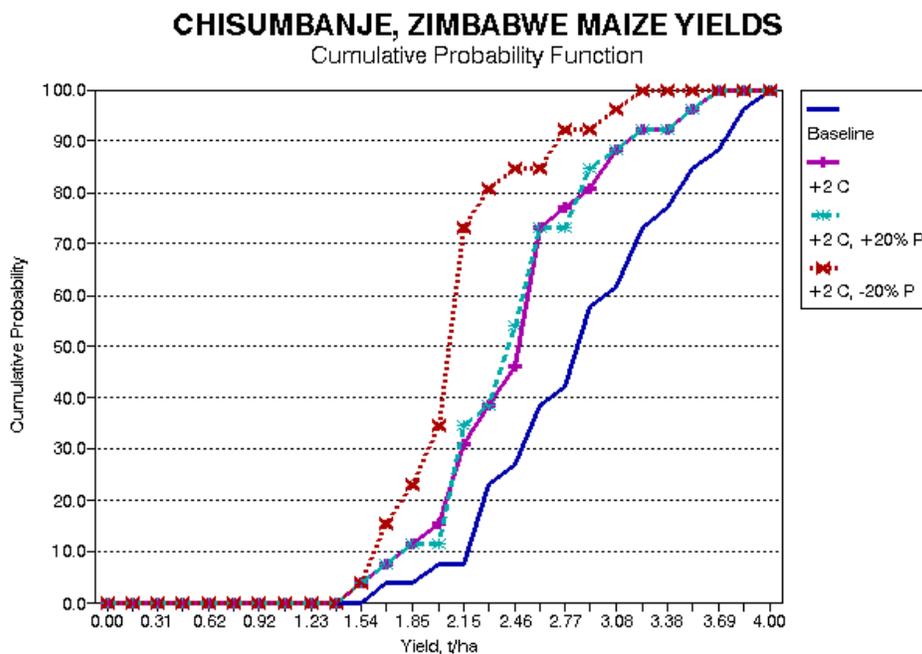
**Figure 5.6.** Southern Africa Maize Water Balance, Difference between the Baseline and OSU Scenario. Maximum water requirements satisfaction index (WRSI) for planting between September and January.

Particularly in Africa where plant protection is often rudimentary, the effect of climate change on weeds, pests and diseases must be considered. Spatial shifts are expected with climate change, as well as timing and intensity of infestations. While studies have been conducted on individual species (see Watson *et al.* 1996), few attempts have linked the impacts to agriculture in Africa.

Very few studies exist that link crop-specific impact assessments to national or subnational agricultural sector models, and the ones that have been published are primarily in developed countries. This is understandable, since the data base and understanding for regional models are more available in countries with commoditised production and systematic reporting systems. A case study of Egypt attempted to integrate sectoral assessments of climate change impacts (Strzepek *et al.*, 1995). However, changes in water availability for irrigation were inadequately incorporated into the international trade model.

Few scenarios of future drought hazard have been developed for Africa. Downing (1992) reviewed concepts of vulnerability, evaluated relative vulnerability at a national scale, and discussed implications of climate change for three case study countries in Africa (Kenya, Senegal and Zimbabwe) (see also Hulme *et al.* 1995). (For an example from Zimbabwe, see Chap.3).

The risk of climate change to this population is very serious, due to both spatial shifts in agricultural resources and shifts in risk. As shown above, spatial shifts in agroecological suitability imply a widespread reduction in potential yields in this region. Warming of 2 ° C and a 20% decrease in rainfall would shift the cumulative distribution of maize toward substantially higher risks (Figure 5.7). Median production would be 2 t/ha, a modest decrease from the present 2.8 t/ha. However, the probability of exceeding 2 t/ha would decrease from 95% to 65%. If such a target were critical for subsistence needs or commercial production, then climate change of this nature would threaten future livelihoods in this region. In addition, the probability of seasonal or prolonged droughts may increase with climate change.



**Figure 5.7.** Cumulative distribution of potential maize yields for Chisumbanje in semi-arid Zimbabwe. Source: Downing (1992).

Without appropriate adaptation, large areas of Zimbabwe would be further marginalised, accelerating rural-urban migration, exacerbating vulnerability and dependency during food crises. It is possible, as noted above, that current and future agricultural technology could overcome many of the impacts of climate change, even in the semi-arid regions. However, agronomic strategies are likely to work only during seasons where some moisture is available. During seasonal and prolonged drought little can be expected to maintain economic agricultural yields in dryland farming.

Ultimately, climate change is a global issue, even more so for traded commodities such as agriculture (in contrast to water resources). Some regions, for example, may be less competitive in national and global agricultural markets, with corresponding impacts on exports and imports. Africa in particular may be sensitive to changes in world prices and stocks since many countries rely on food imports.

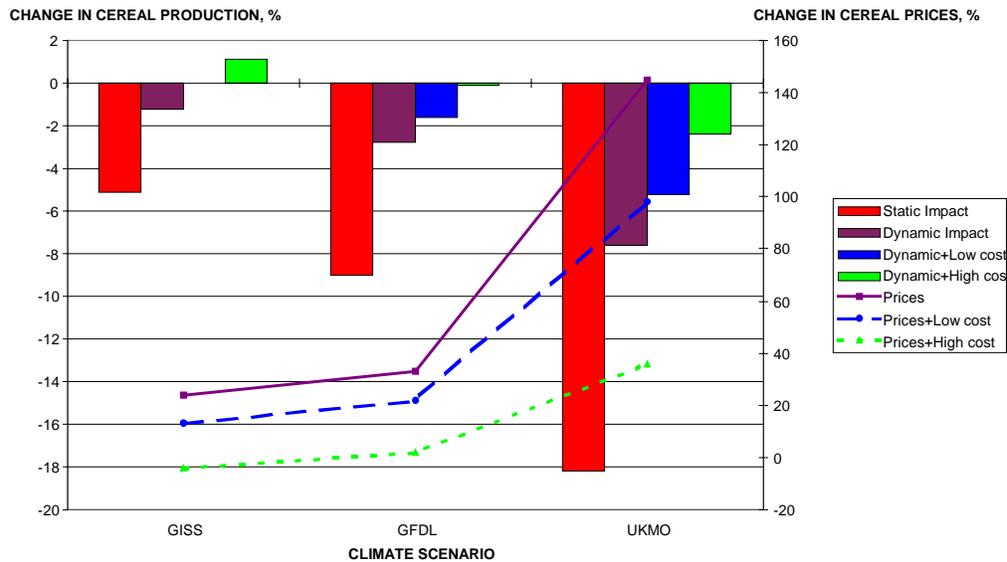
Several world trade models have been tested with scenarios of climate change, with differing assumptions regarding economic growth, population growth, trade liberalisation, and technological innovation. As global simulations they can illustrate some of the dynamic adjustments in world prices and regional imports and exports that may result from climate change. However, Africa is not well represented in such assessments. Scenarios tend to be trend projections that discount the potential for dramatic improvements in agriculture or welfare. And the lack of uniform and accessible data on crop-climate sensitivity in Africa leads to large uncertainties in predicted impacts in Africa.

The most detailed assessment is reported by Fischer *et al.* (1995). Changes in crop yields were estimated based on CERES and SOYGRO simulations, with expert judgement to estimate changes in crops that were not modelled and regions that were not represented by simulation models. National changes in yields for commodity groups were then used as input to the Basic Linked System. The BLS is a partial equilibrium model of demand, production and trade linking two dozen national or regional models with a global clearing mechanism. Scenarios were evaluated for several projections of world agriculture without climate change, three climate changes, and two sets of farm-level adaptation.

The most robust conclusion is that world food production can be maintained at the level that would have been reached without climate change. This does not mean that climate change has no impact. Rather, the world trade system is able to adjust to changes in mean conditions through economic incentives that stimulate production and trade. Figure 5.8 compares the reference scenario of the BLS system with the impact of climate change assuming that climate change occurs without any dynamic response by the world agricultural system. This *implied* impact would be up to a 20% loss in cereal production. However, if the economic system is allowed to respond to the trend of climate change impacts in each year, the impact would be much less, in the range of 1-8% losses in global cereal production.

Further adaptation is possible at the farm-level. Figure 5.8 also compares two sets of adaptive strategies tested in the model. Level 1 is essentially no-cost, the kinds of agronomic adjustments that would be routine in most farming systems: shifts in planting dates by up to 1 month; additional irrigation if already available; changes in cultivars. Level 2 would require some investment by farmers: large shifts in planting dates; increased fertiliser application; installation of irrigation; development of new crop varieties. The more aggressive adaptive strategy, at the global level, could lead to a decrease in cereal production of less than 2%, compared to twice that for no-cost adaptive responses, and eight times that for climate change without any adjustments at either the farm or international economic levels. For the less extreme scenarios, the changes are minor or even positive for the world as a whole.

The constraint on such changes, however, is the change in prices. In the more severe case, prices would double even with low-cost, farm-level adaptation. Again, the less severe scenarios show relatively modest changes in prices.



**Figure 5.8.** Impact of climate change on world cereal production (bars) and prices (lines) in 2060. Static impact refers to climate change without any adjustment. Dynamic impact shows the effect of economic adjustments, with two further scenarios of farm-level adaptive strategies. Low and high cost refer to different adaptive options. Prices refer only to dynamic simulations. Source: Data in Fischer *et al.* (1995).

It must be emphasised that such long-term simulation models are illustrative. They cannot handle the many indeterminate factors that trigger trends in food surpluses or crises, the complex relationships that influence national investment, comparative advantage and trade deficits, or endogenous mechanisms of economic growth, population growth and technological innovation.

What are the main conclusions regarding agriculture and climate change in Africa? The outcome of local climate change hinges on the balance between higher temperatures, CO<sub>2</sub> enrichment and precipitation change. Detailed simulations in a variety of contexts suggest that the impacts on individual cultivars could be significant. The effect of climate change is relatively less than the gap between current smallholder yields and optimum yields. And, relatively modest adaptation can overcome many of the anticipated impacts. Spatial shifts in agricultural zones should accommodate climate change in Africa; some locales in semi-arid regions face a more threatened future. The most significant challenge in fact may be in changes in Africa's position in world agricultural markets. If climate change is relatively less adverse (or more beneficial) elsewhere, severe dislocations in comparative advantage could curb export markets. Adapting to climate change thus focuses on several scales, from improving smallholder livelihoods to maintaining viable national exports.

## Catalogue of adaptive responses in agriculture

Chapter 3 reviews the range of stakeholders involved in coping with or responding to climate change. Within agricultural systems, the key stakeholders are:

- International agribusiness
- U.N. and bilateral aid agencies
- International and national NGOs
- National governments and ministries
- National agribusiness
- Community private voluntary organizations
- Individual consumers and producers

As mentioned in Chap. 3, in addition to stakeholders, one may consider special populations that are vulnerable due to resource constraints, social and political structures and economic conditions.

Table 5.5 lists generic agricultural adjustments that are practised at present and that may be appropriate to adapt to climate change. They are grouped according to the level of the agricultural sector in which they might be applied: land management, crop variety and land use, crop husbandry, and farm-level economic adjustments (macro-economic and sectoral planning should also be considered).

Examples of agricultural adjustments, corresponding to the types of adaptive responses suggested in the guidelines, are discussed below. The next section then evaluates specific adjustments to illustrate their prospective utility.

As noted in the general guidelines, there are several strategic objectives that underlie identification of the range of potential, specific adaptations. The most important in Africa is that the tremendous gap between maximum potential yields (as suggest in research station trials) and current smallholder yields must be narrowed. Climate change may not make this easier; agricultural development in most cases also provides greater flexibility in responding to climate change. Part of agricultural development and responding to climate change must be reducing vulnerability to climatic hazards – drought in particular. With better seasonal and multi-year climate predictions and systematic monitoring efforts, the individual, sectoral and national impacts of drought can be significantly reduced. Coping with climatic hazards is one key to coping with climate change.

These two strategies – agricultural improvement and reducing vulnerability to climatic hazards – should be the major priorities for climate change policy in Africa in the agricultural sector. A third strategy, however, may be warranted for some large projects with substantial infrastructure. If development increases vulnerability to climate change then specific adaptive capacity may be warranted.

### *Anticipatory Adaptation*

Most of the adjustments suggested in Table 5.5 fall into this category. They seek to improve agriculture through more efficient use of resources, development of technology, and diversification of agricultural systems. The objectives are to close the gap between present and potential yields, to increase farm profitability, and to reduce the risk of food crises.

A multitude of adjustments have been suggested for specific agroecological zones and cropping systems in Africa. Extension packages of new cultivars, soil conservation, fertiliser/mulching, and pest control have been researched, tested and propagated. In most cases, the packages are technically feasible and economically justified. That is, they would increase both yields and profits, at least under

**Table 5.5** Agricultural adjustments to climate change

Strategy & Adjustment	Mechanism	Costs	Timing for Implementation	Constraints and Issues
<b>Land Management</b>				
Moisture management: conservation, irrigation, soil drainage, mulching, fallowing; Soil management: mulching, tillage, crop rotation, land drainage	Regulate soil water balance through incremental irrigation, drainage, control of evaporation and runoff; Enhance organic matter, use of fertiliser, control soil erosion. Drainage may be required for saturated soils	Higher costs for additional irrigation works, water, operation and maintenance; Some additional labour and inputs	Gradual implementation with increased temperatures, often in response to drought	Water availability (surface and ground), water quality, terrain, alternative demands for water, investment capital and incentives
<b>Crop Variety &amp; Land Use</b>				
Cultivars; Rotations; Crop substitution; Cropped area; Crop location; Conversion to/from crops or pasture; Changes in specialisation; Livestock types & levels	Switch varieties, crops or rotations: longer maturing varieties, heat and drought tolerant, requiring less vernalization; More flexible cropping system with seasonal forecasts, spread risk; Switch location (regional or within farm) to new climates or soils; Change specialisation, eg, arable/pasture production; Change resource intensity (eg, stocking rate)	Costs include: development of cultivars; livestock breeding; restructuring for different farming systems; Marginal costs may be minimal if encompassed in normal agricultural investment	Costs are staged or incremental, but related to rate of climate change and possible effects of severe episodes; New cultivars require 10-15 years to develop	Lead time to develop new cultivars; Soil suitability and terrain in conversion to agricultural uses; Delayed response to new conditions; need for additional information and training; Availability of genetic material
<b>Crop Husbandry: Planting &amp; Harvesting</b>				
Timing of planting and harvest; Plant mixed varieties; Planting depth; Plant density	Earlier/later scheduling with changed growing season or to shift timing of heat stress; Flexible cropping system; Plant deeper in drier conditions; Thin crop in dry years lowers plant density and reduces competition for moisture	Few additional costs; Shifts in labour requirements during season	Gradual adjustment with little lead time; Possibly greater flexibility in response to seasonal or monthly weather forecasts	Availability of cultivars, changes in winter season, frost, soils, field accessibility due to wet conditions may limit applicability
<b>Crop Husbandry: Fertility &amp; Pest Management</b>				
Herbicides; Pesticides; Fertilizer application; Nitrogen-fixing crops	Control weeds to reduce competition for moisture, nutrients, and light; Control pests and diseases that limit plant growth, yield, or yield quality; Nature, quantity, and timing of fertilizer affect plant uptake	Input costs increase in general; Considerable savings possible for some fertilizer/crop regimes, but increased costs in other regions	Gradual adjustment with short lead time and rapid responses, except for new crops and invading pests, diseases, and weeds	Toxic and ecological concerns with fertilizer leaching; Information to respond to new pests, diseases and weeds, new crops
<b>Economic Adjustments: Farm level</b>				
Investment in agriculture: equipment and machine; farm inputs; Savings & storage; Labour & employment; Off-farm purchases; Food consumption	Increased investment in agriculture to increase yields; Increased food storage reduces variability in supply; Increased savings and purchases supplement storage; Off-farm employment to support increased investment and food purchases; Altered food consumption to cope with seasonal shortages, shifts to new varieties, economic crises, labour demands	Infrastructure for storage, marketing; Operation and maintenance costs for storage; Opportunity cost of off-farm employment; Costs of new technology; Additional costs in dry years for purchases, replanting, etc.	Gradual but variable related to yields; Storage facilities minor on-farm; Gradual shifts in employment, but sudden with extreme episodes	Limited by finance, technology, type of agricultural production, surplus, access to regional and international economic and trade

optimum conditions. For example, the cost-benefit margin of improving soil conservation in eastern Kenya is significant (Holmberg 1985).

A continuing debate concerns the trade-offs between intensifying production through specialisation and reducing risk through diversification. While this tension has present implications, it may be exacerbated with future climate change. The balance for individual farming groups may depend on the extent and terms of their market access. For example, largely subsistence farmers who do not value their on-farm labour at market rates, are likely to favour a higher level of risk aversion and income diversification than a commercial farmer who uses the market (credit, savings, investments) to stabilise income fluctuations over time.

### ***Institutional and Regulatory Adaptation***

Where development increases vulnerability (e.g., coastal development), fails to protect the vulnerable (e.g., economic restructuring) or occurs on a large scale, institutional and regulatory reform may be warranted. In semi-arid regions where climate change may be adverse, water resources for irrigation may not be reliable, and salinization of soils may reduce agricultural potential. Planning for such development should at least evaluate the effect of climatic variations on project performance. Regional monitoring of climatic hazards and enhanced management of food crises, sectoral support to monitor and manage regional production, and medium-term decisions on investment in specific agroecological zones may all be warranted and require institutional changes. Establishing priorities for development based on future land capabilities may be premature for most regions. Flexibility in development priorities should be retained, and new information taken into account.

Regulation of resource allocation and development is deficient in much of Africa. The ability of community groups to manage rapid resource changes may warrant further support. Market structures often support crops with a high level of risk and fail to support markets for drought-tolerant crops. Regulations constraining free trade may increase the volatility of local markets and food supplies in response to climatic variations. Irrigation planning is the most obvious candidate for addressing climate change impacts. Evaluation of a range of crops and cultivars should be undertaken to test the sensitivity of specific crops to water stress and high temperatures.

There is ample justification for enhancing regional monitoring of climatic hazards and institutional capability for mitigating food crises. The threat of climate change should justify additional support. Climatic hazards may well represent the most significant and earliest impacts of climate change. Monitoring might begin to consider potentially new hazards, such as floods and severe storms, although the probability of changes in their incidence is unclear at present.

With higher temperatures and different precipitation patterns the variability of farm-level and regional production may change. At the farm-level it is difficult to recommend specific adjustments related to climate change, although monitoring of vulnerable groups should be enhanced (as noted above). At the national or regional level, planners should evaluate the sensitivity of sectoral management strategies to increased variability in yields and changes in the mix of crops. For example, in Zimbabwe maize production could well be more variable with a modest change in mean climatic conditions. This would necessitate revisions in strategies for holding contingency reserves and options for importing from African and global markets. Increased yield variability in marginal lands might force a shift from maize to millet and sorghum as the staple cereals. At present, regional markets for millet and sorghum do not exist in southern Africa and might warrant stimulation to promote sustainable agriculture in semi-arid regions.

Spatial patterns of investment are related to expected returns, at least in principal. If climate change alters the distribution of agroecological zones, then some areas may be less suitable for future agricultural development. It may be too early to make such a judgement for most regions in Africa. However, project evaluation should recognise that large-scale changes in

the production environment are possible and could affect returns over the next three to five decades.

### ***Research and Education***

In addition to anticipatory strategies, research and education are warranted. The emphasis should be on linking current agricultural strategies to responses to climate change. Planning for long-term agricultural research programmes should include maximising the CO<sub>2</sub> effect, enhancing water use efficiency, and development of heat and drought tolerant cultivars, in addition to present efforts to design new technologies.

A recurrent conclusion is that it may be too soon to mobilise a public education campaign aimed at coping with the potential impacts of climate change. Relatively little advice will be accurate enough to expect individuals to make key decisions at the local scale.

However, broad institutional development and education is warranted in four arenas: (1) development of data bases; (2) assessment of present and future resources and environmental changes; (3) research capacity for developing sustainable agricultural systems; and (4) policy evaluation and support. In particular, the linkages between energy use, greenhouse gas emissions and potentially adverse impacts need to be communicated to develop local and national support for abatement policies.

### ***Development Assistance***

The highest priority in Africa may well be to continue appropriate development assistance that reduces poverty, stimulates economic growth and conserves the environment. While these objectives should not be changed because of climate change, successful development should make it easier to cope with the impact of climate change. Specific arenas that warrant further assistance include promoting economic growth especially in rural areas, nutritional support, and education. In many developing countries, preparation of national communications for the Framework Convention on Climate Change has shown the links between development and adapting to climate change (see Box for an example from Malawi).

#### **Box: Climate Change Adaptation and National Development in Malawi**

The FCCC and Malawi's Statement of Development Policies agree that two central goals are: "...to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner" (cited from U.N. 1992, see MEPD 1987). As a signatory to the Framework Convention, Malawi is committed to preparing a national communication that identifies priority measures for adapting to the country's vulnerability to climate change. Preparing the national communication is well underway.

Vulnerability to current climatic fluctuations is apparent in agriculture and water resources. Farmers must cope with recurrent drought, through strategies such as growing drought-resistant varieties, maintaining strategic reserves, importing additional food for commercial markets and relief aid, managing livestock at sustainable levels, and diversifying farm incomes. Coping with vagaries in local water supplies and hydropower often stretches household resources and in the national economy.

Within the National Development Policy (MEPD 1987), three national plans address specific priorities: the National Environmental Action Plan (MREA 1994), National Disaster Action Plan (MDPRR 1994) and the Policy Framework for Poverty Alleviation (MEPD 1995). An Environmental Support Program funded by the World Bank will become part of the Public Sector Investment Program, providing an opportunity for climate change adaptation policy to be included in national operational planning, through the Climate and Air Pollution Task Force.

The adaptation analysis will (1) assess current adaptation strategies, based on costs, long-term sustainability, social and political implications (including effects on vulnerable groups), market incentives/disincentives, negative impacts, and implications for other sectors, (2) identify prudent anticipatory adaptive measures that could be included in the Public Sector Investment Programme, particularly for cost-effective near-term investments to avoid expensive or irreversible impacts in the future, (3) compare the benefits and costs of adaptation options with other national priorities, (4) identify possible modifications to projects planned for implementing the National Environment Action Plan and the National Disaster Action Plan to ensure that climate change is included.

The detailed planning to adapt to climate change in Malawi has begun and should provide information for future decisions on development and environmental assistance.

Source: Theu *et al.* (1996)

### Evaluation of selected adaptive responses

The full range of adaptive responses to climate change in Africa have yet to be compiled and evaluated. This section provides examples of selected strategies that illustrate some of the issues identified above and suggest the kinds of responses that might be effective. The responses are organised according to the scale of decision-making - farm-level, regional and national food balance, and global food trade - with an additional assessment of drought vulnerability. Table 5.6 shows the relationship between the following analyses and the more general typology of responses proposed in the guidelines. At each scale, responses may fall into different response strategies.

**Table 5.6.** Examples of agricultural sector responses to climate change

Response strategy	Agricultural example
Anticipatory adaptation	
(a) long life-times	irrigation schemes: increased capacity, availability of water, water use efficiency
(b) beneficial	maximize CO <sub>2</sub> effects in development of crops
(c) inexpensive	strategic reserves to accommodate increased variability
(d) extreme climatic events	drought early warning and response capabilities
(e) irreversible impacts	salinization: availability of water for flushing irrigation schemes
Institutional and regulatory reform	
(a) land use	coastal developments susceptible to saline intrusion
(b) institutions	social and economic support to cope with economic restructuring inherent in adapting to new resources
Research and education	
(a) new solutions	development of new crops and agronomic practices
(b) behavioural change	changing dietary preferences for foods no longer suitable
Development assistance for capacity building	
(a) ongoing investments and responses	crop substitution, incremental adjustment in inputs, extension of new varieties and practices

### *Farm-level adjustments*

Common packages of agronomic recommendations include such strategies as fertilising, pest and weed control, soil and water conservation, and changing sowing dates. Using process-based crop models it is possible to simulate the relative effect of some of these recommendations on yield quality and gross margins. In some of the few cases where this has been done, variations in agronomic practices can overcome a significant portion of the impact of climate change.

The impact of climate change is not static - farmers will readily alter their practices to accommodate to the new climate. As noted above, simulation of changes in the date of sowing and application of fertiliser are readily handled in crop models such as CERES. Simulations of the effect of these adaptations suggests that some (if not all) of the impacts of climate change can be effectively ameliorated by low-cost modifications of the cropping system. Even further improvements might be expected with soil and water conservation and switching to better cultivars.

It is important to note that the difference between (simulated) potential yields with and without climate change tend to be less than the gap between potential yields and current yields among smallholders in semi-arid areas. In the lower zone of Zimbabwe, yields are often on the order of 500 kg/ha, less than 25% of the expected yields in well-managed plots on research stations in the same zone. Thus, responding to climate change must emphasise agricultural development before undertaking anticipatory adjustments.

Table 5.7 qualitatively tabulates farm-level adaptive responses for three levels of adaptation: substitution of agronomic practices; altered inputs and agricultural development. The priority stakeholder is the smallholder farming sector. Commercial farms would be less likely to need assistance in these sorts of adaptive strategies. On the other hand, these strategies are less likely to be effective for agropastoralists and pastoralism in general. (A different set of adaptive strategies should be proposed.) There may be some competition for development assistance, but in general these agronomic packages do not entail serious resource use conflicts between farming groups and others or within farming communities.

**Table 5.7.** Evaluation of adaptive strategies: farm-level agronomy

Criteria	Substitution	Input-adjustment	Dev't	Aggregate
Stakeholders:				
Priority	S/holders	S/holders	?	S/holders
Resource conflicts	L	L	M	L
Resilience:				
Multiple benefits	L	L	H	M
Specific to climate change	L	L	L	L
Effectiveness	M	M	M	H
Strategic:				
Adaptation	L	L	H	M
Development	L	M	H	M
Timing:				
Planning horizon	1	1	5	1-5
Irreversible impacts	L	L	L	L
Cost-benefit				
Initial investment	L	L	M	L
Timing of benefits	1	1	1	1
Realization of benefits	Farm	Farm	Farm	Farm
Constraints:				
Information	L	L	M	L
Technology	L	L	L	L
Sociopolitical	L	L	M	L

Notes: Substitution of agronomic practices includes changes in sowing date, planting density, cultivars, etc. Inputs that can be altered include fertilizer, pest and weed control, and crop choice. Development strategies entail soil and water management that require more substantial investment. The aggregate column refers to a package of adaptive strategies that includes each of the above. Subjective ratings against the listed criteria are L=Low; M=Medium; H=High, and the number of years for the planning horizon and timing of benefits.

All of the adjustments can be implemented relatively quickly, often within a single season. Even investment in soil and water conservation represents a relatively modest investment, compared against the potential risk of climate change. The aggregate evaluation suggests that agronomic improvements are effective, can be readily implemented and have few substantial constraints to their adoption.

Irrigation schemes may be a special case in considering responses to climate change. They are sensitive to both direct impacts of climate change and to changes in water supply. The design and investment cycle is such that major schemes are expected to be operational for at least several decades, which puts irrigation planning into the time scale of expected climate change.

### Regional and national agricultural sector

At the national level, economic policies to promote agricultural development focus on maintaining a positive food balance and exports. Three types of strategies can be envisioned (Table 5.8).

**Table 5.8.** Evaluation of adaptive strategies: national economic planning

Criteria	Reserves	Markets	Development	Aggregate
Stakeholders:				
Priority	Consumers	Producers	Commercial farmers	
Resource conflicts	none	M	M	L
Resilience:				
Multiple benefits	L	M	H	M
Specific to climate change	M	M	L	M
Effectiveness	M	H	M	M
Strategic:				
Adaptation	L	M	H	M
Development	L	M	H	H
Timing:				
Planning horizon	1-5	1-5	1-5	1-5
Irreversible impacts	L	L	varies	L
Cost-benefit				
Initial investment	L	L	M	M
Timing of benefits	5-10	1-5	>5	>5
Realisation of benefits	consumers	producers	generic	economy-wide
Constraints:				
Information	L	L	M	L
Technology	L	L	M	M
Socio-political	M	H	M	M

Notes: Reserves indicates marginal increases in strategic stocks to allow for potential increases in production variability. Markets indicates adjustments to trade liberalization to encourage the private sector to absorb higher risks, such as tax and savings incentives. Development indicates the present suite of agricultural investment in research, development and extension. The aggregate column refers to a package of adaptive strategies that includes each of the above. Subjective ratings against the listed criteria are L=Low; M=Medium; H=High, and the number of years for the planning horizon and timing of benefits.

Maintaining strategic reserves allows the government (or marketing bodies) to dampen price fluctuations and release food in emerging crises. Quite large national reserves have been held in the past few decades, in some countries enough food to meet consumption for a year or more. In the 1990s, these reserves were reduced under structural adjustment agreements. International lending organisations noted that such reserves are costly to maintain and absorb a significant fraction of government resources. Better monitoring and more timely responses were seen as more efficient ways to cope with food shortages. However, many analysts have suggested that increased strategic reserves will be required to cope with climate change (most notably, Schneider and Londer 1984).

An alternative strategy would be to adjust markets and trading conditions to promote private sector responses to climate change and climatic variability. This might take the form of tax incentives for carry-over stocks or bonds to smooth income between adverse and good trading years. The stakeholders in such a strategy would be producers, including market traders, millers and agribusiness in general. This kind of strategy would build upon present efforts toward reduced trade barriers, with some specific adjustments to accommodate to climate change

The third realm of national or regional planning is to promote agricultural development in general. This does not require action specifically because of climate change. However, as

noted above, the gap between research and practice is as large as the gap between present yields and agricultural potential in Africa. The need to adapt to climate change could be used as one argument for fresh initiatives in promoting adaptive agricultural research and development in Africa.

The primary beneficiaries of national economic planning are consumers and commercial producers who depend on markets for food consumption. Market adjustments may entail some trade-offs between consumers and producers, or between relatively prosperous farmers and vulnerable smallholders who may not have access to inputs and markets. Yet, the potential for multiple benefits is high (except for strategic reserves which are a burden on the economy). Taken as a group, these strategies would be reasonably effective in preparing for climate change.

All of the strategies can be readily implemented, are not likely to have irreversible impacts (depending on the nature of specific developments), and generally have a strategic role in promoting a resilient economy. Benefits could be realized throughout the economy, although the incremental investment would take 5-10 years to pay off.

### *Global linkages*

Ultimately, prospects for African agriculture depend on global investment, demand and trade. At the global level, some policies to prepare for climate change may be justified. As for national and regional economic development, suggested strategies range from building strategic reserves, encouraging free trade and transfer of agricultural technology (Table 5.9).

The arguments for building global strategic reserves, both for major foods and of financing, follows the same argument as at the national level. Climate change may require additional trade to smooth out fluctuations in national production. Maintaining international prices within acceptable limits would benefit poorer countries who might not be able to afford large imports in times of scarcity (as might occur in a replay of the 1980s drought on the 1972 international scarcity of grains). It should be more effective to hold such as reserve at the global level, or shared among regional trading partners, rather than each country seeking to buffer its internal production. In the transition toward a new climate, such an international capacity to prevent food deficits becoming survival emergencies appeals to humanitarian goals of ending famine and reducing hunger.

Encouraging free trade between countries should stimulate agricultural markets in regions with a comparative advantage. This may be a major benefit to some countries, and a significant cost to others, as the impacts of climate change alter traditional markets. In principle, free trade allows national surpluses and deficits to be accommodated more efficiently. Supply and price fluctuations are thus buffered at the global level, widening the potential pool of responses to climate change. Free trade, of course, is already on the international agenda and little further encouragement is required. However, some incentives to the private sector to absorb additional risks may be required, as noted above.

**Table 5.9. Evaluation of adaptive strategies: global agricultural policy**

Criteria	Reserves	Trade	Technology	Aggregate
Stakeholders:				
Priority	Aid agencies	Com-modity Co.	Agro- technology Cos.	
Resource conflicts	L	M	M	M
Resilience:				
Multiple benefits	M	M	L	M
Specific to climate change	M	L	L	L
Effectiveness	M	M	H	H
Strategic:				
Adaptation	M	M	H	M
Development	L	M	H	H
Timing:				
Planning horizon	1-5	1-5	5-10	~5
Irreversible impacts	L	L	L	L
Cost-benefit				
Initial investment	M	L	H	M
Timing of benefits	5-10	1-5	>10	~10
Realisation of benefits	many: smallholders	many	producers	many
Constraints:				
Information	L	L	M	M
Technology	L	L	H	H
Socio-political	M	M	H	H

Notes: Reserves indicates a systematic approach to global strategic stocks to allow for potential increases in production variability. Trade indicates trade liberalisation to encourage the private sector to absorb higher risks, such as tax and savings incentives. Technology indicates agreements to provide agricultural and biotechnology to developing countries, especially for staple food crops and vulnerable populations. The aggregate column refers to a package of adaptive strategies that includes each of the above. "s/holders" refers to smallholders. Subjective ratings against the listed criteria are L=Low; M=Medium; H=High, and the number of years for the planning horizon and timing of benefits.

The most costly and long-term strategy proposed in this review is to develop international mechanisms to promote agrotechnology transfers to developing countries. An initial agreement might focus on basic foodstuffs: wheat, rice, and maize. International agencies might licence new technologies developed by biotechnology firms for dissemination and use in developing countries. Adaptation and mitigation might be explicitly linked, with a requirement that beneficiaries have agreed to limit greenhouse gas emissions. Funding requirements would be significant, although connections to emission taxes could be made.

The immediate beneficiaries of global linkages are commodity brokers and private companies, although aid and government agencies have strong interests. As for national policies, some resource allocation issues may imply trade-offs between regions, commodities and farming populations. Global policies should be highly effective, with a relatively low specificity to climate change or dependence on specific climate scenarios.

The planning horizon is on the order of five years, with benefits realised somewhat later. Except for agrotechnology transfer, there are few constraints to implementing global policies (other than bureaucratic inertia and funding).

### ***Vulnerability and drought hazard mitigation***

Drought hazard and vulnerability are present risks in Africa and likely to be the most damaging locus of impacts of climate change. Given the current and potential vulnerability in places such as Zimbabwe, concerted action is required in three areas: mitigation to reduce vulnerability, monitoring drought and vulnerability, and preparedness to respond effectively to emerging crises (Table 5.10). Considerable progress has been made in the past decade, a further decade of development might reap substantial rewards in efforts to eliminate widespread famine and enhance livelihood security, at least in times of drought.

**Table 5.10.** Evaluation of adaptive strategies: vulnerability and drought hazard

Criteria	Monitoring	Mitigation	Crisis Interventions	Aggregate
<b>Stakeholders:</b>				
Priority	Vuln	Vuln	Vuln	Vuln
Resource conflicts	L	L	M	L
<b>Resilience:</b>				
Multiple benefits	H	M	L	M
Specific to climate change	L	L	L	L
Effectiveness	M	M	H	M
<b>Strategic:</b>				
Adaptation	H	H	M	H
Development	H	H	L	H
<b>Timing:</b>				
Planning horizon	5	5	5	5
Irreversible impacts	L	L	L	L
<b>Cost-benefit</b>				
Initial investment	L	M	L	M
Timing of benefits	5	1	1	1
Realisation of benefits	Vuln+	Vuln	Vuln	Vuln
<b>Constraints:</b>				
Information	H	M	L	M
Technology	H	M	L	M
Socio-political	M	M	M	M

Notes: Monitoring: Investment in drought hazard monitoring and climate and crop forecasting, vulnerability assessment and monitoring. Mitigation: Activities that reduce vulnerability and the impact of drought episodes, such as small-scale irrigation and food storage. Crisis interventions: short-term relief and rehabilitation, including emergency food imports and distribution, targeted feeding, food and cash-for-work schemes, income support. The aggregate column refers to a package of adaptive strategies that includes each of the above. "Vuln" refers to vulnerable socio-economic groups. Subjective ratings against the listed criteria are L=Low; M=Medium; H=High, and the number of years for the planning horizon and timing of benefits.

The priority stakeholders should be the most vulnerable socio-economic groups affected by drought crises, although many levels of local, national and international actors are required to implement drought monitoring, mitigation and emergency responses. For example, Table 5.11 potential users and benefits of improved climate forecasts. Producers, traders and policy makers are likely to benefit from a range of climate forecasts.

**Table 5.11** Users and potential applications of climate forecasts

Type of User	Potential Application of Forecast			Benefits
	Multi-year Forecasts	Seasonal Forecasts	Within-Season	
Commercial Producers	Capital and land investment	Acreage planted; Planting dates; Crop/variety selection; Water management	Water management; Application of inputs; Harvest dates	Increased certainty and reduced risk; Improved financial viability; Long-term survival; Enhancement of comparative advantage
Subsistence Producers	Limited, possibly diversification and off-farm savings	Planting dates; crop/variety selection	Limited	Improved food security in poor years; Improved marketable surpluses in good years
Agricultural Support Services	Plant and capital investment; Research and development priorities; Location decisions; Production strategies	Product selection; Sales forecasts; Pricing policy	Adjustments to marketing strategy	Improved financial viability; Ability to respond better to farmers' requirements; Recovery from drought
Agricultural Extension Services	Promotion of drought mitigation strategies; Development of improved extension advice	Preparation of dynamic, climate specific extension advice to subsistence and smallholder producers	Specific adjustments to earlier extension messages and advice	Better extension service to subsistence and smallholder producers

Source: after Gibberd *et al.* (1996)

Drought policies provide multiple benefits to the extent that they contribute to development in general by reducing investment risk. However, crisis interventions can be counter-productive if they create a dependency syndrome or compete for resources from other activities with longer term benefits.

Reducing risk can have strategic importance. Increased monitoring and response capabilities should improve the ability to respond to long-term climate change and to economic management of the agricultural sector in general. With foresight, crises can be used to promote sound resource policies, although this remains the anomaly in most of the world rather than the norm.

Drought monitoring, mitigation and preparedness takes time to develop and implement. Once operational the benefits are immediate, although they are only significant during times of potential crisis. There are few irreversible impacts and the initial investment can be fairly modest.

Constraints include the need for sustained information collection, processing and reporting, often requiring significant development of technologies and organisations. While most planners and vulnerable populations agree that drought hazard planning and reduction are desirable, the lack of reliable systems implies further social, economic and political constraints. One that is commonly cited is the short attention cycle - drought planning peaks about a year after the drought and is forgotten until the next crisis. If drought becomes more frequent, this constraint may be overcome.

## Conclusion

It is essential to begin planning effective adaptive strategies for climate change. This is particularly true for large investments, such as dams and irrigation schemes. It is equally true for sustainable agricultural development. The extent to which Africa is able to intensify production and enhance resiliency to existing resource, social and economic threats may well be the critical measure of its capacity to cope with climate change.

In the near term, however, agricultural adjustments specifically required to cope with climate change are few. What matters in the next half decade is building the research and institutional capacity to respond appropriately and effectively as climate forecasts improve.

One logical starting place is implementing regional climate monitoring and forecasting systems that meet the needs of farmers and resource planners. Planning responses to take advantage of improved information on short-term, seasonal and longer climate requires a concerted effort.

Over the medium term, say the next 10-20 years, the first effects of climate change may well be signalled by persistent drought, or possibly floods in some regions. Disaster preparedness is therefore critical.

The effects of changes in mean climates, including the beneficial effects of CO<sub>2</sub> enrichment, may not be realized in Africa until after 2020 or so. More specific and robust regional forecasts of climate change in Africa may be available in the next ten years or so, allowing some lead time for implementing specific strategies if required.

The research effort on climate systems should be matched by further research on the impact of climatic variations, vulnerability and coping strategies. For example, although numerous studies of drought hazard and vulnerability have been undertaken in Africa, there is not at present a regional or continental assessment supported by climatic, soil and crop data, vulnerability modelling, and response evaluations. Specifically regarding climate change, the cost of potential adaptation is wholly lacking. Integrated assessments, spanning agriculture, water, biodiversity and health, need to be compiled in such a way that they can link to ongoing global efforts, yet building up from present resource understanding and issues in Africa.

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## CHAPTER 6. CLIMATE CHANGE AND WATER SUPPLY IN AFRICA

### Introduction

The implications of climate change for water systems managers are complicated by the spatial coarseness of climate change predictions, differences between regional and district level management of water resources, and the predicted decline in water availability facing water supply systems due to other factors over the next fifty years.

Scenarios of future climate change are discussed in Chapter 2. While projected CO<sub>2</sub> and temperature changes can be made with some confidence, the balance between increased evaporation and precipitation is uncertain—even the direction of the change is not known in Africa. Thus, planning responses to future climate change must be undertaken in the context of risk and uncertainty. Of course, water managers are accustomed to risk assessment. Adding additional values to embrace potential climate change should not be difficult.

Factors that contribute to vulnerability in African water systems include high seasonal and interannual variations, international basins, and poorly developed national and regional institutions. In practise, water management in Africa is compounded by the disparity of decision makers involved, from local users to international river basin agreements. Institutional development, especially between countries, is lacking.

Water availability in Africa varies between countries and regions (Table 6.1). The FAO suggest that the ratio between internal renewable water resources and rainfall can be interpreted as a "run off coefficient" which takes into account recharge of aquifers which are not connected to the river network. At the regional level this coefficient varies from 6% in arid areas to over 30% in humid zones. On a country level the coefficient varies from 2% in arid countries like Libya and Niger to over 80% in the most humid areas of Sierra Leone and Liberia. Although they cover the largest part of the continent, the Northern and Sudano-Sahelian regions contribute only 1.2% and 4.3% respectively of the total water resources of Africa.

**Table 6.1.** Regional Distribution of Water Resources in Africa

Region	Population	Area	Rainfall	Internal renewable water resources				Internal renewable water res. per caput (m <sup>3</sup> )
	1994			(km <sup>3</sup> /yr)	(mm/yr)	% of total	% of rainfall	
	(1000)	(1000km <sup>2</sup> )	(km <sup>3</sup> /yr)	(km <sup>3</sup> /yr)	(mm/yr)	% of total	% of rainfall	(m <sup>3</sup> )
Northern	123,697	5,753	411	50	8.7	1.2	12.1	404
Sudano-Sahelian	83,350	8,591	2,878	170	19.8	4.3	5.9	2,040
Gulf of Guinea	172,804	2,106	2,965	952	452.0	23.9	32.1	5,509
Central	71,473	5,329	7,621	1,946	365.2	48.8	25.5	27,227
Eastern	142,531	2,916	2,364	259	88.8	6.5	11.0	1,817
Indian Ocean Islands	15,048	591	1,005	340	575.3	8.5	33.8	22,594
Southern	92,205	4,739	2,967	271	57.1	6.8	9.1	2,939
Total	701,108	30,024	20,210	3,988	132.8	100.0	19.7	5,688

Notes: **Northern:** Algeria, Egypt, Libya, Morocco, Tunisia; **Sudano-Sahelian:** Burkina Faso, Cape Verde, Chad, Djibouti, Eritrea, Gambia, Mali, Mauritania, Niger, Senegal, Somalia, Sudan; **Gulf of Guinea:** Benin, Cote d'Ivoire, Ghana, Guinea, Guinea Bissau, Liberia, Nigeria, Sierra Leone, Togo; **Central:** Angola, Cameroon, Central African Republic, Congo, Equatorial Guinea, Gabon, Sao Tome and Principe, Zaire; **Eastern:** Burundi, Ethiopia, Kenya, Rwanda, Tanzania, Uganda; **Indian Ocean Islands:** Comoros, Madagascar, Mauritius, Seychelles; **Southern:** Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe.

Table 6.2 shows the distribution of water withdrawals by region between the three major sectors of water use: agriculture, communities and industry (FAO 1995b). For the continent as a whole, about 85% of water withdrawals are directed towards agriculture, but this figure varies considerably from one region to another (FAOa, 1995). Arid regions, where irrigation plays an important role, have the highest level of water withdrawal for agriculture. The Northern region alone represents more than 50% of the agricultural withdrawal of the continent. The importance of surface water transfers between countries is also clear, as withdrawal in arid areas can often exceed the level of internal resources. Seven countries concentrate about 60% of the irrigation potential of Africa (Angola, Sudan, Egypt, Zaire, Ethiopia, Mozambique and Nigeria); at the other extreme 18 countries share only 5% of this potential.

**Table 6.2.** Regional Distribution of Water Withdrawals in Africa

Region	Agriculture	Communities	Industries	Total	As % of internal resources	
	x 10 <sup>6</sup> m <sup>3</sup> /yr	%	%			
Northern	65 000 (85%)	5 500 (7%)	5 800 (8%)	76 300 (100%)	50.9	152.6
Sudano-Sahelian	22 600 (94%)	1 200 (5%)	300 (1%)	24 100 (100%)	16.1	14.2
Gulf of Guinea	3 800 (62%)	1 600 (26%)	700 (12%)	6 100 (100%)	4.1	0.6
Central	600 (43%)	600 (43%)	200 (14%)	1 400 (100%)	0.9	0.1
Eastern	5 400 (83%)	900 (14%)	200 (3%)	6 500 (100%)	4.3	2.5
Indian Ocean Islands	16 400 (99%)	200 (1%)	20 (-)	16 620 (100%)	11.1	4.9
Southern	14 100 (75%)	3 000 (16%)	1 800 (9%)	18 900 (100%)	12.6	6.9
Total	127 900 (85%)	13 000 (9%)	9 020 (6%)	149 920 (100%)	100.0	3.8

Notes: Regions as above.

Even without climate change, water resources in Africa are predicted to come under extreme pressure during the next half century. Using the World Bank bench mark for water scarcity of 500m<sup>3</sup>/cap/year (Falkenmark and Widstrand, 1992), water availability in selected African countries indicates the extent of the future crisis (Table 6.3). Changes in water availability due to global warming for African water managers add further pressure on the adaptability of the water system.

This chapter reviews potential impacts of climate change on water resources in Africa, followed by evaluation of potential adaptation strategies. The priority for responding to climate change must be on improving the *flexibility* of water resource management systems to cope with increased variability and decreased availability over time, including the impacts of climate change. Developing water management institutions would address economic development objectives and prepare for environmental change.

**Table 6.3.** Water Availability (m<sup>3</sup> per capita per year) in 2050

Country	Present (1990)	Present Climate (2050)	Climate Change, 2050 (range of scenarios)
Egypt	1005	452	300-600
Kenya	640	150	210-250
Madagascar	3330	710	480-730
South Africa	1320	540	150-500
Togo	3400	900	550-880

Source: Watson *et al.* (1996)

### Impacts of Climate Change on Water Supply

An increasing body of literature on climate change and water has appeared over the past few years, as witnessed by the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report (see Watson *et al.* 1996) among other studies (for example, Oliver and Oliver 1995, Smith *et al.* 1996, Strzepek and Smith 1995). While we draw upon the global literature for suggested adaptive strategies, relatively little work has been carried out for Africa. In general, the IPCC notes with regards to water resources management and the potential impacts of global warming the:

- uncertainties in GCM's and the lack of a regional specificity of consequences
- uncertainties in estimating changes in basin water budgets over next 100 years
- uncertainties in future water demands by sector
- uncertainties in the socio-economic and environmental impact of response strategies

Climate change will affect both water demand (related to higher temperatures) and water supply (the balance of CO<sub>2</sub> enrichment, evapotranspiration and precipitation (Table 6.4). While CO<sub>2</sub> enrichment is significant in annual plants, it is less clear the extent to which CO<sub>2</sub> will reduce transpiration for river basin catchments. So far, there is no consensus as to how much this might be especially in Africa.

**Table 6.4.** Effects of climate change on water resources

Climate change	Effect	Impact
CO <sub>2</sub> enrichment	Increased photosynthesis; Reduced transpiration	Increased water use efficiency
Increased temperature	Faster plant growth, increased transpiration; Increased evaporation from lakes and reservoirs; Reduced runoff and reduced groundwater recharge; Higher demand for water for irrigation, bathing and cooling	Changes in water yields; Higher stress on water delivery systems during peak loads
Rise in sea level	Land loss; Saline intrusion into coastal aquifers; Movement of salt-front estuaries affecting freshwater abstraction points	Reduced water quality in coastal areas, reduced groundwater abstraction
Change in seasonal precipitation	Change in soil moisture; Change in river runoff and groundwater recharge	Changes in projected yields of reservoir systems, changes in water quality
Change in spatial patterns of temperature and precipitation	Shift in basin hydrology (surplus and deficit regions)	Changes in infrastructure to supply water
Change in variability of precipitation (daily and interannual)	Changes in water stress between rainfall events; Changes in peak runoff	Increased requirement for storage in water supply systems
Change in drought hazard	Change in seasonal water stress or off-season water replenishment	Altered risk water resources
Change in flood hazard	Change in risk in flood plain, change in area affected	Altered risk for water resources, change in reservoir operations

Higher temperatures increase plant demand for water and evaporation from lakes and reservoirs. Lakes such as Victoria, Malawi and Tanganyika are in delicate hydrological balance—small changes in temperatures and rainfall could result in lower lakes levels (Arnell *et al.* 1996). Lake Victoria dried out completely in past eras. Water demand also responds to temperature changes, principally for irrigation (and watering gardens in urban areas). Some increased demand for cooling towers, consumption and recreation is also expected.

The major effects of climate change on African water systems will be through changes in the hydrological cycle, the balance of temperature and rainfall. There is some concern that the negative impacts of climate change on water supply could actually be larger and the gains smaller than reported in current assessments. Many GCM's have not explicitly incorporated the influence of drought in evaluating the impact of global warming. In particular, equilibrium models begin each year with no model memory of water depletion in a preceding year. Yet it is often the successive accumulation of back to back drought years that can have the most devastating effect on reservoir storage, marginal agricultural activities and water quality (Cline 1992).

Despite these uncertainties and limitations in scientific knowledge, Africa is generally regarded as the continent most sensitive to climate change. The current best guess climate change predictions and impacts on water resources in Africa by region and for major river basins are summarised below.

#### *Southern and Eastern Africa*

Runoff in southern Africa spans a great range, from less than 10mm to over 700mm (Table 6.5). Interannual variability is greatest in the semi-arid regions (for example, runoff in southern Zimbabwe between 1961 and 1990 varied almost 0 to over 150). Reynard and Andrews (1995, see also Hulme 1996) predict an overall reduction in annual rainfall in southern Africa and a change in the inter-annual variability of runoff. Model scenarios for 2050, following the standard IPCC methodology (Carter *et al.* 1994), indicate that runoff would decrease in two of the scenarios (UKTR and CCC) across most of the region. However, runoff increases in the “wet” scenarios, based on the OSU GCM experiment. For the drier scenario, decreases of 10-40% are widespread.

With climate change, the variability of runoff increases for the UKTR scenario, which included GCM results on the interannual variability of rainfall (Table 6.5). Changes in annual runoff may be less important than the change in the monthly distribution of runoff or changes in runoff variability. Scenarios suggest a lengthening of the onset of seasonal changes, resulting in a more variable wet season and monthly rainfall levels for the SADC region 15 degrees south latitude.

With much of the region depending on a defined wet season for rainfed agricultural production, these impacts would be significant. In particular, recent drought events during 1991/92 highlighted the sensitivity of water resources in Southern Africa to climate variations.

**Table 6.5.** Annual Runoff Statistics for Selected Grid Cells

Region	Mean, mm	Range, mm	Coefficient of variation, %	
			1961-90	UKTR
W Tanzania	377	598	38	57
Coastal Tanzania	585	735	31	42
NE Angola	744	1089	29	39
SW Angola	264	485	46	59
W Zambia	197	414	51	69
Central Zambia	709	855	25	37
N Mozambique	503	742	30	42
Kalahari	6	9	36	50
S Zimbabwe	47	152	70	96
E South Africa	89	296	66	83
Central South Africa	8	13	34	45

Source: Hulme (1996), based on contributions by N. Reynard.

In contrast to southern Africa, in parts of East Africa (Kenya, Western Tanzania, north-west Mozambique and Madagascar) current runoff may be as much as doubled (Arnell 1996). Temperature changes in GCMs are smaller at the equator than at the poles. For Kenya this translates to between 0.5 and 1.5 ° C, depending on the month. Increases are lower between Jan and April and highest in July. Based on the UK Meteorological Office High Resolution GCM scenario (other scenarios could show different results), annual rainfall increases throughout the country especially in the highlands where current rainfall of 1000mm per year may increase by 20% by 2050. Much of the north and west of the country may experience smaller increases of about 5%, based on smaller current annual totals. This suggests that current moisture gradients will become more exaggerated.

Potential evapotranspiration (PET) will increase throughout the region by 10% due to the increase in temperature alone. With other climatic changes, and changes in the plant physiological characteristics in a CO<sub>2</sub> enriched environment, this increase may be on the order of about 15%.

These scenarios of climate change imply favourable changes in water resources for Kenya. Largely because of the increases in rainfall, runoff would increase across the entire country, with much of it 50% above current levels. The exception to this general pattern is the extreme west of the country and around Lake Victoria where increases may be quite small.

This compares to other regions of East Africa such as Tanzania and southern Mozambique where significant decreases in annual runoff are modelled, in the region of 10 to 20%. Regional differences in climate change impacts on water resources highlight an essential feature of climate change: there will be winners and losers. It is not possible, however, to predict which regions will benefit and which will suffer. The extent to which present scenarios depict favourable responses may be construed as a disincentive to plan strategic adaptation.

#### *Zambezi River Basin*

Using scenarios based on equilibrium GCM experiments, Salewicz (1995) illustrates the vulnerability to climate change of an African water management system which relies on the performance of single large reservoirs. In the upper Zambezi river basin the Barotse Plain and Chobe swamps function as

significant evaporation pans and sediment traps, to the extent that that two-thirds of the region's 2400 mm annual precipitation is lost to evaporation before it passes over Victoria Falls. The swamps also act as filters, contributing to the lower Zambezi's very small sediment load, an economic benefit for the downstream hydropower schemes. Consequently the lower Zambezi is relied upon for the region's power production.

There are two major hydropower schemes in the lower Zambezi, fed by the Kariba and Cabora Bassa dams, and a third planned as part of the Batoka Gorge dam. 75% of the lower Zambezi river flows into the Kariba dam. With or without climate change the joint operation of the Batoka-Kariba power generation is vital for optimal energy production for the region. However Salewicz (1995) suggests that this water management system faces high demand and operational problems under climate change. Climate change scenarios indicate a shift in the seasonal reliability of given discharges for the Lower Zambezi such that the probability of a hydropower station receiving  $1000\text{m}^3/\text{s}$  in 2060 changes by between  $\pm 40$  and 51 %.

The study shows the use of having an additional hydropower system at Batoka, although the net value of the addition is reduced by climate change. Power output at Kariba is predicted to decrease by 11% and that of Batoka to fall to 49% of potential output in the dry season due to limited reservoir storage capacities. Under climate change, water levels at Kariba could average 6m below base level with significant impacts not only on power production but on fish populations. However, these impacts on the river basin could well be dwarfed by those of poorly planned future water projects that do not consider the hydrological interrelationships of the basin as a whole. Under increasing demands and multiple uses for water resources, improved co-operation in water resource development in the basin is urgently required. Water managers of schemes in the region concur that responses to climate change will not be anticipatory, but will occur in response to, and be affected by, the general path of regional development in the river basin.

#### *The Sahel, Western and Northern Africa*

For the Sahel, the IPCC-90 Impacts Report predicts decreases in precipitation of 0-10% during winter (December to February), and increases of 0-5% during summer (July to August). Temperatures are predicted to increase by 1-2 degrees in both summer and winter. In general IPCC predicts a much larger variability in precipitation and soil moisture changes for the Sahel and West Africa. In dry areas, such as the Sahelian Zone, runoff is very sensitive to precipitation. A study of the Senegal, Niger and Shari river basins (Sircoulon 1987) suggests that an increase in runoff of 30-50% could occur from an increase in precipitation of 20-30% and similarly a 15-59% decrease in runoff due to 9-24% increase in annual precipitation. For predicted levels of climate change in Northern Africa, there is much less data available. As part of an integrated assessment of the impacts of climate change in Egypt, a range of GCM models by the Geophysics Fluid Dynamics Laboratory predict temperature increases of 3.1 - 4.7 degrees and precipitation increases of 5-31%. A 37cm rise in sea level was also predicted Strzepek *et al.* (1995).

#### *Nile River Basin*

The Nile river basin is thought to be the most sensitive river basin in Africa to climate change, based on assessments undertaken by Strzepek *et al.* (1995) and Conway *et al.* (1996). The river basin is centred around a 5000km spine running from Lake Victoria through to the Aswan dam and Egypt, and discharging into the Mediterranean. Access to the waters of the Nile between Egypt, Sudan and Ethiopia remains one of the most hotly contested water resource issues in the world. Equilibrium GCM models predict temperature increases of 3.1 - 4.7 ° C and precipitation increases of 5-31%. These scenarios result in an impact on Nile river flow at Aswan varying from a 30% increase to a 77%

decrease. The Sudd swamps act as significant evaporation pans, particularly under the predicted decrease in riverflow scenarios.

The impact of such a variable change in river flow for Egypt is quite significant. Almost the entire population of Egypt lives in the Nile river valley and delta, dependant on the water resources and riverine economy that the Nile provides. An increase in temperature would lead to increased water demands for irrigated agriculture, but a decrease in precipitation levels and an increase in evaporation would lead to significant reductions in water availability. The UKMO GCM scenario for Egypt predicts a 13% decrease in water resources. Lake basin managers in Egypt state that they can adapt to a 10% reduction in water availability, but any reduction greater than 25% would cause major water resource management problems.

Climate change will also induce sea level rise. The majority of Egypt's population, agricultural activity and industry is located in the low lying Nile delta. The Aswan dam acts as a block to sediment from the Nile reaching the Mediterranean, effectively starving the delta of fluvial deposition and thus weakening it against sea level rise. As the delta subsides under sea level rise an increase in saline water intrusion and soil salinisation is anticipated (Nicholls and Leatherman 1995). A predicted 37cm rise in sea level by 2060 would inundate or salinise 4% of Egypt's arable land in the Nile Delta.

Possible response strategies such as infrastructural adaptation measures, improved agricultural technology and irrigation are thought to be able to mitigate 7-8% of the agricultural impacts of climate change. Completion of the Jonglei canal scheme, which aims to divert Nile water from entering the Sudd swamps, is anticipated to mitigate 20% of the decrease in total water availability. Strzepek *et al.* (1995) thus suggests that expensive adaptations alone are unable to mitigate the impacts of climate change, and water resource managers in the Nile river basin will have to look at strategies of improving irrigation efficiency and water demand management. By 2060 Strzepek suggests that water, with or without climate change, will have a much higher marginal value than at present and be the key limiting resource to development in the Nile river basin.

In conclusion, the impact of climate change on African water resources is still uncertain. While many studies have looked at runoff and river flows, relatively little research has been carried out on groundwater. A few studies of river basins have evaluated adaptation options for augmenting supply. So far, it appears that no integrated studies have evaluated both supply and demand to identify a wide range of adaptive strategies.

### **Stakeholders and Climate Change Responses**

Planning for climate change in the water resource sector must be cognisant of the many interests and decision-makers involved in shaping policy, implementing decisions and coping with the consequences of changes in resources and hazards. The principal stakeholders range from local end-users to national water ministries and nongovernmental organisations (Table 6.6). Stakeholders will suffer the consequences of climate change to varying degrees and have primary concern for different types of adaptations. This is likely to influence their involvement in planning and implementing adaptive responses.

**Table 6.6.** Stakeholders and adaptive interests in the water resources sector

Stakeholders	Conseq.	Adaptive Responses			
		Antic.	Inst./ Regl.	Res. & Edn.	Devt
Rural and urban consumers	✓				+
Large-scale users: irrigation, energy and industry	+	?		+	✓
Private water carriers	✓				+
Irrigation, water and sewage boards			?	+	✓
River basin development agencies		?	?	+	✓
National and international research		?		✓	+
Government water and planning ministries		+	+	+	✓
Aid and community development organisations		?	?	+	✓

Notes: Conseq. refers to bearing the consequences of climate change impacts, that is those stakeholders who are directly affected by altered agricultural production. The adaptive strategies corresponding to the guidelines: Antic. is Anticipatory Adaptation and strategies targeted for coping with climate change; Inst./Regl is Institutional and Regulatory Adaptation to prevent increased vulnerability; Res. & Edn. is Research and Education to develop and implement new solutions; and Devt is Development Assistance for Capacity Building that implements current options for sustainable agricultural development and reducing vulnerability to climatic hazards.

The ratings indicate the type of response likely to be of interest to each stakeholder:

✓ indicates primary interest in adapting to climate change.

⊕ indicates secondary, but important, interest in adaptive strategies.

? indicates uncertain but potential role in adaptation.

Stakeholder participation can help to overcome some of the uncertainties regarding response strategies. Regional and district water development authorities, scientists and international research panels and local users can effectively identify the range of responses that could be undertaken at the watershed or river basin management level. Incentives and constraints will become clearer through stakeholder involvement.

Consumers (end-users) are the ultimate stakeholders in adapting to climate change. For particularly vulnerable groups, the outcome of strategies to adapt to climate change and climatic hazards may alter their livelihoods. Failure to cope with adverse change could lead to significant deprivation, social disruption and population displacement.

Large water users, irrigation schemes, energy producers and industry can manage their water use provided adequate information on future supplies and prices. Significant changes in irrigation efficiency or industrial processes, however, take several years to design and implement.

Water suppliers, private developers and traders and government boards may take a longer term perspective on development, research and education, depending on the size of the enterprise. Local traders who deliver water from boreholes are unlikely to evaluate the risk of climate change to the same extent as a river basin authority.

The bulk of responsibility at present for designing, evaluating and implementing strategic responses (anticipatory actions, planning institutional change and research/education) are national governments, assisted by international research centres and aid organisations. Since the majority of water supplies in Africa are provided through direct access and public institutions, the role of private water companies is

relatively less important than a national strategy and response capability. However, water user groups and nongovernmental organisations can be instrumental, particularly in enabling stakeholder participation in the identification of management and climate change adaptation strategies. National and regional authorities can take a longer term perspective (on the order of decades rather than years) and evaluate means to mitigate the risk of extreme events.

### **Adaptive Responses for Water Resources**

Prospective adaptive responses for water resources can be identified through a number of means. A useful starting point is present management strategies, including experience in other countries (see US Army IWR 1994 for an inventory related to drought). An agreed climate change response strategy may involve no response ("business as usual" or "wait and see"), implementation of cost-effective anticipatory adaptation ("no regrets"), research for better information, and improved co-ordination of water policy.

The first priority should be improved institutional management of water, including stakeholder and external assistance, if required, toward the creation of a national water strategy. Most assessments of global warming in Africa examine the potential impacts on water resources without recognising that water resource management strategies is inherently dynamic, with continuous adaptation and responses to climate variability. Current water management strategies are constructed to serve the present range of climate variability, but also have some scope to respond to future perturbations. In practice, water management authorities will attempt to accommodate the impacts of global warming using existing management options, in relation to their more immediate development concerns. The need is to make sure ongoing strategies are flexible enough to anticipate the extra stress climate change will place on managing water in the future.

Ongoing adaptation involves managing water supply, demand, technology, and access to hydrological information. Four complementary approaches are required: new investments to expand capacity; operation of existing systems for optimal use; maintenance and rehabilitation of existing systems; and modifying water demand (Rogers 1993). Performance criteria within the water sector include robustness (the sensitivity of design parameters and economic costs to climate variability), reliability (how often the system is likely to fail), resiliency (how quickly a system recovers from failure) and vulnerability (the severity of the consequences of failure) (Hashimoto *et al.* 1982a and 1982b). Adaptation in the sector is the result of continuous assessment of performance criteria against the four elements of the water system and subsequent responses. Continuous management attaches a high value to hydrological information and on both short term climate variability and long term climate change, as explicitly recognised in the United Nations Framework Convention on Climate Change (UN 1992).

Anticipatory adaptation can entail substantial transformation costs for the water sector. (Development of water markets and full cost recovery, even without climate change, also has substantial costs.) These costs may be perceived to outweigh social, economic or environmental improvement, unless the benefits from the shift in strategy accrue relatively quickly to the end user. This is not likely to be the case for adaptation to climate change. The *time frame* of the adaptation process thus becomes a critical part of the management strategy. Short term adaptation in terms of water supply mechanisms (emergency water rationing) can often occur in response to drought, for example, but do not add much long term flexibility to management strategies. In contrast, longer term adaptation in water supply institutions and water demand management strategies (the adoption of economic and legal instruments) in reaction to climatic variability, forecast population growth or resource degradation levels can add greater flexibility to the water resource strategy. Due to the longer term uncertainties surrounding climate change impacts, water demand management and institutional adaptation are also seen as the primary components for improving flexibility in the management system to take account of global

warming. However, as a result of their long term nature, these "planned resilience" adaptations are likely to occur much more slowly in the water sector and with greater political cost. African water resource managers and river basin authorities, although often being aware of the need for improving the demand and institutional management of water resource systems over time to maintain per capital availability even without climate change, are therefore often constrained by the costs of transforming the water system for the longer term benefits of greater flexibility.

Drawing upon the general guidelines of adaptation options, specific strategies for water are shown in Table 6.7.

**Table 6.7.** Significant water resource strategies to adapt to climate change in Africa

Type of Adaptation	Examples of Water Resource Strategies
<i>Anticipatory Adaptation</i>	<ul style="list-style-type: none"> <li>New water supplies</li> <li>Combined use of groundwater and surface supplies</li> <li>Increase recycling and reuse of waste water</li> <li>Build capacity to transfer water within and between basins</li> <li>Flood protection, flood plain management, warning and evacuation</li> <li>Marginal increases in water supplies (drill existing wells deeper) and storage capacity (enlarge existing reservoirs)</li> <li>Drought response planning and preparedness</li> <li>Switching water use from agriculture to domestic, municipal and industrial uses during dry years, and importing additional food</li> <li>Demand management: conservation</li> <li>Better operation of existing water supplies</li> <li>Protecting groundwater and estuarine water quality from salt water intrusion</li> </ul>
<i>Institutional and regulatory adaptation</i>	<ul style="list-style-type: none"> <li>Comprehensive river basin and lake/reservoir management plans that address climate change along with future growth and other management challenges</li> <li>Integrated planning with other sectors</li> <li>Regional co-operation in transboundary water basins, share lessons learned in resilient water management, undertake joint assessments of climate change impacts and responses</li> <li>Community and participatory water resource management</li> <li>Socio-economic measures to minimise the effects of water scarcity: insurance, contingency plans, compensation</li> <li>Measures to protect vulnerable wildlife and ecosystems</li> <li>Electricity conservation and planning where hydropower is important: national strategies, diversity of sources including solar</li> <li>Facilitate water markets that encourage conservation and transfers between users and among suppliers</li> </ul>
<i>Research and education</i>	<ul style="list-style-type: none"> <li>Public awareness about climate change issues</li> <li>Water resource monitoring and modelling</li> <li>Water saving technology, especially for irrigation</li> <li>Institutional requirements: legal issues, resettlement</li> <li>Promoting conservation, particularly in garden landscaping</li> <li>Water treatment technology</li> </ul>
<i>Development assistance for capacity building</i>	<ul style="list-style-type: none"> <li>Flexible water management systems</li> <li>Decrease current water pollution</li> <li>Increase prices to ensure full cost recovery</li> <li>Optimal water system operational rules</li> <li>Rehabilitation of existing systems</li> <li>New capacity and delivery systems</li> <li>Interregional transfers</li> <li>Demand management</li> </ul>

Sources: see Benioff (1996), Riebsame (1995), Kaczmarek and Napiorkowski (1996), Golubtsov *et al.* (1996), Campos *et al.* (1996), Smith and Lenart (1996), Stakhiv (1996).

*Anticipatory adaptation*

Water managers typically deal with 90-99% levels of reliability as useful performance indicators to select “optimal” design criteria. The marginal cost of reducing each increment of risk rise rapidly as reliability approaches 100%. At the project design stage the uncertainty in climatic conditions over the life of the project should be incorporated into the performance evaluation, with explicit estimates of the trade-offs between acceptable risk and costs. To the extent that climate change may increase this uncertainty, anticipatory adaptation should be considered. This is most likely for long-term investments (over 30 years), such as major reservoir developments, particularly in regions where water supplies are uncertain. However, engineering designs tend to be influenced by political and financial realities, rather than finding “optimal” balances of supply, demand and risk.

In some cases, critical water resources are at-risk from climate change or from policies to adapt to climate change. Critical resources that might be irreversibly lost due to climate change include groundwater in areas subject to salt water intrusion.

An extensive list of potential anticipatory adaptations has been suggested based on studies around the world. It is not necessarily the case that new or incremental supplies are required. In some circumstances, different operating rules and risk management can be effective. Particular in regions where seasonal forecasts are improving (see Chapter 2), reservoir and supply management can be more reliable and shortages mitigated through preparedness planning.

*Institutional and regulatory adaptation*

Undertaking anticipatory adaptation requires a national water strategy. The IPCC recommends that the principles for sustainable water use in Agenda 21 and laid out by the World Bank (1993, 1994) can serve as a useful guide for developing flexible long-term water resource management strategies for nations, river basin authorities and water utilities.

The World Bank's policy paper on water resource management (1993) and technical paper on the formulation of a water resources strategy (1994) provide the building blocks for African water resource managers to implement both anticipatory and institutional adaptation, fulfilling the sustainability and development obligations of Agenda 21 (UNCED 1992) and preparing for climate change. The core of the strategy focuses on four key components:

- A comprehensive policy framework
- Treatment of water as an economic good
- Upgrading of institutional and regulatory systems
- Decentralisation and stakeholder participation

National water plans should complement National Environmental Action Plans, disaster plans and development initiatives in general (see the box on Malawi in Chapter 5). The Global Environment Facility could be used to complement national environmental plans with water strategies. Adoption of such strategies should accommodate the hydrological effects of global warming, at least for the next few decades. While national strategies are justified by present and future water shortages in Africa, the threat of adverse climate change makes preparedness planning imperative.

Large-scale changes in resource allocations may require interventions in institutions that regulate land use. For example, if development increases vulnerability to climate change than present controls can preserve future options.

Where institutions constrain adoption of effective responses to climate change, adjustments may be

required. Specifically, managing water demand may require adjusting the institutions that price water and promote conservation. Analysing the opportunity costs of water can identify cross-sectoral differences in water availability. The implementation of water pricing or other demand management tools (property rights, tradable permits, quotas) can encourage consumers to adopt more efficient practices. The reallocation of water within regions or districts can increase aggregate economic benefits. The introduction of efficiency prices for incremental consumption and price schedules aimed at obtaining full cost recovery from water services for irrigation or other user groups can greatly improve both efficiency of water use and the reliability of supply through re-investment in the sector. All of these water demand management tools are flexible enough to fit into African water management strategies and adapt over time to the changes in water availability that may occur from climate change.

Institutional and legal systems should be upgraded to administer water rights, service standards (particularly with respect to water quality and environmental impacts) and water pricing. The co-ordination of water related agencies (irrigation boards, regional development boards, power and energy agencies) should be achieved through the establishment of water policy co-ordinating committees at regional and national levels, their role being to enforce consistency with the national water strategy, whilst remaining separate from the operational bodies. Such committees can take account of the longer term implications of climate change on the operational potential of the water strategy in relation to their own particular use requirements.

The scope for more efficient water use through an increased reliance on decentralised mechanisms to deliver water related services should be broadened. Water utilities in Africa should be given greater financial autonomy, and stakeholder participation and water user associations should be encouraged. Improving stakeholder participation in planning, operating and maintaining water facilities and services would decrease the financial burden on the state and improve the sense of ownership regarding water resources. The disclosure of scientific, environmental or performance related information is an integral part of this process. The implications of climate change for water resource users could be discussed and assessed in conjunction with other resource use pressures. Appropriate response strategies could then be formulated.

#### *Research and education*

Research is required to develop responses to climate change that are not presently available. Development of national water strategies requires support from research centres, encompassing the regional distribution of water and its variability to technologies for efficient end uses. Such research capacities are best undertaken at the national level, with support from international centres and commercial enterprises.

Implementation of demand management will require targeted education. Although anticipatory adaptation to climate change need not be stressed among water users, promoting greater flexibility in water resource management requires a partnership between consumers, producers and managers. A broad capacity to address environmental issues and communicate understanding to stakeholders is urgently needed. This is even more critical in linking greenhouse gas abatement with sustainable development issues.

#### *Development assistance for capacity building*

As mentioned above, most of the proposed adaptation strategies for climate change are also appropriate for development objectives. The highest priority for Bank assistance is to support sustainable water resource management in Africa. The first priority is enhancing institutional capacity, complemented by anticipatory strategies where warranted and underpinned by research and education.

These are ongoing development objectives, but further assistance is warranted in light of the risk of changes in regional climates and climatic hazards.

Table 6.8 shows a range of criteria that can be used to evaluate a selection of the most likely, effective or commonly suggested adaptive responses to climate change in the African water sector. The table indicates clearly the dilemma facing water resource managers and decision makers. Those adaptations that add resilience to the water sector or improve the longer term strategic nature of the national water strategy in the light of the predicted impacts of climate change on water resources, are also those with the greatest level of economic and domestic political constraints hindering their adaptation although multilaterally they are agreed upon as rational strategies to take. Conversely, those strategies that are most acceptable domestically, add little resilience or strategic improvement to water resources management, either with or without the threat of climate change. The one strategy that does emerge to satisfy both points of view, although it fails to create long term adjustments in the water sector, is that of implementing "no regrets" responses.

**Table 6.8.** Evaluation of Adaptive Strategies.

Property	Adaptive Strategies						
	<i>no regrets</i>	<i>improve information</i>	<i>business as usual</i>	<i>anticipatory adjustments</i>	<i>improve demand management</i>	<i>improve co-ordination between water agencies</i>	<i>external assistance for national water strategy</i>
<b><i>Adds resilience to the national water sector</i></b>							
multiple benefits	H	L	L	M	H	H	H
benefits specific to climate change	M	H	L	H	M	M	M
increases ability to meet mandate	H	L	L	M	H	H	H
<b><i>Has a longer term strategic aspect</i></b>							
aids adaptation to climate change in long term	L	H	L	H	M	H	H
aids in general development of water sector	M	L	L	M	H	H	H
<b><i>Timing of Response</i></b>							
long term planning horizon	L	H	L	H	H	H	H
level of initial investment required	M	L	L	H	H	H	M
immediacy of benefits	H	L	H	L	M	M	M
<b><i>Constraints to adaptation strategy</i></b>							
lack of information/uncertainty	L	H	L	H	L	M	L
high financial costs	L	L	L	H	H	H	M
high transformation costs	L	L	L	M	H	H	H
domestic political resistance	L	L	L	H	H	H	H
lack of international agreement over the strategy	M	L	H	M	L	L	L

### Evaluation of Adaptive Responses

The transformation of African water systems to market pricing is an enormous change in policy. This section outlines some of the economic issues in water markets and management that will come to the fore in implementing national water plans as envisioned above.

In evaluating the economic incentives for engaging in adaptation policies whose benefits may be uncertain to society over time, stakeholders emphasise the choice of discount rate used in cost-benefit analyses. Discounting places less value on the well being of future generations. It is integral to benefit-cost analysis in that it allows the comparison of present costs (in this case as a result of adapting to climate change) to benefits that may or may not occur in the future. The issue becomes particularly pertinent if a stakeholder is advised to undertake an anticipatory response where considerable investment is needed for which there would be little benefit in the immediate future, and little benefit if climate change does not occur. For example, at a typical discount rate of 12% the present value of \$1 in 2050 is \$0.001 in 1996. Hence, \$1 worth of predicted damage due to climate change in 2050 seems negligible when valued today. A higher discount rate would put less value on \$1 of damage in 2050, and would thus emphasise the immediate costs of financing the adaptation more strongly. Conversely, lower discount rates imply greater concern about future costs.

For decisions or projects that affect society, the social rate of time preference should be used as the discount rate. This is the sum of the pure rate of time preference (utility discounting; the rate of people's impatience for utility) plus the effect of decreasing marginal utility. Often, for ease of calculation and standardisation, the rate of return for capital is used as the discount rate. In utilising the benefit-cost approach for assessing the potential benefits of climate change adaptation responses, it is important to note that adjusting the discount rate in order to address particular intergenerational equity or water resource concerns may not be the best policy approach for the stakeholder. A zero discount rate would boost investment in damaging projects that would otherwise be uneconomic. Utilising a range of discount rates for different types of analyses or projects would not allow for meaningful comparisons of damage costs or policy options. Instead, potential environmental damage and risks to future generations should be incorporated within total economic valuation techniques, which include stakeholder's option values (Markandya and Pearce 1991).

Society demonstrates a willingness to pay to avoid future costs, given information or probabilistic predictions (estimable risks) through an "option value" (Pearce *et al.* 1996). An option value is the value society attaches to a resource to keep it intact until later on when it may be used to greater advantage - similar to a risk premium. A high option value identified by the stakeholder for an environmental resource, such as for particular water resources, would promote a need within a benefit-cost framework for investments in uncertainty reducing activities. Anticipatory adjustments might therefore emerge as economically justified to the stakeholder.

The impacts of climate change, however, are slightly different. Climate change impacts involve a form of pure public risk that cannot be pooled (spread out) across society - each individual's assumption of risk does not reduce the risk borne by others (Fisher 1973). In these cases of general uncertainty or inestimable risks, a "quasi-option value" may be elicited for the resource or damage within the benefit-cost framework. The quasi-option value reflects the fact that new information or research regarding the use of the resource, or the nature of the damage to the resource, is of high value. Until then it is efficient to err on the side of caution and attach a high value to damages to the resource and hence high values to responses that protect the resource. Therefore, by attaching a high "quasi-option value" to the water system, the stakeholder encourages long term protection against the risk of impacts (Arrow and Fisher 1974, Arrow *et al.* 1996). In this manner the risk of damage costs to or protection of the water systems in Africa as a result of climate change is valued highly for future generations, until further information tells the stakeholder otherwise. Again, anticipatory adjustment responses might be

economically justifiable for the stakeholder.

The benefit-cost approach of examining the impacts of climate change examines the economic trade-offs between the costs of policy options and the benefits from avoided climate change impacts over time. Benefit-cost approaches (including multi-criteria analysis and cost-effectiveness analysis) recognise the dynamic nature of climate change and its impacts by trading off response strategy costs and predicted impacts over several time periods, such as outlined in inter-temporal optimisation models such as CETA (Peck and Teisberg 1992) and DICE (Nordhaus 1994). Cline (1992) suggests that quantification of the overall welfare loss from a reduced water supply can be approximated by the monetary value of the quantity cut back. Titus (1991) suggests there may also be additional costs in terms of the increases in the level and frequency of water pollution. Other environmental impacts (eg declines in ecosystem water budgets, land degradation from the increased variability of precipitation) and health costs should be taken into account in an economic analysis of the impacts of climate change on water resources in Africa. Where some of the impacts of climate change are measured in non monetary terms, multi-criteria analysis could be utilised. Where the stakeholder is seeking to find the lowest cost option to attain a specified level of social welfare, or impact mitigation, cost-effectiveness analysis could be used.

The most accepted approach for evaluation in this context remains however a standard cost-benefit analysis. An operating structure for a cost-benefit analysis of the *damage costs* of climate change on water resources for Africa could proceed as follows (Cline 1992):

1. Define and clarify the boundaries of analysis to be considered.
2. Obtain estimates from GCM's as to the net impacts and spatial impacts of climate change on the water resource systems in the region
3. Specify the flow of damages that occur at different points in time.
4. Take account of adaptation measures.
5. Undertake a monetary evaluation of the relevant impacts; determine the flow of damage costs and at what points in time they will occur, including option vales for risk perception. (It is also possible to include some form of weighting for welfare differences between affected populations.)
6. Discount the flow of damage costs to permit a comparison of impacts at different time periods; obtain a net present value (NPV) of potential damages.
7. Undertake sensitivity analysis to discover which parameters the NPV for damages is most sensitive to.

A meaningful cost-benefit analysis of the inter-temporal economic impacts of climate change on water management systems hinges on the accurate *identification* and *evaluation* of the impacts (damage costs) over time. On the scientific side this implies that further work on GCM prediction. Calibration is necessary in order to minimise uncertainty regarding the scale, timing and nature of climate change. Further scientific work should also look at the interface between climate change and the functions of the water resource system, in order to define more clearly the slope of the predicted damage function on water resources. Without scientific analyses of this kind it is more difficult for stakeholders to justify the accuracy of economic trade-offs that a benefit-cost model may predict for a region over time.

However, in terms of identifying optimal water management strategies for Africa in the light of the impacts of climate change on water resources, an economic evaluation of damage costs alone may not be enough. Sustainable and practical management solutions can emerge from an integrated hydrological and economic assessment approach. The aim of integrated hydrological and economic research should be to see how climate change fits into the portfolio of pressures that constrain the

sustainable management of hydrological resources in Africa. To assess the effects of climate change in the next century the baseline of environmental, social and economic conditions must be projected with and without the interactions between the presumed baseline and its perturbation due to climate change (see various papers in Downing 1996). Geo-engineering options, carbon removal and sequestration, abatement of other greenhouse gases and international adaptation strategies should be evaluated (Fankhauser 1995). Spill over effects to other policy areas such as regional migration flows, national economic policies, trade flows etc. – the secondary impacts of climate change – should be taken into account. Regional integrated land use modelling could help to incorporate these secondary effects:

- Vulnerability models integrate the dynamics of resources, population and economics by adopting a risk framework that takes account of the nature and magnitude of a range of specific impacts of climate change. For example, the World Food Trade Model, a general equilibrium model (see Downing 1993), looks at current vulnerability, the risk of present or future climate change or variations, the sensitivity of agricultural systems to those fluctuations and responses to reduce vulnerability or improve resilience.
- Integrated Watershed Management models (IWM), such being used to manage the Murray Darling River Basin (Blackmore 1994), could be used to look at the effects of land use change on local climates and vice versa. For example, an aim could be to seek to maximise evaporation in the region during the wetter months to enhance rainfall.
- Integrated land use planning models – for example, the NERC/ESRC NELUP model (O' Callaghan 1995) – could be used to optimise decisions of land use and land allocation by examining trade-offs between hydrology, ecology, market and policy systems. An aim could be to quantify the effect of changing one or more inputs to the model (climate change, secondary effects) to examine "what if" scenarios.

## Conclusion

Climate change will have various effects on water resources and water management in Africa. Unlike agriculture, runoff and groundwater recharge is less likely to benefit from CO<sub>2</sub> enrichment and increases in water use efficiency by plants. And, it is more difficult to ship water than food, especially if supplies are affected throughout a region at the same time. Potential scenarios of higher temperature, modest decreases in precipitation and prolonged droughts are a real cause for concern. While some regions may get wetter, water scarcity looms in the future with or without climate change.

Organising effective national water strategies, in the context of both Agenda 21 and the Framework Convention on Climate Change, is of paramount importance. Water management with full cost recovery pricing, a balance between supply and demand management, concern for environmental impacts and quality, waste water treatment, and other adaptive options is costly and a long way from present resource management in most countries. The transition from the present to water systems that meet future demand and are prepared for climate change will require additional investment.

Implementing responses to climate change in the water sector takes a long time. Even developing trustworthy, practical national strategies can take five years. Transforming institutions and implementing new operating procedures can take a decade. Designing and building new reservoirs can take 25 years, especially if social and political issues are addressed. Thus, African water managers will need to respond to climate change earlier than most other sectors. They will need to enhance flexibility and make choices about investment in the face of a range of climate scenarios.

Integration in the management of water supplies and demand is essential – new supplies are not the automatic solution to climate change. Irrigation efficiency is key since most water is used in agriculture.

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Developing drought contingency plans will mitigate the risk of a water crises having severe social and economic impacts. For example, water users in the US have developed agreements regarding transfers of rights during a drought. Irrigated agriculture is bought out, at a fair price, and the water saved is used for domestic, municipal and industrial purposes. Particularly important is keeping power stations functioning and ensuring industry can operate efficiently. The loss in agriculture can be made up by food imports, although some income support may be necessary to support farm labourers.

Developments in seasonal and interannual (up to 10 years) climate forecasts are promising and offer the prospect of greater predictability of water supplies and demand. Water systems can then be managed to achieve targets over 2-5 years, rather than unconstrained releases in wet years followed by diminished supplies and a water crisis before the next wet year. Managers should begin now to plan how such forecasts could be incorporated into their operating procedures.

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## CHAPTER 7. THE ATTENTION GIVEN TO ADAPTATION TO GLOBAL CLIMATE CHANGE IN THE WORLD BANK - REVIEW OF ECONOMIC AND SECTOR WORK

In order for the Bank to develop adaptive responses, it will be necessary to identify adverse and beneficial impacts of global climate change, analyse adaptive response options, and make appropriate policy modifications in relevant economic and sector work in the Bank. Possible future modifications of Bank projects will be facilitated to the extent current sector work and currently used data, tools and models can be extended to integrate adverse effects of climate change. It is useful, therefore, to review to which extent information, data, models and tools relevant for the purpose of adaptation to global climate change are currently available to the Bank.

This chapter examines to which degree and in which ways twenty-four recent Bank documents pay attention to, and perhaps examine, the issue of adverse effects of global climate change in Africa. Among the twenty-four Bank documents concerned with Sub-Saharan Africa are National Environmental Action Plans (NEAPs), Country Environmental Strategy Papers (CESPs), and agricultural and infrastructure sector work from 1990 to 1995. The selection of countries represents a wide range of institutional capabilities and vulnerabilities to climate variability and global climate change. Although the documents were selected in a less than systematic way, the results of the examination are considered generally valid for recent Bank documents.

**Figure 7.1** The countries covered in the Bank document sample.



Figure 7.1 shows the fifteen countries which are covered in the reviewed documents. The areas cover biomes such as rain forests, savannahs and deserts. The countries differ considerably in climate variables such as temperature, amounts and distribution of precipitation, humidity, evaporation, radiation and sunshine hours. Taken together, these documents should be representative for the total collection of Bank documents on Africa with respect to climate change, climate variability, vulnerability and adaptation capacity.

The review consists of, first, a table with six questions addressing whether and to which degree the individual documents take climate change into account, and, second, additional analysis of in which ways individual documents consider climate conditions and climate variables (but perhaps ignore the issue of climate change as such).

In the first part of Table 7.1 it is assessed whether the issue of climate change is important for the topic analysed in the individual Bank documents. If climate change is considered to be of minor relevance, a low score on the subsequent questions is also likely.

The second section of Table 7.1 assesses to which extent the climate change issue is judged to be relevant to the topic treated in the individual documents. Question One is concerned with the perceived importance of the environment, environmental robustness and vulnerability. It is expected that a high score on Question One also will result in a high score on Question Two. However, a low score could be an indication of lack of knowledge about the adverse impacts of climate change. Climate change and climate impacts is a quite recent global environmental issue and awareness of it would not necessarily result in careful assessment of climate change, its adverse and beneficial effects, or recommendations for adaptive measures. However, such issues are dealt with by questions Three, Four and Five.

**Table 7.1.** Coverage of climate change in Bank documents.

<b>To which extent is:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
the climate change issue judged to be relevant to the topic treated in this document?				
<b>To which extent does the document:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
1. discuss the state of the environment, the biological resources and their overall vulnerability?				
2. consider climate change an important issue?				
3. deal with the issue of current and/or possible future climate change?				
4. contain an assessment of possible impacts of climate change?				
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?				

1 = nil or a very small extent; 2 = small extent; 3 = some extent; 4 = considerable extent

When documents do take into account climate change, it is valuable to identify more precisely which climate effects have been considered and which policy recommendations have been put forward. Moreover, although the climate change issue *per se* might be ignored, documents might consider, and even pay considerable attention to, some climate variables and climate events. Some of the most important climate variables and climate events are listed below (Table 7.2). Table 7.2 is intended to produce a qualitative assessment of the attention given to climate variables and climate events in the reviewed Bank documents.

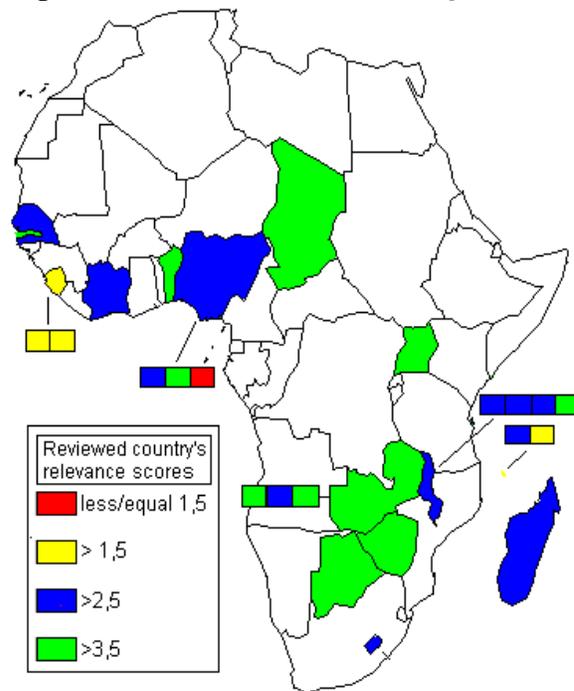
**Table 7.2:** List of important climate variables and prominent climate events

Climate variables/climate events	Attention to and/or assessments of climate variables and events
Temperature	
Precipitation	
Soil moisture	
Droughts	
Flooding	
Wind speed, storms etc.	
Sea level change	
Climate variability	
Extreme events and other elements	

**Coverage of the issue of global climate change: Findings**

It is concluded that the issue of climate change is very relevant for the topic examined in nine of the twenty-four documents (Figure 7.2). Further, the climate change question is to some extent relevant for ten documents, and to a small extent relevant for three documents. Noteworthy, just one of the twenty-four documents can reasonably neglect climate issues (the document is concerned with macro-economic risk management of the oil market in Nigeria).

**Figure 7.2: Relevance of climate change for the topic treated in the document**



The majority of the documents pay attention in one way or another to the state of the environment (Figure 7.3 Map 1). Considerable discussion about natural resources is presented in the environmental/conservation/agricultural documents concerned with Botswana, Chad, The Gambia, Malawi and Uganda.

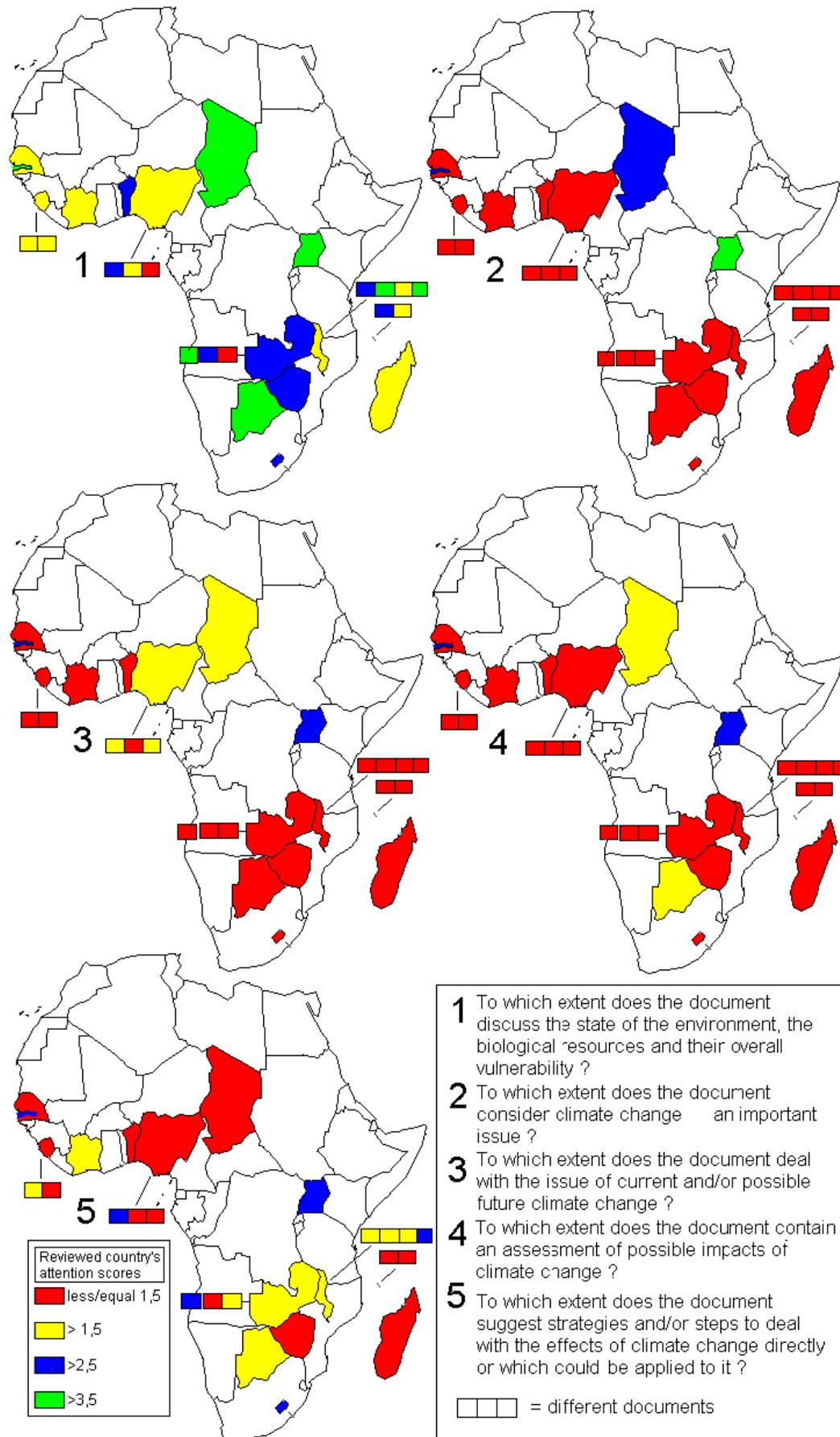
Only in the documents on The Gambia, Chad and Uganda is global climate change considered an important issue ('to a considerable' or 'some extent') (Figure 7.3 Map 2). The fact that meteorologists contributed to the document may explain the high score in case of Uganda. Climate variability is discussed with respect to its direct impact on socio-economic activities. Chad gives climate change high attention perhaps because of the existence of large agricultural

sites in marginal land which are very vulnerable even to small changes in climate variables. The document discusses the rainfall variability and its impacts on production systems. The Gambia is concerned about sea-level rise - much of the populated area is located close to the coast and coastal erosion has already occurred. The document also mentions the possible effects of burning fossil fuels on global warming and recommends supporting renewable energy programs and natural resource management. Only one document on Uganda to some extent examines climate change and assesses impacts on the environmental resources (Figure 7.3 Maps 3/4).

The final step in this assessment (Figure 7.3 Map 5) concerns the question whether the documents suggest strategies for dealing with effects of climate change. A high score is given when documents recommend strategies which could be directly applied in the context of climate change. It is concluded that some documents make recommendations and guidelines for improving and strengthening the environment, especially documents on The Gambia, Lesotho, and Uganda, and one document on Malawi, and one on Nigeria.

Where climate change is (very) relevant to the topic treated in the reviewed documents, it is of great importance to determine to which extent the documents pay sufficient attention to climate change (Figure 7.2). This analysis shows that only two documents with a climate relevant topic give climate change priority attention. Only little awareness of the significance of climate change, or no attention whatsoever, is detected in the case of seventeen documents for which climate change is judged to be relevant for the subject matter covered by them. As already mentioned, some documents contain guidelines and strategies which perhaps could be extended to deal with climate change adaptation, however.

Figure 7.3 Maps showing judged attention to climate change and variability in reviewed documents.



\* If more than 1 study of a country, country colour shows the average value of the different documents; 1= nil or a very small extent; 2= a small extent; 3= to some extent; 4= to a considerable extent.

In summary, although global warming could be an important environmental and socio-economic issue for most of the reviewed documents and should be included in the assessments, most documents do not pay sufficient attention to global warming. The state of the environment and overall environmental vulnerability are to some extent discussed in most documents. Noteworthy, a few studies make recommendations in regard to environmental or economic issues that perhaps may be usefully applied in the context of climate change adaptation. It is likely that the fact that climate change only recently became a prominent global environmental issue explains that this issue has so far been neglected in the World Bank. See Annex I below for a more detailed assessment of the twenty-four Bank documents.

### **Coverage of important climate variables: Findings**

Rainfall and drought are the most prominently covered climate variables in the documents. These issues are mainly considered in terms of their impact on yield. Decline in agricultural products in years with reduced rainfall (most countries only have rain-fed agriculture) impacts negatively on the economy, affecting terms of trade and credits. To prepare for repeated occurrence of adverse weather conditions, documents recommend to develop drought resistant crops and change farming practices and environmental management. The documents further highlight current impact on aquifer and river recharge through decrease in precipitation and impacts on the capacity of countries to sustain their populations and animals and movement of herders towards more fertile land. The resulting pressure on the over-settled marginal land causes additional conflicts over scarce land and water resources. Vulnerability to sea-level rise, natural hazards and climate variability are mentioned only in a few documents.

Several documents make environmental recommendations which perhaps could be extended to become guidelines for climate change adaptation. Among the most important recommendations are:

- diversification of the economy in order to distribute the risk of failure through climate determined impact,
- water management,
- reduction of intensive agriculture and livestock in marginal lands,
- strengthening the use of environmental impact assessments, and
- further education and research in environmental issues.

Two different country studies are presented below. Box 1, *National Environment Action Plan 1994 for Uganda*, examines the issue of climate change.

#### **Box 1**

*National Environment Action Plan 1994 for Uganda* gives an overview of the country's natural resources, the backbone of the economy. Environmental degradation, such as smoke from bushfires and deforestation, is considered to influence and change local climate. Climate and variability have a direct impact on socio-economic activities. Therefore, strategies to manage greenhouse gas emissions and to strengthen early warning systems for food security and disaster preparedness for extreme events should be implemented. Monitoring and collecting climatic data, as well as increasing awareness about climate change, will become major issues. The report states that there is yet no comprehensive mechanism or strategy to contain or mitigate the effects of climate. But it presents an action plan for environmental investment to guarantee sustainable economic growth for present and future generations.

Although the issue is judged to be relevant for the topic treated in the second document - Nigeria, *Livestock Development: Issues and Opportunities, 1993* - the document ignores the issue of climate change and the country's vulnerability to climate change (Box 2).

### Box 2

Nigeria's report about *Livestock Development: Issues and Opportunities, 1993*, is a review of the livestock sector analyzing constraints and potentials for its development. A combination of social, technical, economic and institutional constraints hampered investment in and development of the livestock sector. The report states that the low quality of native pastures, particularly during the dry season, leads to inadequate nutrition. Additionally, feed availability for livestock is now becoming an important issue in the dry north of the country, due to low and erratic rainfall combined with heavy grazing pressure. Although these changes in precipitation patterns could be connected to climate change and climate variability, no assumption about this is mentioned and no strategies, such as disaster preparedness and reducing vulnerability, are suggested to deal with the effects of climate change.

### Conclusion

The overall attention given to climate change in the reviewed Bank documents varies from low to non-existent. However, a few Bank documents appear to contain some basis for including climate change within their sector assessments. While the issue of global warming is not explicitly mentioned, considerable attention is paid to climate variables and climate events such as precipitation and droughts. Some guidelines for reducing vulnerability of natural resources and socio-economic sectors could probably be extended to include climate change adaptation.

Although decreases in rainfall and soil moisture and related drought are the most obvious climatic features, the impacts of potential sea-level rise, increase of tropical cyclone frequencies and climate extremes should not be understated. Monitoring climate variables and raising awareness about the issue have to become essential features of any adaptive planning.

In order to develop adaptive responses in the Bank, it will be necessary (1) to include a much broader spectre and better representation of climate variables in social and economic sector work and strategies as well as in overall development programs for sectors that are prone to adverse impacts of climate variability and climate change, and (2) to develop a long-term strategy which includes changes in agricultural practices and economic specialisation for a better adaptation to increased climate variability and climate change.

See Annex I below for detailed description of climate variables in the reviewed Bank documents.

## Annex I

This is an assessment of the attention given to climate variability and change in 24 selected economic and sector Bank documents in Sub-Saharan Africa from the period 1990-1995. Four elements are presented for each document:

- a short summary of the paper;
- a set of questions intended to assess whether and to which degree the Bank documents have taken climate variability and change into account;
- a table describing the main climate variables and prominent climate events which have been focused on in the individual Bank documents and
- some comments on the document concerning climate change.

The following Bank documents are reviewed:

- Benin. Agricultural Sector Review. 30 May, 1992.
- Botswana. Botswana National Conservation Strategy. December 1990.
- Chad. Country Environmental Strategy Paper. June 1994.
- Comoros: Strategy for Agricultural Growth. July 1993.
- Comoros. Economic Strategy Note: A Strategy for Sustainable Growth with Equity. September 15, 1993.
- Cote D'Ivoire. Agricultural Sector Review. Vol.1: Main Report. 20 August 1994.
- The Gambia. The Gambia Environmental Action Plan 1992-2001. Vol. I.: Final Draft. May 7, 1992.
- Lesotho. Environment and Agricultural Diversification Study. A World Bank Sector Report. 24 May 1993.
- Madagascar. Agricultural Strategy Note. 23 February 1994.
- Malawi. Towards a National Environmental Action Plan for Malawi: Emerging Issues. 29 December 1993.
- Malawi: Agricultural Sector Memorandum - Strategy Options in the 1990s. Vol. I: Overview. June 23, 1994.
- Malawi. Agricultural Sector Memorandum: Strategy Options in the 1990s. Vol. II. Main Report. 8 March 1995.
- Malawi. Economic Report on Environmental Policy. Vol. 1: Main Report. 20 March 1992.
- Nigeria. Development Issues in Agriculture. Part I. June 4 1993.
- Nigeria. Macroeconomic Risk Management: Issues and Options. 9 August 1994.
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## REVIEW OF ECONOMIC AND SECTOR WORK

### 1. Benin: Agricultural Sector Review, 1992

Although prices for food crops are falling, agriculture is expected to be the driving force in Benin's economy in the next decade. Raising rural income, combating poverty, support to the agricultural and private sector in general is a main target. The country's main export crop, cotton, suffers unstable price-levels, and the degradation of natural resources is proceeding at an alarming rate, attributed to a combination of uncontrollable external factors. Strengthening institution-building for economic growth in agriculture and meeting the real needs of farmers (management and education, crops, technology, investment credit), as well as improving food security are the main recommendations of the report.

To which extent do we:	1	2	3	4
judge the climate change issue to be relevant to the topic treated in this document?				X
To which extent does the document:	1	2	3	4
1. discuss the state of the environment, the biological resources and their overall vulnerability?			X	
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?	X			

1 = nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

Climate parameters	Attention and/or assessments of these parameters
Temperature	none
Precipitation	Recognition of reduced rainfall as a major cause of degradation of natural resources. Decline in agricultural output due to poor weather conditions in the 1980s, until 1988/89, when rainfall returned to normal. Necessity of monitoring rural credit operation to predict liquidity crises, such as after insufficient rainfall.
Soil moisture	none
Droughts	Herds from the north have increased in size with the drought in the Sahel countries. Storage capacity of farmers faces problems posed by high relative humidity and the existence of an unpredictable dry season. The practice of cattle herding is to sell them only when need arises as during a severe drought.
Flooding	Transportation problem, as many villages are cut off in areas that are flood prone.
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events and other elements	Climatic conditions during the crop season determine the agricultural market volume. Research on improving farming practices given climatic and ecological changes.

Great fluctuations in rainfall regimes influence agricultural output. Although very climate dependent, two strategies have been suggested to adapt the agricultural sector to possible climate changes.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 2. Botswana: National conservation strategy, 1990

The economic value of Botswana's environment has already been recognised by the country's government. Therefore, multipurpose use of natural resources in a sustainable way has become the main goal. This requires monitoring as well as environmental impact assessment of economic activities undertaken to satisfy restoration and conservation needs of the valuable natural resources. Education for improving management qualities will increase awareness of the country's wildlife, water and land area and ensures the protection of natural capital stocks for future generations.

To which extent do we:	1	2	3	4
judge the climate change issue to be relevant to the topic treated in this document?				X
To which extent does the document:	1	2	3	4
1. discuss the state of the environment, the biological resources and their overall vulnerability?				X
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?		X		

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

Climate parameters	Attention and/or assessments of these parameters
Temperature	none
Precipitation	Surface and groundwater recharge depend upon rainfall. For groundwater recharge, rainfall is only effective when associated with fairly intensive rain storms and falling on already moist soil, especially in view of the high evaporation rates.
Soil moisture	none
Droughts	During drought periods, the length of time over which grasses can withstand overgrazing is reduced. Last drought, in 1987, degraded 25% of the rangeland, together with water shortage and overstocking.
	Grain yield in drought years is only 1/5 of those in non-drought years. Game population suffered devastating effects during the last drought.
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	Adverse weather conditions reduces up to over 60% of the crop sown to produce acceptable yield.

The document describes in detail the kinds of environmental problems with which the country is currently faced. A number of recommendations for dealing with these problems could be applied to climate change. The issue of climate change is not mentioned.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 3. Chad: Country Environmental Strategy Paper, 1994

The report describes the general environmental situation in Chad, touching on natural resources, urban infrastructure problems, and the legal and organisational frameworks for addressing these issues. Environment is seen as an important input into most productive activities, therefore natural resource management must be integrated into economic planning. Forestry, fishery and urban problems are considered to be most seriously faced by environmental problems. As Chad's resource base is limited by low precipitation in most parts of the country, temporal and spatial rainfall variability enhances poverty even more and contributes to changes in the vegetation pattern and water availability.

To which extent do we:	1	2	3	4
judge the climate change issue to be relevant to the topic treated in this document?				X
To which extent does the document:	1	2	3	4
1. discuss the state of the environment, the biological resources and their overall vulnerability?				X
2. consider climate change an important issue?			X	
3. deal with the issue of current and/or possible future climate change?		X		
4. contain an assessment of possible impacts of climate change?		X		
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?	X			

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

Climate parameters	Attention and/or assessments of these parameters
Temperature	none
Precipitation in rainfall moved herders further south, causing competition and conflict, and forced rural dwellers to change	While total rainfall is sufficient to produce adequate harvests, its spatial and temporal variability poses significant risk. Fluctuations in rainfall moved herders further south, causing competition and conflict, and forced rural dwellers to change their production systems, particularly agricultural and fishing activity. Variability is high in the north. Natural resource degradation also caused by decreased rainfall over the past forty years. Decline in average annual rainfall could be due to long-term climate change, but yet no evidence. River flow and lake level determined by rainfall. When uncertain rainfall, agrochemicals can decrease yields due to destruction of the plants through undiluted chemicals.
Soil moisture	none
Droughts	The risk of localised drought is reduced by spreading the fields out as far as five kilometres from the homes. Reserving groundwater to ensure availability in case of drought. Drying out of lakes. Drought as a major threat to fauna. Reduces carrying capacity - which should be estimated in case of resource base - for worst case conditions.
Flooding	Urban drainage is a significant problem during the rainy season, creating serious hazards from standing water.
Wind speeds, storms etc	none
Sea level change	none
Climate variability	Variability in rainfall is very great, especially in northern areas of low precipitation.
Extreme weather events and other elements	none

High spatial and temporal rainfall variability in many parts of the country raise the concern of great vulnerability to climate change. It is stated that decreased rainfall and increased human and animal population combined place increasing pressure on the supply of pastoral resources. Although the document mentions climate change, it does not suggest strategies of how to handle the issue.

### 4. Comoros: Strategy for Agricultural Growth, 1993

## REVIEW OF ECONOMIC AND SECTOR WORK

The agricultural sector of the Comoros has a dominating position in the national economy, providing almost 98 percent of the Comoros' export receipts. Given significant structural constraints on the development of the agricultural sector and the lack of development in other productive sectors, the Government must implement a national development strategy. This strategy is focused on employment generation, foreign exchange and export diversification, and management of natural resources, to reduce the balance of payment deficit and provide food security for the Comoros. An important part of this development strategy is the protection of the environment in order to guarantee a viable use of national resources within the agricultural sector.

<b>To which extent do we:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
judge the climate change issue to be relevant to the topic treated in this document?			X	
<b>To which extent does the document:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
1. discuss the state of the environment, the biological resources and their overall vulnerability?		X		
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?	X			

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

<b>Climate parameters</b>	<b>Attention and/or assessments of these parameters</b>
Temperature	none
Precipitation	Intense rainfalls cause erosion.
Soil moisture	none
Droughts	none
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	Climatic conditions permit extended harvesting.

Although a small island state - which might be vulnerable to sea-level rise and tropical cyclones - with high dependence on agriculture for export, the document does not mentioned how climate change could affect the Comoros.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 5. Comoros: Economic Strategy Note - A strategy for sustainable growth with equity, 1993

The study analyses economic prospects for the Comoros in a short- and long-term perspective. It describes strategic objectives and potential sources of growth within the agricultural, manufacture and tourism sector. Diversifying the economy and strengthen some export-oriented industries are urgent needs to accelerate sustainable growth and to alleviate poverty. A smaller and more efficient public administration has to be included in the adjustment program, as well as effective allocation of the public resources for human resource development, infrastructure and environmental management.

<b>To which extent do we:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
judge the climate change issue to be relevant to the topic treated in this document?		X		
<b>To which extent does the document:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
1. discuss the state of the environment, the biological resources and their overall vulnerability?			X	
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?	X			

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

<b>Climate parameters</b>	<b>Attention and/or assessments of these parameters</b>
Temperature	none
Precipitation	none
Soil moisture	none
Droughts	none
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	none

The country's economic strategy concentrates mainly on the agricultural sector. In its long term planning the issue of climate change or sea level rise is not considered.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 6. Ivory Coast: *Agricultural Sector Review, 1994*

The agricultural sector's former role as the engine of growth for the Ivorian economy has to be re-established. The sector is currently facing a deep-seated structural crisis, aggravated by decline in international prices of major export commodities. Out of lessons learned from the past, pervasive State intervention should be replaced through devoting commercial functions to the private sector. The state's new role needs to focus more on policy definition and monitoring to create a macro-economic framework suitable for private agricultural incentives. On the long run, problems of demography and preservation of natural resources have to be included in future agricultural strategies.

<b>To which extent do we:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
judge the climate change issue to be relevant to the topic treated in this document?			X	
<b>To which extent does the document:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
1. discuss the state of the environment, the biological resources and their overall vulnerability?		X		
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?		X		

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

<b>Climate parameters</b>	<b>Attention and/or assessments of these parameters</b>
Temperature	non
Precipitation	Due to heavy rainfalls, erosion control is essential. 90% of the rice area is rainfed.
Soil moisture	none
Droughts	Loan delinquency became widespread partly because of the 1982/83 drought.
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	none

Intensification and diversification or production in agriculture are main strategies of the agricultural sector. Climate change or related issues have not been mentioned.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 7. *Gambia: National Environmental Action Plan, 1992*

Gambia is faced with serious environmental problems threatening agriculture, and thus food-security. One important feature of the Government's response to the country's accelerated environmental degradation is its recognition of the cross-sectoral nature of environmental problems, and the need for the involvement of all parties in finding a solution. Through recognising the necessity of forest- and biodiversity protection and vulnerability of sea-level rise through possible climate changes in the future, the country supports renewable energy programs and natural resource management. For the realisation of this challenging task, institutional changes are proposed and financial support from the donor-community are applied for.

To which extent do we:	1	2	3	4
judge the climate change issue to be relevant to the topic treated in this document?				X
To which extent does the document:	1	2	3	4
1. discuss the state of the environment, the biological resources and their overall vulnerability?				X
2. consider climate change an important issue?			X	
3. deal with the issue of current and/or possible future climate change?			X	
4. contain an assessment of possible impacts of climate change?			X	
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?			X	

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

Climate parameters	Attention and/or assessments of these parameters
Temperature	none
Precipitation	Groundwater recharge negatively affected by reduced rainfall, thus danger of salt-water intrusion and over-extraction of ground water. Secular changes in rainfall patterns. While analyses of historical rainfall data show a succession of high and low rainfall cycles, the occurrence of dry years has increased markedly in the last two decades average rainfall minus 30%. Loss of soil depth and reduced water holding capacity.
Soil moisture	none
Droughts	Natural resource depletion during successive years of drought, decline in agricultural production, reduction of surface water flows and increasing salinity in the rivers. Due to drought, grazing resources under pressure.
Flooding	Serious flooding and storms pushed the waves into an hotel during 1990 rainy season.
Wind speeds, storms etc	none
Sea level change	Rising sea levels responsible for coastal erosion and degradation of coastal ecosystems, thus threat of tourist industry. The Gambia is one of the ten most vulnerable countries due to sea-level rise.
Climate variability	Climatic changes in an area were particularly dramatic.
Extreme weather events and other elements	none
	Salt water intrusion reduced the swamp area.
	Burning fossil fuels effects global warming and sea-level rise due to melting of polar ice.

The document deals with a number of issues which would be addressed in a climate change context. It raises concern about sea-level rise and resulting erosion due to global warming, but characterises the climate issue by the lack of scientific knowledge. The document further states the necessary collaboration with scientific bodies on climate change.

### 8. *Lesotho: Environment and Agriculture Diversification Study, 1993*

## REVIEW OF ECONOMIC AND SECTOR WORK

Lesotho's main environmental problems are described which are overgrazing through overstock of cattle and goats, and resulting soil-erosion. The agricultural sector as the main source of income, has been studied in order to assess possibilities for diversification to create employment and expand exports. Different horticultural products have been analysed regarding their effect on the economy and on the environment. Problems of pesticides and fertilisers have been investigated. Recommendations are given to improve the natural environment in a cost-effective way. The government is advised to cease too intensive business involvement and recommended to establish a good investment climate for the private sector.

<b>To which extent do we:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
judge the climate change issue to be relevant to the topic treated in this document?			X	
<b>To which extent does the document:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
1. discuss the state of the environment, the biological resources and their overall vulnerability?			X	
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?			X	

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

<b>Climate parameters</b>	<b>Attention and/or assessments of these parameters</b>
Temperature	Decreased yield due to low temperature and rain during harvesting season.
Precipitation	none
Soil moisture	none
Droughts	Yield effects of present drought are not known yet, as it depends on on how long drought will last.
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	Constraints for most crops include temperature, rainfall and hailstorms. Possible to purchase insurance cover against hail damage. Torrential rain contributes to soil erosion.
and other elements	none

In spite of the fact of only sporadic rainfall and the problem of hailstorms, climate change and variability are ignored.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 9. Madagascar: Agricultural Strategy Note, 1994

Although the country's agricultural sector is the most important contributor to the national economy, it has not kept pace with population growth. Still, Madagascar produces 20 percent more food on a per capita basis than the minimum level proposed by the FAO. The country has a huge potential for accelerated agricultural growth, as it has competitive advantage in nearly all domestic food crops. Nevertheless, to use this potential requires considerable structural change, as current constraints of agricultural growth are found to be inconsistent macroeconomics policies, legal and regulatory framework, low technology and ineffective farmer support service. The first step for improvement is to create a forum of discussion which includes also representatives of agricultural interests outside Government.

To which extent do we:	1	2	3	4
judge the climate change issue to be relevant to the topic treated in this document?			X	
To which extent does the document:	1	2	3	4
1. discuss the state of the environment, the biological resources and their overall vulnerability?		X		
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?	X			

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

Climate parameters	Attention and/or assessments of these parameters
Temperature	none
Precipitation	none
Soil moisture	none
Droughts	none
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	Unfavourable weather affects rice supply.

The most important constraints of the agriculture are more of institutional and political nature, rather than determined by climate. The issue of climate change or variability is not mentioned.

## REVIEW OF ECONOMIC AND SECTOR WORK

### *10. Malawi: Towards a National Environmental Action Plan for Malawi: Emerging Issues, 1993*

Poverty is considered to be Malawi's main cause for environmental degradation. But the likelihood for economic growth, and thus poverty reduction, is most of all limited by natural resources. This vicious cycle has to be broken through by addressing issues of creating an institutional and legal framework for land-use policy, resource management and community participation. The country faces huge population growth, malnutrition and illiteracy, and has a severe shortage of agricultural land. These factors have to be addressed in combination with environmental improvement in order to achieve real benefits.

<b>To which extent do we:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
judge the climate change issue to be relevant to the topic treated in this document?			X	
<b>To which extent does the document:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
1. discuss the state of the environment, the biological resources and their overall vulnerability?			X	
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?		X		

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

<b>Climate parameters</b>	<b>Attention and/or assessments of these parameters</b>
Temperature	none
Precipitation	Surface water is dependent on variable rainfall from year to year and seasonal flow patterns.
Soil moisture	none
Droughts	Country is subject to periodic droughts and fluctuation in production levels. This affects the terms of trade and contracts the economy considerably.
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	none

As nearly all cultivation is rainfed, periodic droughts cause fluctuations in production levels. Climate change and variability are not mentioned. But some of the strategies described for combating environmental degradation might also be useful in the context of adaptation to climate change.

## REVIEW OF ECONOMIC AND SECTOR WORK

### *11. Malawi: Agricultural Sector Memorandum - Strategy Options in the 1990s, 1994*

Malawi's main target is to raise productivity and reduce poverty. Key source of growth is the agricultural sector, with over 90 percent of the nation's employed people working there. The government encourages diversification within agricultural crops for promoting sustainable growth and poverty alleviation through increased market flexibility. Policies for increase in fertiliser input should help to improve soil-fertility and thus yields. To revitalise the smallholder sub-sector, policy reforms and technological improvements should contribute to an increase in cash crop and food crop production for meeting the basic food needs of the population.

<b>To which extent do we:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
judge the climate change issue to be relevant to the topic treated in this document?			X	
<b>To which extent does the document:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
1. discuss the state of the environment, the biological resources and their overall vulnerability?		X		
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?		X		

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

<b>Climate parameters</b>	<b>Attention and/or assessments of these parameters</b>
Temperature	none
Precipitation	none
Soil moisture	none
Droughts	Favourable rainfall and increased soil nitrogen resulting from a drought accounted for yield increase.
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	Variations of up to 70% in yield due to climatic factors.
Extreme weather events	Commercial banks are not interested in lending to smallholders mainly because of the high costs and risks arising from their vulnerability to weather and other natural hazards.
and other elements	Less favourable climatic conditions contributed to decline in yield.

The large variations in yield have been related to climatic factors. The policy advises to increase food production diversity and to introduce new crops - important issues when considering future climate change. Nevertheless, issue of climate change is not mentioned explicitly.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 12. Malawi: Economic Report on Environmental Policy, 1992

The country, heavily dependent on natural resource, experiences considerable welfare loss from degradation of environmental assets. Causes for resource depletion are derived from excessive population growth and poverty, market and policy failures, such as insecure property rights and limited access to land. Short-time consumption is preferred to long-term sustainable resource use, in order to meet the basic needs of the population. Welfare loss is caused by extreme soil erosion due to inappropriate agricultural practices and deforestation, which itself is seen as a major contributor to water degradation. Recommendations for natural resource management are given through strengthening the regulatory framework of the country and to re-orient public expenditure priorities. The development of sector investment programs should prioritise smallholders to favour sustainable management practices. Nevertheless, through limited financial resources, expectations about the outcome of a framework for environmental impact management have to be modest.

To which extent do we:	1	2	3	4
judge the climate change issue to be relevant to the topic treated in this document?			X	
To which extent does the document:	1	2	3	4
1. discuss the state of the environment, the biological resources and their overall vulnerability?				X
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?		X		

1 = nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

Climate parameters	Attention and/or assessments of these parameters
Temperature	none
Precipitation	none
Soil moisture	none
Droughts	Increased research in drought-resistant crops. Some regions show acute water shortage.
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	none

The country has many environmental laws, but they lack enforcement and penalties. No analysis is given how to manage seasonal water shortage. Even if the issue of climate change and its possible consequences is not mentioned, some of the recommended measures will also lead to a better preparedness to tackle the effects of climate change.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 13. Malawi: Agricultural Sector Memorandum: Strategy Options in the 1990s, 1995

The report provides an in depth review of how constraints to increased and sustainable agricultural growth and rural poverty reduction can be dealt with. Agriculture, as the backbone of the country's economy, is prone to variability in yields due to recurring droughts, decreasing soil fertility, as well as financial and structural constraints. Nearly all crops are derived from rainfed agriculture. Current policy is to increase self-sufficiency, diversification and promoting growth and improving social welfare. Malawi has considerable potential to diversify its production (away from maize and tobacco), but this needs first to enhance food security, market liberalisation and government assistance to trigger this private-sector led diversification. Obstacles such as inappropriate policies, weak institutions and inadequate investments have to be removed.

To which extent do we:	1	2	3	4
judge the climate change issue to be relevant to the topic treated in this document?				X
To which extent does the document:	1	2	3	4
1. discuss the state of the environment, the biological resources and their overall vulnerability?				X
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?			X	

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

Climate parameters	Attention and/or assessments of these parameters
Temperature	none
Precipitation	Nearly all cultivation is rainfed.
Soil moisture	none
Droughts	Recent droughts require promotion of drought-resistant food varieties and drought risk management strategies. Fiscal deficits and GDP growth rates have fallen due to drought. Nearly all cultivation is rainfed, which increases vulnerability of drought. Drought-related assistance of free seeds. Extra nitrogen available in the soil as a result of drought in previous years. Financial situation exacerbated by drought. Promote more resistant varieties.
Flooding	During the rainy season, passage becomes difficult in many areas.
Wind speeds, storms etc	none
Sea level change	none
Climate variability	Malawi has relatively reliable rainfall patterns, but may, because of its dependence on rainfed cultivation, be subject to periodic droughts.
Extreme weather events and other elements	Erratic rainfalls reduce yield. Agricultural risks tend to be covariant due to the vulnerability to weather and other natural hazards.
	none

The study focuses on the two last droughts and the need to promote more drought resistant food varieties and drought risk management. Several strategies could be applied to climate change although the issue has not been mentioned.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 14. Nigeria: Development Issues in Agriculture, 1993

In Nigeria, although very much oil-export oriented, an important function for the government is to provide a policy and institutional environment that is conducive to agricultural intensification, private investment in agriculture, and to resource conservation. Until now, the inefficient (largely subsistence) agricultural sector has failed to keep up with rapid population growth, and Nigeria, once a large net exporter of food, now must import food. High import duties and trade prohibitions give rise to great distortions in the allocation of agricultural resources. A critical review of these import and export prohibitions and the liberalisation of internal trade is needed.

To which extent do we:	1	2	3	4
judge the climate change issue to be relevant to the topic treated in this document?			X	
To which extent does the document:	1	2	3	4
1. discuss the state of the environment, the biological resources and their overall vulnerability?			X	
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?		X		
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?			X	

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

Climate parameters	Attention and/or assessments of these parameters
Temperature	none
Precipitation	Very poor rains plagued the Sahelian and Sudanian zones throughout the 70s and had impacts on overall economic situation. Low rainfall contributed to pressure on resources and land degradation. Agriculture is overwhelming rainfed. Provide guidelines for water use in order to avoid over-exploitation. Monitor aquifer draw down and recharge and water quality.
Soil moisture	none
Droughts	Accelerated output growth after 1986 as average rainfall returned to more normal long-term levels.
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	none

The overwhelming rainfed agriculture was severely constraint by a combination of poor weather and adverse policies. For improving agricultural performance, recommendations are given which could be also considered regarding climate change. The issue of climate change is not discussed.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 15. Nigeria: Macroeconomic Risk Management, 1994

Nigeria's reliance on oil production for income generation clearly has serious implications for its foreign exchange earnings and economic policy management. Only small fluctuations in oil prices have significant economic impacts. Additional vulnerability also derives from changes in currency exchange rates and interest rates. Large government expenditures during oil booms caused budget deficits during oil shocks. This recurrent situation has caused serious economic problems to return to a path of sustainable growth and poverty reduction. While export diversification has a disadvantage in that it can take a longer time to be achieved, Nigeria may pursue this more actively and should remove unnecessary barriers, especially in the agricultural sector. Export-promoting activities might contribute to improve risk management.

To which extent do we:	1	2	3	4
judge the climate change issue to be relevant to the topic treated in this document?	X			
To which extent does the document:	1	2	3	4
1. discuss the state of the environment, the biological resources and their overall vulnerability?	X			
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?	X			

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

Climate parameters	Attention and/or assessments of these parameters
Temperature	none
Precipitation	none
Soil moisture	none
Droughts	none
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	none

The document focuses on oils sector management to improve risk adversity. The issue of promoting energy efficiency is mentioned, but any relationship to climate change is not apparent.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 16. Nigeria: Livestock Development: Issues and Opportunities, 1993

The paper presents a review of the livestock sector, analysing constraints and potentials for its development. A combination of social, technical, economic and institutional constraints hampered private investments within livestock development strategies. Additionally, policies favoured imports over local production. As a result, the livestock sector has grown at a rate less than half of that of the crop sector and the supply of milk and meat products was not able to meet the rising demand of the growing population. As prices of milk and imported meat are increasing, an incentive framework may favour domestic production. Trade restrictions have to be reviewed, particularly on feed imports.

<b>To which extent do we:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
judge the climate change issue to be relevant to the topic treated in this document?				X
<b>To which extent does the document:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
1. discuss the state of the environment, the biological resources and their overall vulnerability?		X		
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?		X		
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?	X			

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

<b>Climate parameters</b>	<b>Attention and/or assessments of these parameters</b>
Temperature	none
Precipitation	Feed availability is becoming an issue in the dry north, due to low and erratic rainfall combined with heavy grazing pressures.
Soil moisture	Gradual southward movement of herds to more humid areas.
Droughts	none
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	none

The problem of feed availability is mentioned which is caused by low and erratic rainfall and heavy grazing pressure. Although changes in climatic conditions might have an apparent influence on the economic sector of livestock development, the issue of climate change has not been considered.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 17. Senegal: Stabilisation, Partial Adjustment and Stagnation, 1993

The report focuses on the various steps of the adjustment process - from design to implementation - and on macroeconomic and sector adjustment impacts. The internal adjustment process pursued in Senegal has not produced even the modest results targeted in the government's medium-term financial program. Distortions in the real exchange rate, the labour market, the civil service, the legal system, agriculture, education and health are the focus of future reform programs.

<b>To which extent do we:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
judge the climate change issue to be relevant to the topic treated in this document?			X	
<b>To which extent does the document:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
1. discuss the state of the environment, the biological resources and their overall vulnerability?		X		
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?	X			

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

<b>Climate parameters</b>	<b>Attention and/or assessments of these parameters</b>
Temperature	none
Precipitation	Poor rains affected agricultural production, as it is primarily rain-fed. The sector depends mostly on climatic conditions.
Soil moisture	none
Droughts	GDP affected by severe drought.
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	Increase in agricultural production was largely due to favourable weather conditions.

Although the agricultural sector contributes only to a smaller extent to GDP, it has a major impact on overall growth through the multiplier effect on the rest of the economy. The recent increase of the sector was largely due to favourable weather conditions. Strategies for preparing agriculture against climate change have not been suggested.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 18. Sierra Leone: Agricultural Sector Recovery - Challenges and Opportunities, 1993

The integrated assessment highlights fundamental problems of agricultural growth, food production, foreign exchange earnings and environmental sustainability. Although Sierra Leone has rich agricultural resources, the sector has performed poorly over the past decade. This is caused by large economical and structural problems. The transition from a nearly food-surplus to food importing, aid-dependent nation within two decades reflects the failed policies in economic and social issues.

To which extent do we:	1	2	3	4
judge the climate change issue to be relevant to the topic treated in this document?		X		
To which extent does the document:	1	2	3	4
1. discuss the state of the environment, the biological resources and their overall vulnerability?		X		
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?		X		

1 = nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

Climate parameters	Attention and/or assessments of these parameters
Temperature	none
Precipitation	none
Soil moisture	Food crops should be produced increasingly in the lowlands where natural runoff does much to maintain soil fertility.
Droughts	none
Flooding	Mangroves are subject to seasonal flooding by sea water.
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	Uplands have relatively low soil fertility, readily leached of nutrients by heavy rains if tree cover is removed.
and other elements	none

The document states that the agricultural sector has performed poor mainly due to policy and incentive mistakes. The high exploitation of forests contributed to natural destruction. Climate issues have not been described.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 19. Sierra Leone: Policies for Sustained Economic Growth and Poverty Alleviation, 1993

As one of the poorest countries in the world, Sierra Leone's main focus is to achieve economic growth and to reduce poverty. Government's strategy emphasises the development of the agricultural sector, improvement of management of natural resources and government supply of basic services, such as health and education. To realise these objectives, great political and economic challenges have to be overcome. Sierra Leone has only limited financial resources and run down institutions which implies the need of investments through external assistance.

To which extent do we:	1	2	3	4
judge the climate change issue to be relevant to the topic treated in this document?		X		
To which extent does the document:	1	2	3	4
1. discuss the state of the environment, the biological resources and their overall vulnerability?		X		
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?	X			

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

Climate parameters	Attention and/or assessments of these parameters
Temperature	none
Precipitation	Sierra Leone is predominantly a tree crop country, readily leached of nutrients by heavy rains if tree cover is removed.
Soil moisture	none
Droughts	none
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	none

The performance in agriculture is in the short term driven more by weather conditions than by changes in the incentive structure. But no scenario is made about how climate change will affect future agricultural production.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 20. Uganda: The Draft National Environment Action Plan, 1994

The study gives an overview of the country's natural resources, which are the backbone of the economy. Overall goal of Uganda's Environmental Investment Program is to halt and reverse environmental degradation, build human and institutional capacity and hold open future options for resource conservation and development. Objectives for sustainable management and conservation for each environmental resource are described, as well as strategies for its implementation. A multi-sectoral responsibility for environmental management is promoted, also to guarantee sustainable economic growth for present and future generations. Due to financial restrictions, criteria for the choice of program for environmental protection have to be established, in order to give higher preference to issues with serious and irreversible impacts.

<b>To which extent do we:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
judge the climate change issue to be relevant to the topic treated in this document?				X
<b>To which extent does the document:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
1. discuss the state of the environment, the biological resources and their overall vulnerability?				X
2. consider climate change an important issue?				X
3. deal with the issue of current and/or possible future climate change?			X	
4. contain an assessment of possible impacts of climate change?			X	
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?			X	

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

<b>Climate parameters</b>	<b>Attention and/or assessments of these parameters</b>
Temperature	Monitoring.
Precipitation	Degradation depending on rainfall amounts.
Soil moisture	none
Droughts (such as drought) and local warming trends.	Human environmental degradation leading to climatic instability
Flooding	Disastrous effects of droughts and flooding are continually being felt in many parts of the country.
Wind speeds, storms etc	none
Sea level change	none
Climate variability	Lake system helping to smooth out seasonal as well as inter-annual variations in rainfall. Variability has direct impact on socio-economic activities.
Extreme weather events and other elements	In connection to drought and flooding. Micro climatic and hydroclimatic changes already experienced. Smoke from bushfires contributes to build-up of CO <sub>2</sub> and global climate change. Unsustainable fuelwood practices contribute to changes in local climate. No comprehensive mechanism to mitigate effects of climate. Objective to monitor climate for economic development decisions and managing emissions. Data collection of climate indicators, early warning systems, international co-operation, capacity building in climate monitoring. Known fact that pollutants affect atmospheric processes with impact on climate. Mentions signing of Climate Convention.

It is stated that environmental degradation has already led to climatic instability and in many cases to microclimatic changes, particularly local warming trends. Climate impacts are described and strategies are mentioned to monitor the climate in order to enable reactive strategies within the economic sector. The report concludes that there is yet no comprehensive mechanism or strategy to mitigate the effects of climate change.

### 21. Zambia: Towards a National Environmental Action Plan for Zambia, 1993

## REVIEW OF ECONOMIC AND SECTOR WORK

Zambia is going to establish a framework for integrating environmental concerns in the general development planning processes and activities of the country's economy. Major concerns about land use practices, air pollution, biological stock depletion and water quality are described and strategy options addressing these environmental problems are developed. Policy and institutional options and specific programs to address environmental problems are listed, whereby all strategies for environmental and natural resource management have to be established under the principle of market allocation and democratisation.

<b>To which extent do we:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
judge the climate change issue to be relevant to the topic treated in this document?			X	
<b>To which extent does the document:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
1. discuss the state of the environment, the biological resources and their overall vulnerability?			X	
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?	X			

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

<b>Climate parameters</b>	<b>Attention and/or assessments of these parameters</b>
Temperature	Altitude makes the climate temperate.
Precipitation	Rainfall in Zambia is strongly seasonal, and management of water distribution across seasons comes mainly through use of dams.
Soil moisture	none
Droughts	none
Flooding	Cost of inundation and changes in seasonal flooding regimes due to reservoir creation include negative ecological consequences and social disruption.
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	none

For the country, most concern is raised about local air pollution. Acid rain from the copper production is already addressed in the country's environmental policy. Climate change is not considered.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 22. Zambia: Prospects for Sustainable and Equitable Growth, 1993

Zambia's living standard has deteriorated sharply since the peak in the early 1970s. This was mainly caused by the drop in copper prices and the increase in oil prices. Central issue addressed by this report is whether economic growth is possible for the country. External debt, deteriorated infrastructure and a poorly developed endowment with human capital give reasons to be pessimistic about expected growth. Nevertheless, ample arable land and numerous natural resources and considerable scope for increased economic efficiency give reasons for optimism in the longer run.

To which extent do we:	1	2	3	4
judge the climate change issue to be relevant to the topic treated in this document?				X
To which extent does the document:	1	2	3	4
1. discuss the state of the environment, the biological resources and their overall vulnerability?	X			
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?		X		

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

Climate parameters	Attention and/or assessments of these parameters
Temperature	Increase in average daily temperature for more than 100 years.
Precipitation	Decline in rainfall for 100 years. Most crops and all livestock are rainfed.
Soil moisture	none
Droughts	Drought has earlier largely reduced output. Agricultural diversification towards more drought-tolerant crops is encouraged.
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	none
and other elements	none

Variations in weather critically determine the performance of the agricultural sector. Due to measurable changes in rainfall and average daily temperature throughout the last 100 years, the use of other crop varieties are recommended. Although this diversification is encouraged, the issue of climate change is not raised.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 23. Zambia: National Environmental Action Plan

The country is richly endowed with natural resources. However, population growth, industrialization and increasing agricultural demands pose a threat to sustainable use of the natural resources. The overall concern of the National Environmental Action Plan is to integrate environmental concerns into the social and economic development planning process in Zambia. Major sectors with the greatest social costs have to be identified. Environmental Assessments should be integrated at all levels of the development process. Economic instruments and a new property rights regimes should contribute to proper environmental management. Recommendations are given for selected sectors for contributing to economic development while minimizing negative effects on the environment.

To which extent do we:	1	2	3	4
judge the climate change issue to be relevant to the topic treated in this document?			X	
To which extent does the document:	1	2	3	4
1. discuss the state of the environment, the biological resources and their overall vulnerability?				X
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?			X	

1= nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

Climate parameters	Attention and/or assessments of these parameters
Temperature	none
Precipitation	Principal source of water is rainfall.
Soil moisture	The common physical limitation of all the soils is the low water holding capacity
Droughts	The frequent droughts in certain regions have shifted attention from maize to sorghum and millet which are more drought tolerant. The water supply situation is critical during the dry season, more so following successive drought years. Action plan for the water sector: building national and local community capacity to minimize the effects of drought and manage water resource. The past overemphasis on the promotion of hybrid high yielding crop varieties, through research and commodity extension service, has increased the vulnerability of these crops and livestock to natural disasters, such as disease, drought and pest outbreaks.
Flooding	none
Wind speeds, storms etc.	none
Sea level change	none
Climate variability	none
Extreme weather events and other elements	Burning fossil fuels releases surplus oxides of carbon and other reactive gases which accumulate in the atmosphere where they cause global warming.

The document describes in detail many kinds of environmental problems with which the country currently is faced and recommends actions for dealing with these problems which could be applied to climate change. Climate variability or change have not been considered in any detail.

## REVIEW OF ECONOMIC AND SECTOR WORK

### 24. Zimbabwe: Towards a National Environmental Action Plan, 1993

Zimbabwe has one of the most diversified economies in Sub-Saharan Africa. Virtually all major industries are based on natural resources. As a result, sustained economic growth depends upon effective natural resource management and environmental conservation. The report identifies environmental problems of the country, assesses its severity and analyses the underlying causes for these problems. Strategies are formulated how to address these problems.

<b>To which extent do we:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
judge the climate change issue to be relevant to the topic treated in this document?				X
<b>To which extent does the document:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
1. discuss the state of the environment, the biological resources and their overall vulnerability?			X	
2. consider climate change an important issue?	X			
3. deal with the issue of current and/or possible future climate change?	X			
4. contain an assessment of possible impacts of climate change?	X			
5. suggest strategies and/or steps to deal with the effects of climate change directly or which could be applied to it?		X		

1 = nil or a very small extent; 2 = a small extent; 3 = some extent; 4 = considerable extent

<b>Climate parameters</b>	<b>Attention and/or assessments of these parameters</b>
Temperature	none
Precipitation	none
Soil moisture	none
Droughts	Since 1981, the country experienced a serious drought over much of the country nearly every second year.
Flooding	none
Wind speeds, storms etc	none
Sea level change	none
Climate variability	none
Extreme weather events	High intensity rainstorms.
and other elements	none

Recurring droughts and intense rainstorms are considered to be a great environmental problem, but have not been related to climate change.

# ***This is CICERO***

CICERO was established by the Norwegian government in April 1990 as a non-profit organization associated with the University of Oslo.

The research concentrates on:

- International negotiations on climate agreements. The themes of the negotiations are distribution of costs and benefits, information and institutions.
- Global climate and regional environment effects in developing and industrialized countries. Integrated assessments include sustainable energy use and production, and optimal environmental and resource management.
- Indirect effects of emissions and feedback mechanisms in the climate system as a result of chemical processes in the atmosphere.

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