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Climate strategy for Africa

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by

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Executive Summary

1. General observations

Africa south of the Sahara is probably the most vulnerable region when it comes to the impact and consequences of climate changes. Yet the African continent runs a serious risk of being marginalized in the global dialogue on climate issues.

Africa contributes little to the global emissions of CO_2 and other greenhouse gases. The major focus of the Framework Convention on Climate Change is on abatement and mitigation of emissions rather than adaptation to the consequences of climate change, and African states have therefore been slow to ratify the treaty and not as active in the international negotiation process as states from other parts of the world. Curbing emissions if justifyably not a central African concern. Yet Africa's potential vulnerability should demand attention from both African policy makers and other decision makers. Africa's natural resource base is seriously threatened.

The two central guiding principles of African climate policy both on the part of governments and of international institutions should be reducing vulnerability on the one hand and increasing resilience on the other.

Decision makers should not use the remaining scientific uncertainty and the acknowledged dearth of detailed information on African resource management as an excuse for inaction. Not taking climate change into account could be a serious source of mismanagement and fallacious planning. Both increase in temperature and increasing variablility of climate are serious dangers in the future. Land degradation policies as well as future energy development should be central concerns.

Any strategy for Africa should seek to minimize the potential conflicts among the concerns and priorities for development, adaptation and abatement.

Africa's vulnerability to climatic changes relates to a number of factors, including 1) the dependency on bio-fuel, 2) the importance of agriculture, 3) immobility, 4) poor health services, 5) population growth, and 6) low material standards. In the case of Africa, it is difficult to make clear distinctions between abatement and adaptation measures. Social and economic development are necessary in order to prepare the continent for adaptation.

2. African obligations and opportunities under the Climate Convention

Forty-nine African states have signed the Climate Convention, but only 33 have ratified so far (23.06.95). Ratification is important because- 1) it signifies the acceptance of the principles of the convention and 2) ratification will be required for financial support under the FCCC.

The substantive obligation of all African Parties is a commitment to formulate a climate policy and how it could be implemented. Developing countries shall report on their inventories of GHG emissions, along with their plans and measures to meet the convention's objective within three years after the entry into force of the convention. Least-developed countries may report at their own discretion.

Multilateral financing institutions should invest in data gathering on all levels to enhance awareness and improve the possibility for responsible governance in respect to natural resource management and environmental protection.

Joint Implementation (JI) can allow for cost effective implementation of the Climate Convention, and provide funding for climate related projects for countries where financial resources are scarce or lacking.

3. Modelling of climate change in Africa

There are still substantial limitations in the ability to provide accurate predictions of future climate in Africa. Confidence in regional model predictions is low and there are substantial differences between the models. One can distinguish between three regions when it comes to climatic changes in Africa: 1) Sahel region, 2) corresponding dry regions south of the Equator in Zimbabwe, Botswana, Malawi, etc., and 3) the tropical region centered around the Equator.

Major findings from IPCC -90 and -92 of relevance for Africa
Temperature. Expected increases in annual average surface temperature at the time of CO_2 doubling:

- Northern subtropical region (including Sahel): 2°C (0.5-3.0°C),
- Tropical region: 1.5°C (0.5-2.5°C), and
- Southern subtropical region: 2°C (0.5-3.0°C).

Precipitation: Increase in surface temperature and increased radiative cooling of the atmosphere due to doubling of CO_2 concentrations lead to increased evaporation at the surface and increased intensity of convective precipitation (e.g. thunderstorms from large cumulus towers).
Sea level rise: Thermal expansion is regarded as the most important process. Predictions are a 20±10cm increase in sea level at the time of CO_2 doubling. IPCC-90 estimates up to a 65cm increase in sea level in year 2100, but this number is likely to be decreased to 40-45cm in the new IPCC-95 report.

Observed trends. Since 1895, annual average temperatures has increased by 0.53°C over continental Africa. The recent 25 year dry period in Sahel is the most substantial change in observed precipitation in the global record. Explanations have been sought in 1) land use changes, and 2) circulation changes caused by changing patterns of sea surface temperatures (SST). If the drought represents the first sign of a global warming remains however uncertain.

Current anthropogenic emissions of greenhouse gases (GHGs) in Africa. 1) Carbon dioxide (CO_2): The major source is land use change (~70%); the rest originates mainly from industry and transportation. The African contribution of CO_2 was in 1990 estimated to be about 7% of the world's total. 2) Methane (CH_4): Emissions in Africa are about 7% of the world's total, with livestock being the main source. Industrial sources are oil and gas production and coal mining. 3) Nitrous oxide (N_2O) sources are mainly of natural origin. 3) Chlorofluorocarbons (CFC): Africa's share of global CFC emissions is estimated at 3%.

4. Natural resource management

The uncertainties in predicting climate change impacts in Africa must be underlined, and other human or natural influences may mitigate or exacerbate the effects. Natural variability in Africa is also substantial, and people are to a large extent adapted to changes. Still, predicted human-induced climatic changes are expected to occur very rapidly, and little is known about the capability of the ecosystems - which forms the basis for human existence - to adapt to such changes. It is also clear that impacts of climate change will be unevenly distributed: groups with the highest present vulnerability, such as poor people and people living in marginal areas, will most likely suffer most. Generally, changes in the frequency of extreme weather events would probably have greater impact than changes in average conditions.

Agricultural Resources. The fertilizing effect of enhanced CO_2 level on plant growth is well documented in laboratory studies, but disputed when it comes to complex "real-world" systems. Other factors concerning climate change impacts on agriculture include 1) Warmer climate and changes in rainfall may reduce the appropriability of present crops. Already being a major problem today, loss of crop and livestock genetic resources may threaten sustainable agricultural development and adaptations to future changes. 2) Increased intensity of rainfall may increase soil erosion, nutrient leaching and crop damage, 3) Changes in timing and length of growing seasons may lead to planning problems, 4) Loss of rainfall in marginal and vulnerable areas would exacerbate drought and desiccation problems, increase risks for bushfire and put forests at their dry margins at risk, and increase problems in animal husbandry, 5) Some models predict a noticeable loss of food production in Africa, but regional variations would probably be large, and local differences (such as in cropping systems) will to a large extent determine how significant the climate change impacts will be. 6) Sea level rise will put low lying agricultural areas at risk, and may render major rivers unsuitable for irrigation.

Fish resources. Fish make up a significant part of the food supply in Africa, with a total harvest potential estimated at 10.5 million tons. It is expected that global warming will, varying with species, relocate fish populations. Freshwater populations in small rivers and lakes are vulnerable due to restricted ability to move in response to changes. In areas becoming drier, loss of habitat would also represent a threat. Fish populations are generally very sensitive to even small changes in frequency of extreme events. For the more mobile marine fish populations, relocation does not necessarily mean that production and potential yields are lowered, but subsistence and small scale-fishermen may suffer if institutional arrangements do not enable them to move within regions and across boundaries.

Biodiversity. Impacts on biological diversity should be of particular concern, as the welfare of human beings strongly depends on the existence of biological systems and processes. Biological diversity provides a wide range of goods and services, including a genetic basis for agricultural development, and represents a heritage of unique species and ecosystems.

Species will probably respond differentially to climatic changes, leading to new aggregations and ecosystems. In ecological terms, the predicted changes will occur over a short period of time. Migration is expected to be the main adaptation strategy, and adaptation success will be determined by the species' ability to respond quickly enough, as well as the suitability of the migration routes: Migration may be blocked by natural or human imposed barriers, or the natural environment (e.g. soils) may be inappropriate. A large part of the natural biodiversity in Africa is confined to isolated reserves surrounded by agricultural land. Small populations are particularly vulnerable, and endemic species will be at risk of extinction. The changes would on the other hand favor species with high dispersal rates, ability to colonize a wide range of habitats and a high tolerance towards stress.

Water resources. Past droughts have shown that for marginal and vulnerable areas, even a small reduction in water supply is critical. Water scarcity has substantial health and ecological consequenses. Even today, there is growing scarcity of water in many African regions, and several countries rely on water originating outside their borders. Sea level rises can be expected to lead to increased saltwater intrusion in the groundwater. Desalinization is too costly for most countries. Hydro power generation is also vulnerable to temperature increases and rainfall changes.

Social, political and economic impacts. Many authors mention the risk of getting more "eco-refugees". In addition to the social and health problems they may create, major migrations would also increase political tensions. Economic impacts include costs of climate-caused damages and costs of adapting to climate changes. In low-lying areas, sea level rise may cause substantial losses of land for human habitation, which in river deltas and urban centers will be aggravated by subsidence caused by extraction of water and hydrocarbons.

5. African priorities

African policy statements emphasize that contributions to Climate Change mitigation efforts should not adversely affect their development targets. Few African countries have national policies explicitly aimed at combatting climate change impacts, as they are not required to develop such plans until 1997. African policies are expected to concentrate on combatting vulnerability. More specifically, this involves capacity building in a number of areas, including formulation of national and regional inventories and programmes, development of effective negotiation skills, developing research capabilities, conducting cost-benefit analyses, and capacity building in the area of technology assessment and transfer. Improvement in planning capacity and governance would improve Africa's resilience to eventual climate changes.

Future energy scenarios. African countries should get support in taking advantage of new technology for alternative energy resources, where no-regret options should be given priority. It should be underlined that effective mitigation measures against global warming must reinforce national economic policies and enhance the welfare of households. Three different energy scenarios for Africa are discussed: 1) Stagnation, 2) Growth based on fossil fuels, and 3) Sustainable growth. Scenario 1 is characterized by slow economic development and rapid population growth. Scenarios 2 and 3 involve high social and economic development and falling fertility rates. Scenario 2 is a fossil-fuels based development, while scenario 3 provides large scale use of alternative energy sources and sustainable economic development. Economic development and improved living standards, especially among women, are necessary to reduce population growth.

Abatement measures. Abatement measures may be carried out as part of a development strategy. Such no-regret options may however need additional funding to be carried out, since market failures and national constraints to the economy may make such options too costly for African governments. One should focus on measures with limited impacts on activities "outside" the market economy. The concern for climate change could make the support of new technology in Africa more attractive, but one should be aware that this may bias the countries' preferences for projects.

Preface

The objective of this report is to prepare an initial statement on the problems of climate change in Africa, with the aim of contributing to the development of a climate strategy for the Environmentally Sustainable Development Division of the Africa Technical Department of the World Bank. Given the limited scope and timeframe of this study, the paucity of reliable information, and the scientific uncertainty inherent in the climate issue, the preliminary nature of the exercise must be underlined.

A comprehensive climate strategy for Africa would need to take into account existing national energy plans and general development strategies, as well as national environmental action plans where they exist, and modify these in accordance with the realities of climate change. Our recommendations reflect this general view.

CICERO (Center for International Climate and Environmental Research, Oslo) is an interdisciplinary institution specializing in global climate and environment issues. This report was prepared by geophysicists, forestry specialists, resource specialists, economists and policy scientists on our staff. Stein Hansen, Senior Research Fellow, and Stein W. Bie, Director of NORAGRIC have given extensive comments on an earlier draft and we thank them for their contributions.

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Acronyms and Abbreviations

°C	Degrees Celsius
ACTS	African Centre for Technology Studies
CFC	Chlorofluorocarbon
CH_4	Methane
CICERO	Center for International Climate and Environmental Research - Oslo
CO_2	Carbon dioxide
DJF	December - January - February
GHG	Greenhouse gas
DT	Change in Temperature
ENSO	El Niño-Southern Oscillation
FAO	Food and Agriculture Organization
FCCC	UN Framework Convention on Climate Change
GCM	General Circulation Model
GFDL	Geophysical Fluid Dynamics Laboratory of NOAA, Princeton
GDP	Gross Domestic Product
GEF	Global Environment Facility
IBRD	International Bank for Reconstruction and Development
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical convergence zone
JI	Joint Implementation
JJA	June - July - August
LPG	Liquid Petroleum Gas
Mt	Megaton
N_2O	Nitrous oxide
NOAA	National Oceanic and Atmospheric Administration, USA
NORAGRIC	Center for International Environment and Development Studies
ODA	Official Development Assistance
SEI	Stockholm Environment Institute
SST	Sea surface temperature
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WMO	World Meteorological Organization

Chapter 1

Recommendations

Relationship between global and national interests and priorities, mutual reinforcement

The recommendations are mainly concentrated around two principal objectives:

1. To reduce present vulnerability
2. To increase resilience towards future changes

It is important to prepare the African continent for the effects of global warming, which implies a strategy that is closely related to general political, social and economic development both at the national and the local level. This does not mean that African countries should neglect the call of the FCCC to participate in reducing the growth of GHG emissions. Abatement may be important in a number of situations, albeit more limited than in many other regions.

Few if any African countries have the institutional capacity to cope satisfactorily with the issue of long term climate variability. It is therefore necessary to increase preparedness, develop institutional capacity and research competence in order to assist countries to adapt to long term climate changes. This can only succeed in a macro policy environment that promotes sound and sustainable economic development within existing environmental constraints. One of the most effective measures of curbing GHG emissions in Africa would be to reduce population growth. In addition, it would be particularly important to remove subsidies on fossil energy, which would reduce economic waste, remove price distortions, and reduce local pollution. Climate issues should always be included in structural adjustment negotiations in Africa. Support to energy efficiency programs, development of viable non-carbon forms of energy as well as less energy intensive technologies are recommended.

National and global interests in climate change adaptation and mitigation can reinforce rather than conflict with each other in most instances. (One exception to this general rule is an increased reliance on coal as a potential source of new energy, a complex issue especially relevant in Southern Africa).

Even though there is no time limit for when the least developed nations shall report on inventories or action plans under the Climate Convention such inventories should be encouraged and supported since they may well become important tools in the planning process.

Most of the recommended policies are national in scope and consist of no regret options that should be undertaken regardless of climate concerns.

African vulnerability is caused by the continent's overwhelming reliance on natural resource based economies. The major anthropogenic source of carbon dioxide emissions from Africa (about 70%) are from land degradation and land use changes. Flexible and sustainable agricultural strategies that reduce the need for slash and burn agriculture should therefore be given priority.

To increase resilience to climate change, development policies should focus on the need for more diversified economies, local level adaptation measures, appropriate technologies and improved governance.

Central to the issue of reducing vulnerability to climate change are a nation's population policies, family planning efforts, and educational policies (particularly education for girls and women).

The mandate of the Global Environment Facility (GEF) is funding projects that would not meet normal lending criteria which are based on consideration of national costs and benefits rather than the global environment. In the case of cooperation between funding of projects from IBRD or ODA resources and the supposedly new and additional resources of the GEF, the general rule is that GEF should leverage global environmental benefits from the regular development projects through changes in projects design or technology. The GEF would thus cover the so called "incremental costs", yet these are difficult to extract.

The GEF has been chosen as the financial mechanism of the FCCC. The majority of industrialized countries (the Annex I group), are of the opinion that their financial global obligations towards developing countries are to be covered by the core fund of GEF.

Given the difficulties in the concept, the GEF should, in the area of climate change, give priority to support national reporting and to mitigation projects. Mitigation projects in Africa in the area of forest conservation be considered also with a view to biodiversity interests. In the area of energy the focus should be on developing renewable energy sources.

Encouragement should be given to projects which combine multiple national and global benefits.

Operational priorities

African GHG emissions are low compared with emissions from other continents. African countries are, however, threatened by severe impacts of future climate change due to a fragile natural resource base, a weak economic foundation and a low level of institutional preparedness. Programmes and projects related to climate should first and foremost be aimed at addressing national development needs. Some of these may also be globally beneficial and thus be candidates for GEF funding.

1. Increase knowledge of climate issues and risks

The general knowledge of climate issues, short term climate variability, likely climate change impacts and possible "no regret" options to mitigate negative effects are low. This may *inter alia* cause loss of opportunities to integrate mitigation or adaptation measures at low cost in national economic strategies and development planning. It is therefore suggested to:

1.1 Support north/south and south/south research cooperation and network establishment in the field of climate change, (FCCC, Art. 5)

1.2 Support capacity building programmes and projects aimed at capacity building among decision makers in government and industry on issues such as possible climate change effects, possible response measures and opportunities.

1.3 Support public awareness, training programmes and viable schemes for practical responses (FCCC, Art. 4 and 6)

2. General measures to limit emissions and help adapt to future climate change

African countries should participate in international initiatives meeting the objectives of the FCCC to curb emissions. Even if priority must be given to national development projects, projects that also yield global climate benefits should be encouraged. An important consideration is the need to involve the finance and planning ministries actively in the development of national climate policies and plans.

2.1 Support should be given to national and regional planning initiatives to enable integration of climate considerations in national and regional development plans. This would include plans for urban development; energy supply, distribution and utilization; transport sector development; regional cooperation and institutional building. In particular, consideration should be given to development of a programme for the creation of a new format for energy planning, where energy efficiency improvements are maximised, the utilization of viable non-carbon forms of energy are captured and where less energy intensive technologies are considered.

2.2 Support should be given to systems for improved climate change predictions and early warning systems and reliability of forecasts, and the practical utilization of such data, perhaps in cooperation with UNEP, UNDP, WMO and FAO.

2.3 Support should be given to mapping of vulnerable areas and national/regional assessments of climate change effects. This should be followed by preparation for reduced impacts and mitigation.

2.4 Support should be provided for participation of African countries in international coordinating activities where opportunities for cooperation and assistance can be demonstrated.

2.5 Support to the preparation of national inventories (FCCC, Art. 4+12)

3. Measures to mitigate GHG emissions

When considering mitigation options in Africa, one should emphasize the need for identifying cost-effective measures with multiple social, economic and environmental benefits ("win-win" situations) in addition to changes in national economic structures, mitigation measures may be grouped in three broad categories:

3.1 One should generally encourage fuel switching to energy sources with lower carbon content. It is important not only to look at the capital costs of such investments, but also be aware of the fact that emission reductions will involve a number of other benefits besides reduction of global warming. These may include reduced acid rain, reduced air pollution and health problems, and perhaps also reduced fossil fuel dependency and reduced costs because of more efficient equipment.

In southern Africa large investments in energy development are in the initial planning stages. Such investments will be of vital importance for the level of GHG emissions from this region in decades to come, and are in practical terms irreversible. This region can boast both of rich sources of coal and of hydroelectric power. At the same time there is a high potential for utilization of photovoltaics and other renewable energy sources, suitable especially for rural areas.

Viable options seem to be present. As considerable financial resources are needed for large scale investments, donors are probable sources of such funding. One should therefore consider decisions related to Africa's future energy scenario in light of their climate impact.

a. Serious consideration should be given to the possibility of providing incentives for countries or group of countries for choosing an environment friendly energy future. Feasible cooperation with the GEF should be considered.

b. Fossil fuel dependency is a serious problem for several African countries. The price of fossil fuels has in many instances increased after an initial investment has been made. Fuel switching might in many cases be a "no-regret" opportunity, but may have institutional or other barriers for implementation.

c. Further development of reliable and efficient energy systems and technologies based on renewable sources such as photovoltaics, solar thermal, solar heating, wind power, small hydroelectric and biomass for rural Africa should be supported.

3.2 Consideration should be given to policies and measures to increase energy efficiency and to energy conservation where that may be appropriate and beneficial in a national setting. Waste or inefficient use of energy is not only costly, but often also harmful to the environment. Such measures will to a large extent involve a transition towards cleaner technologies (technologies which combine more energy efficient operations or processes and reduced pollutant production without necessarily entailing a change in the form of energy used).

3.3 In a consideration of options, it is important to figure out how the measures might give incentives to local adoption and acceptance over time, thus having a decisive importance for the success of a project. The identification of barriers to energy efficiency improvements is perhaps one of the difficult, but promising areas to attack in formulation of a mitigation policy. We would in this short paper only draw attention to two types of barriers, those arising from imperfections in the markets, and the institutional barriers preventing companies to act in a normal manner.

3.4 The full cycle of energy production, conversion, transport, distribution and consumption should receive attention to arrest sources of inefficiency, leakages etc. Likewise, measures to capture methane gas drainage from coal mines, land fills etc. should be identified. The introduction of new technologies should be encouraged.

3.5 As mentioned in paragraph 2.1 support should be given on planning for meeting future energy demand and distribution. The issue of barriers to a rational, cost-effective and environmentally sound behaviour should be given priority.

Thirdly, support should be given to enhance carbon sinks. This category covers carbon fixation in biomass through reduced deforestation, reforestation schemes, improved forest management, or changes in land use and agricultural management practices.

3.6 Reforestation and improved forest management still have a significant potential for increased storage of carbon in Africa. Where population densities are high, the introduction of agroforestry systems may cause less conflict with food production objectives and still contribute to increased sinks. Increased below ground storage of carbon through the use of more rock phosphate is an interesting possibility.

3.7 Emission abatement may be of particular concern for the coal using industry and power production in South Africa. Emission abatement technology should be further developed.

3.8 Improved land use in vast areas of Africa may reduce carbon emissions, perhaps particularly through reduced grassland and bush burning, and reduced slash and burn agriculture.

3.9 As national governmental institution often have a limited control over local land management, programmes which may give incentives to local communities to take climate issues into consideration in land management decisions should be encouraged.

3.10 Improved soil management practises may contribute considerably to reducing vulnerability to climate impacts. Soil stability and integrity, productivity, organic matter content, and water runoff control are among the determining factors.

4. Adaptation measures

As mentioned above, any strategies for adaptation to a climate change scenario must be speculative, given the quality of data we have today. There are however, a number of areas where we know that the preparedness for adaptation is weaker than necessary, a conclusion which is confirmed after each severe drought in Africa. The competence and capacity to deal with climate variability and the effects thereof should therefore be strengthened. Increased resilience to climate change must also be a priority focus. Support should be given to research in adaptive agriculture, climate change resilient crops, better infrastructure in industry and agriculture, better technology in agriculture, improved water management technologies, and environmental health.

Natural resources

4.1 Thermal agricultural crop limits may move from present ranges. Development of crops and crop systems that are flexible and resilient towards change, should therefore be a priority.

4.2 Biodiversity monitoring and conservation of crop genetic resources preservation are therefore important adaptation measures, and policies that maintain biodiversity through the maintenance and increase of conservation areas should be supported.

4.3 Improved weather and climate change forecasting and early warning systems, and improvement in the reliability of these forecasts, should be promoted in cooperation with UNEP, WMO, UNDP and FAO.

4.4 Coastal protection, including forest and mangrove protection, river deltas, sand banks and coral reefs protection are among the important measures to protect against extreme weather conditions.

4.5 Forests should also be protected or re-established where necessary for watershed protection.

4.6 Concerns for potential sea level rise should be included in all coastal zone plans, including harbour construction, oil terminals, sea lanes etc.

4.7 Extreme weather disaster preparedness should be supported, including plans, equipment and institutional responsibility allocation.

Chapter 2

General background

African obligations and opportunities under the Climate Convention

Any presentation of the specifically African aspects of the convention must take as its point of departure four of its basic principles:

1. that industrialized countries have accepted taking the lead in combatting climate change, and the adverse effects of this change,
2. that developed countries will aid developing ones in meeting their commitments,
3. that measures under the convention may be carried out cooperatively between interested parties, and
4. that development of their economies, rather than solving global environmental problems will remain the major concern of African governments and that climate concerns will therefore at most become an aspect of developmental policies and strategies rather than a central concern.

The United Nations Framework Convention on Climate Change (FCCC) went into force on March 24, 1994. Forty-nine African states have signed the Convention, but only 33 have ratified so far (June 23, 1995). Ratification is important not only because it signifies the acceptance of the convention text but also because it will probably be decided at the first Conference of the Parties in Berlin that only those countries that have ratified will be qualified for support under the FCCC.

The Framework Convention sets out principles and general commitments, (thus the name framework convention) but has left precise obligations and specifications to future protocols. Thus a two-step approach for response strategies to climate change was adopted, and a great deal was left to future negotiations. The general aim of the Convention is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

Developed states are obliged to report on how they aim to return to their 1990 levels of GHG emissions through national action plans. The Convention has two types of commitments: general and specific. The general commitments obligate all countries that are parties to the FCCC to report on their inventories of GHG emissions, along with their plans and measures to meet the objective of the convention. The developed countries (Annex I countries) are obliged to report to the first meeting of the Conference of the Parties, while the developing countries shall make their communication on the above aspects within three years after the entry into force of the convention. The least-developed countries may report at their own discretion.

The second type of commitments are only related to the industrialized countries and present an objective for these countries to return, individually or jointly, by the end of the decade to their 1990 levels of GHG emissions. The developing countries are expected to abide by the general commitment of the Convention only to the extent that they are financially supported by the industrialized countries.

One may perhaps distinguish between two types of financing objectives. One is the support needed to develop the inventories and plans, and the other is to support more substantive measures under the FCCC. The industrialized countries have chosen the Global Environmental Facility (GEF) to constitute the financial mechanism of the Convention.

With respect to technology transfer, the Convention does not specify the terms of transfer, and there is no commitment concerning preferential and non-commercial terms. The convention states that developed states "shall take all practical steps to promote, facilitate and finance as appropriate the transfer of or access to environmentally-sound technologies," and that the development of endogenous capacities and technologies shall be supported.

From an African perspective, it is important to realize that the convention lists no less than 9 different types of developing states and that all of these can be found in Africa: small island countries; countries with low-lying coastal areas; countries with arid and semi-arid areas, forested areas and areas liable to forest decay; countries with areas prone to natural disasters; countries with areas liable to drought and desertification; countries with high urban atmospheric pollution; land-locked countries; countries with areas with fragile ecosystems, including mountainous ecosystems; and least-developed countries. Some of these are overlapping characteristics, and one country may easily fall into two or more of these categories, thus exacerbating the problems connected to the impact of climate change. These categories outline various types of vulnerability to climate change which are specially relevant to Africa. The substantive obligation of all African Parties to the convention is in effect a commitment to formulate a climate policy and an account of how it could be implemented.

Most developed countries regard their contribution to the core fund of the GEF as their funding obligation to the process. The cost effectiveness of projects funded should be judged from a global rather than a national standpoint and funds should cover the "incremental costs" needed for a national project to also provide global climate benefits when possible. Although the term "agreed full incremental cost" is established as the guiding principle for GEF funding, it is not easily defined. Several projects have demonstrated the difficulty in making this concept operational. Within the area of climate change, GEF funding might choose to focus on support for development of national reports, while the financing of adaptation measures, which in a strict sense are not global benefits, might be left to national funding with ODA assistance. The intention is, however, that GEF projects should wherever possible also leverage environmental benefits from regular development projects through changes in design or technology. From an African perspective, it was especially important that projects in desertification and deforestation were added to the list of eligible global problem areas, if they can be shown to relate to climate or other global environmental problems.

The financial commitments of Annex II countries can provide opportunities for sustainable development policies for developing countries. The ability of developing states to meet their commitments is dependent on the availability of finances and of technology provided by others (Article 4,7). The practical significance of the Convention will in all probability depend on the availability of these funds. Future negotiations will need to clarify what is meant by the phrase "funds covering the agreed full incremental costs of implementing measures," which obligate developed states vis-à-vis developing ones (Article 4,3).

Another potential future source of financial resources is provided for within so-called joint implementation (JI) activities (Article 4,2). The underlying idea in joint implementation as a mechanism is that private investors and/or governments from countries with high marginal costs for emission reduction can invest in abatement measures in another country in a more cost efficient manner. On the general level JI can serve two purposes: 1. allow for cost effective implementation of the Climate Convention, and 2. provide funding for climate related projects for countries where financial resources are scarce or lacking. Cost effectiveness of measures is one of the bearing principles of the Climate Convention. The concept is still controversial, although projects would bring with them such benefits as technology transfers, greater energy efficiency and private investments for development purposes. Joint implementation projects should be very attractive for African countries or companies. Although the criteria for JI have not been agreed upon it is likely that the Conference of the Parties in April 1995 will adopt a formal pilot phase, although such projects have already been carried out on a voluntary basis (Torvanger et al. 1994:6).

Modelling climate change in Africa

The development of computer models for simulating the global climate has taken great steps forward during the last 10 years. The complexity of the climate system is, however, immense, and there are still substantial limitations in the ability to provide accurate predictions of the future climate and to reproduce the climate of the past.

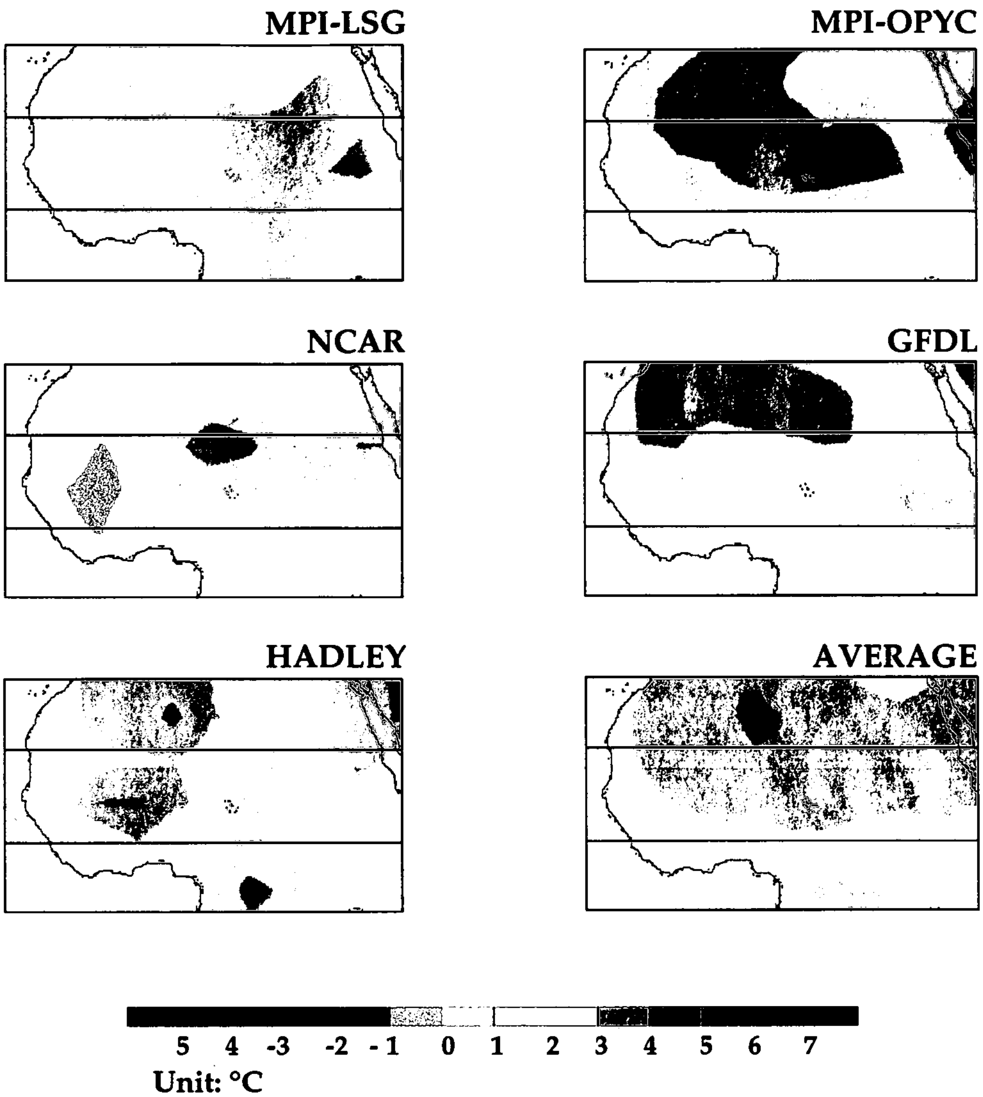
The climate models applied in the first IPCC (Intergovernmental Panel on Climate Change) scientific assessment (IPCC 1990a) focused on the steady state effect of doubling CO_2 concentrations (2xCO_2) The rationale for choosing 2xCO_2 was mainly to get a simple base for performing model intercomparisons that could improve understanding of the climate system and how to model it. Consequently, the change in radiative forcing driving the climatic change in the models was spatially homogeneous. Based on the experience with these models, new versions have been developed with improved parameterizations of cloud processes, ocean circulation, the hydrological cycle and inclusion of such short-lived greenhouse gases (GHGs) as ozone and anthropogenic aerosols (small particles/droplets suspended in the air). This has led to significant regional differences in the radiative forcing. In the 1992 IPCC supplementary report, transient results (with time dependant increase of GHGs) from four coupled atmospheric/ocean models were reported.

The confidence in the predictions made by the climate models for regional climatic changes has been low, as the differences between the models in the predictions of regional climate change have been substantial. The figures 2.1 and 2.2 show calculated changes at the time of CO_2 doubling in surface temperature and precipitation in Sahel for the summer (growing) season for five coupled atmosphere/ocean climate models. To improve predicting regional climate change, nested model techniques and statistical downscaling methods have been developed. Both methods rely heavily on the quality of the large scale flow pattern given by the global climate models. Applications of these techniques to regions other than Africa shows promising results, but so far they have not been applied to Africa. The nested model technique is probably best suited for African studies. This is because the statistical downscaling requires meteorological data from a dense net of observational sites over a sufficient period to provide a basis for the statistical extrapolation of the large scale fields from the climate models.

African climate to a large extent is governed by the Hadley circulation, which causes the convergence and rise of moist humid air in the tropics and subsidence of dry warm air in the subtropical regions around 25° north and south. The inter-tropical convergence zone (ITCZ) moves north during northern hemisphere summer and south during northern winter, giving summer rain in the arid regions south of the Sahara and north of the Kalahari. Using this knowledge, it is possible to distinguish between three regions when it comes to climate changes in Africa. First is the Sahel region, which is characterized by generally subsiding air motions and very limited precipitation during summer (the growth season). Secondly comes the corresponding dry regions south of the Equator in Zimbabwe, Botswana, Malawi, etc. Third, there is the tropical region centered around the Equator. Regions with winter rain (the Mediterranean coast and the southern parts of South Africa) are not discussed in this report.

The IPCC-90 report focused on the Sahel region as one of the regions that received special attention. The fully updated 1995 IPCC report will include the Sahel region as one of the regions that will be studied in greater detail. So far, only figures giving the direct results from five coupled atmosphere/ocean climate models are available (draft discussion and analysis will be ready by summer 1995). Since 1990, the improvements of the models have also resulted in a greater complexity in the models. In particular has been the inclusion of tropospheric aerosols, which, in an African perspective, mainly originate from organic and elemental carbon from biomass burning and add to the difficulty in regional climate forecasting. Over surfaces with low reflectance of solar radiation (low surface albedo), these small particles scatter the solar radiation back to space and thus cool the surface. The lifetime of these particles is short and therefore the effect will be regional. This in turn causes regional differences in radiative forcing as opposed to the spatial homogeneous forcing from well-mixed GHGs (CO_2, CH_4, N_2O, CFCs etc.). The spatial variance in the forcing is likely to give rise to significant uncertainties in the regional climate estimates given by the climate models.

Changes in sea surface temperature (SST) patterns have been shown to have significant effects on the African monsoon circulation, which is crucial in providing much of the summer (the growing season) precipitation to the Sahel region (Druyan 1991). The most recent model calculations of future climate change are based on transient



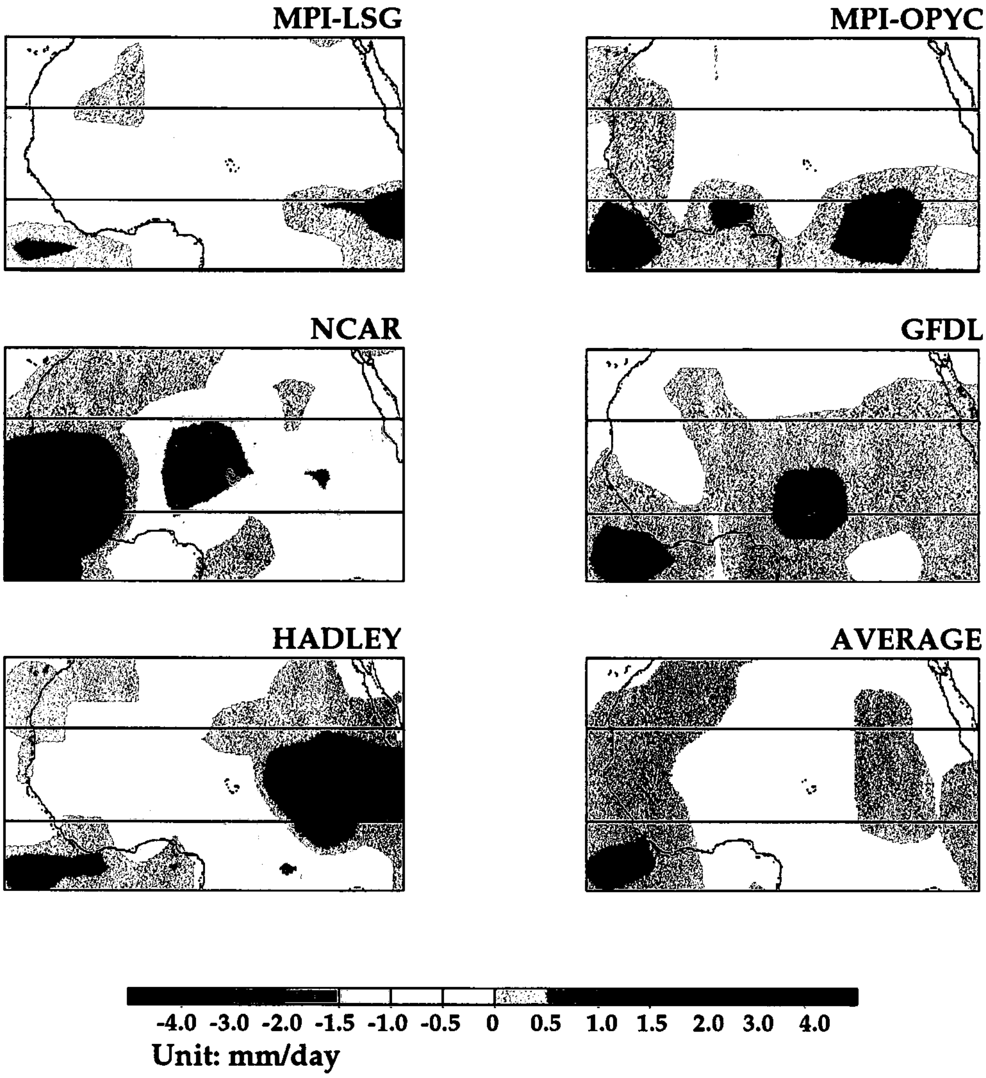
SURFACE TEMPERATURE JJA - SAHEL

(DIFFERENCE: CLIMATE CHANGE - CONTROL)

Source: Model Evaluation Consortium for Climate Assessment (MECCA)
and Deutsches Klimarechenzentrum

Location: http://www.epri.com/Strategic/Environment/MECCA/pics/IPCC/sahel/temp/sahel.temp.diff.jja.gif

Figure 2.1. Calculated change in temperature for June-August at the time of CO_2 doubling in the atmosphere from 5 coupled atmosphere/ocean general circulation models. Average of the 5 models is shown in the lower right panel.



PRECIPITATION JJA MEAN - SAHEL

(DIFFERENCE: CLIMATE CHANGE - CONTROL)

Source: Model Evaluation Consortium for Climate Assessment (MECCA)
and Deutsches Klimarechenzentrum

Location: http://www.epri.com/Strategic/Environment/MECCA/pics/IPCC/sahel/prec/sahel.prec.diff.jja.gif

Figure 2.2. Calculated change in precipitation for June-August at the time of CO_2 doubling in the atmosphere from 5 coupled atmosphere/ocean general circulation models. Average of the 5 models is shown in the lower right panel.

increases of GHGs. As the oceans have large heat capacity, the temperature increase in the oceans shows significant time-lag compared with increases over the continents. Since IPCC-90, the major models have been improved to become coupled ocean/atmosphere models. This degree of freedom is also likely to impose greater differences between the predicted climate for a given increase in GHGs.

Sea surface temperature above 27°C, humid air, and a latitudinal distance from the equator of at least 5° are necessary conditions for the formation of tropical cyclones. Increased SST in the Indian Ocean can give increased occurrences of tropical cyclones hitting Madagascar, Seychelles and possibly also the coast of eastern Africa 5° north/south of the Equator. However, as the climate models presently are too coarse to simulate tropical cyclones, there is no evidence from the models that they will increase in number or intensity.

IPCC 1990 and 1992

The IPCC-90 report (together with the supplementary 1992 report, IPCC-92) provides the latest comprehensive scientific assessment of climate change. The major findings of relevance for Africa are summarized below. It is our opinion that analysis of increased changes in precipitation and soil moisture (IPCC 1990a), and changes in surface temperature and sea level rise (IPCC 1992) are the best available at the moment. The discussions and recommendations given later in this report are thus based on the following results extracted from IPCC-90 and IPCC-92.

IPCC 1990

- The first IPCC report (IPCC 1990a) discusses equilibrium climate changes resulting from a doubling of atmospheric concentrations of CO_2.
- General agreement among models: Increase in surface temperature and increased radiative cooling of the atmosphere due to doubling of CO_2 concentrations lead to increased evaporation at the surface and increased intensity of convective precipitation (e.g. thunderstorms from large cumulus towers).
- Focus on regional changes from preindustrial times to 2030 (applying the IPCC "business as usual" scenario) with 3 high resolution climate models in 5 regions, one of them being the Sahel region. Confidence in these estimates is low.
- In Sahel: Temperature increases of 1-2 °C both summer (JJA) and winter (DJF). Precipitation decreases of 0-10% during winter, increases of 0-5% during summer. Soil moisture increases 0-10% during winter and decreases of 0-10% during summer.
- Large variability in precipitation and soil moisture changes even inside the Sahel region for each model.

IPCC 1992

- The 1992 IPCC report presents results from transient calculations with four coupled atmospheric/ocean climate models.
- Increased annual averaged surface temperature (DT) around the time of doubling of CO_2 in the four models is presented.

Northern subtropical region (arid region with summer rain, includes Sahel):
DT = 2°C (0.5-3.0 °C).
Tropical region: **DT = 1.5°C (0.5-2.5 °C).**
Southern subtropical region (arid region with summer rain): **DT = 2 °C(0.5-3.0 °C).**

- Sea level rise: Transient model calculations generally give slower sea level rise than equilibrium calculations due to the large heat capacity of the ocean. Thermal expansion (the most important process) is thus much less than in equilibrium calculations. The expected temperature rise during the next century is likely to increase the precipitation in Antarctica, however it will still be in the form of snow. The volume of the glaciers in Antarctica is thus expected to increase and lead to a decrease in the sea level. Melting of mid-latitude mountain glaciers and possibly parts of the Greenland ice-cap will contribute to sea level rise. Predictions are a **20±10cm** increase in sea level at the time of CO_2 doubling (approximately year 2030). However, the increase in sea level is likely to go on for a long time (at least another century), even if the climate forcing was stabilized after a CO_2 doubling. IPCC-90 estimates up to a **65cm** increase in sea level in year 2100. (This number is likely to be decreased to **40-45cm** in the new IPCC-95 report (Bert Bolin, private com.).)

In a longer perspective, a study with a simple model by Lapenis and Shabalova (1994) suggests a positive feedback between soil parameters and precipitation. They find that a 2°C warming of ocean surface waters could, after 1500 years, lead to an inland shift of about 400 km in the transition between the vegetation zones. If this effect is real, and if other processes not included in their simple model do not change their conclusion, this could lead to significant reforestation in the monsoon areas of Africa (mainly the sub-Saharan region of West-Africa).

Analysis of climate change in Africa

The observed trend in annual averaged temperature over continental Africa has been +0.53 °C/100 years since 1895 (Jones and Briffa 1992). Compared with estimates of future temperature increases, this is two to eight times less than the models predict for the 21st. century.

IPCC 1992

In IPCC-92, surface temperature observations have been used to obtain regional trends in surface temperature (1980-1990 means vs. 1951-1980 means). In Western subtropical Africa, an increase in temperature of 0.5-1.0 °C is observed during March-November, while there is no significant change during the winter months. In the subtropical areas south of the Equator there has been an increase of 0.25-1.0 °C during all seasons. In the tropical regions of Africa the observations show a decrease in surface temperature of 0.25-0.75 °C, with no significant seasonal differences.

This observed pattern of surface temperature changes is consistent with a strengthening of the Hadley circulation (subsidence over sub-tropical dry areas, and ascent in the tropics) possibly due to heating at the surface and increased radiative cooling in the upper troposphere due to increased levels of greenhouse gases.

Droughts

The recent 25 year period, with annual precipitation 20-50% below normal (1931-1960 average) in the Sahel region, is the most substantial change in observed precipitation in the global record of instrumental measurements (Olaniran 1991; Hulme 1992). Possible explanations for the weakening of the summer monsoon circulation that causes the droughts are land use changes and circulation changes caused by changing patterns of SST. Land use changes, in particular deforestation, can give changes in the energy balance of the atmosphere through increased albedo, reduced fluxes of humidity (latent heat), and increased fluxes of sensible heat. Mylne and Rowntree (1992) found in experiments with the UK Meteorological Office climate model that the potential impact on precipitation was significant, but not large enough to explain the observed drought. Model experiments have shown that warm SSTs in the southern Atlantic decrease the summer monsoon circulation and hence the precipitation in the Sahel region. Some of the climate models predict that increased greenhouse warming, through such a change in SSTs, could lead to droughts. However, the observed drought is more severe than the model predicts for concentrations of GHGs at the 1970-1990 level, and some models do not simulate this effect at all. The question of the drought representing the first sign of a global warming therefore remains uncertain.

A severe regional drought in southern Africa, with reductions in rainfall of 90% in certain regions of southern Zimbabwe and southeastern Botswana, occurred during the early 1990s. The drought was largely a result of the El Niño/Southern Oscillation (ENSO) phenomenon, which is a naturally occurring shift in the circulation of the tropical Pacific. However, in a generally warmer climate the impact of these natural variations is likely to be much more severe.

Current emissions of greenhouse gases in Africa

The contribution from Africa to current anthropogenic emissions of GHGs is low. The African contribution of CO_2 in 1990 was estimated to be about 7% of the world's total anthropogenic emissions, if emissions from land use changes were included (WRI 1992). The African emissions of CO_2 from fossil fuel combustion in industrial processes (including transportation) constitutes only 2-3% of the global emissions in this category (Table 2.1). These numbers are in excellent agreement with emission estimates from IEA (IEA-94). The major anthropogenic sources of CO_2 in Africa are presently from land use changes (~70%), while industrial sources and transportation constitutes about 30%. Table 2.2 shows contributions to CO_2 emissions from land use changes from each country. The African (1500 Mt/y) and South American (1800 Mt/y) emissions in this category are of similar magnitude (23 and 28% of global emissions respectively).

Table 2.1. CO_2 Emissions from industrial sources and land use change (1990). 10^6 metric tons pr. year. Source: WRI 1992

Region	Solid	Liquid	Gas	Gas Flaring	Cement prod.	Land Use Change	Total
Africa	270	260	52	45	24	1500	2150
North & Central Am.	1960	2620	1110	21	58	420	6180
South Am.	67	350	100	19	24	1800	2360
Asia	3150	1950	390	67	260	2600	8410
Europe	1970	1620	620	15	120	-	4350
USSR	1330	1240	1130	38	69	-	3810
Oceania	150	100	40	0	4	12	303
World	8760	8860	3470	205	560	6400	28200

Other greenhouse gases

The anthropogenic emissions of methane (CH_4) in Africa is about 7% of the total anthropogenic source globally, with livestock the main source on a continental scale (WRI 1992). The two large industrial sources of methane are oil and gas production (primarily Nigeria and Algeria) and coal mining (South Africa). African contributions to emissions of nitrous oxide (N_2O) probably make up a larger fraction than methane, as tropical soils are major sources. This source is mainly of natural origin, and there is considerable uncertainty in the global source distribution of nitrous oxide, so the African contribution to total emissions is difficult to assess. Emissions of chlorofluorocarbons (CFCs) in Africa is about 3% of global emissions, and the effect on climate is probably minor as their direct greenhouse effect is offset by a cooling due to decreased ozone concentrations in the stratosphere. The emissions of CFCs are controlled by the Montreal protocol to protect the ozone layer. In the future, non-chlorine CFC-substitutes like HFCs (hydrofluorocarbons) applied in refrigerators, could add significantly to the African emissions of greenhouse gases.

Table 2.2. CO_2 emissions from Land Use Change (1990). 10^6 metric tons pr. year. Source: WRI 1992. X: not available

Country	Emis-sion	Country	Emis-sion	Country	Emis-sion	Country	Emis-sion
Algeria	X	Djibouti	X	Mada-gascar	120	Somalia	5.2
Angola	33	Egypt	X	Malawi	58	South Africa	X
Benin	9.5	Eq. Guinea	1.8	Mali	7.7	Sudan	98
Botswana	2.6	Ethiopia	30	Mauritania	X	Swaziland	X
Burkina Faso	17	Gabon	30	Maritius	X	Tanzania	21
Burundi	0.5	Gambia	1.9	Morocco	X	Togo	2.9
Cameroon	60	Ghana	31	Mozam-bique	30	Tunisia	X
Cape Verde	X	Guinea	37	Namibia	X	Uganda	10
Central African R.	13	Guinea-Bissau	18	Niger	7.4	Zaire	130
Chad	15	Kenya	13	Nigeria	270	Zambia	27
Comoros	X	Lesotho	X	Rwanda	2.1	Zimbabwe	16
Congo	12	Liberia	39	Senegal	11		
Côte d'Ivoire	350	Libya	X	Sierra Leone	4.6	**Africa Total**	1500

Chapter 3

Natural resource management

According to present climate models, future climate change may be expected in Africa, albeit with a low confidence level for the scientific estimates (Chapter 2). Despite uncertainties, one may nevertheless predict certain likely changes to affect natural resources on the African continent.

This section is based on a selection of recent studies which focus on the potential impacts of climate change in Africa. These are, among others, 1) 8 country reports and 4 regional reports presented at the African conference on Policy options and Responses to Climate Change, held in Nairobi, December 5-8, 1994, 2) Hulme et al. (1995), which summarizes current knowledge of potential impacts and recent case studies, and 3) Reports from the IPCC Special Workshop on Article 2 of the United Nations Framework Convention on Climate Change (IPCC 1994). The latter reports contain the current state of knowledge on impacts of climate change in different sectors, but do not relate specifically to Africa. A selection of case studies on climate change is shown in figure 3.1 below.

The literature reflects the present uncertainties and lack of scientific knowledge, and, at the same time, the serious concern among the African countries for what *can* actually happen. These concerns are understandable, considering that Africa is regarded as the continent which is most sensitive to climate change while contributing the least to GHG emissions.

In the following, natural resources are grouped under a few headings, and the potential climate change impacts are discussed for each group. The potential climate change impacts are discussed in relation to assumed variations in one or more of the following components, depending upon availability of scientific evidence:

CO_2 level increase
Temperature increase
Rainfall increase or decrease
Frequency of extreme weather events (storms, floods, droughts)
Sea level rise
Changes in radiation and cloud cover

Agricultural resources

Agriculture is the mainstay of the economies of African countries, contributing to 34% of the Gross Domestic Product (GDP), 40% of the exports and 60% of the employment (Obasi 1994). Climate change will affect the agriculture sector mainly through increased atmospheric CO_2 concentrations, altered weather patterns (temperature and precipitation), and changes in cropping systems and markets (Hulme et al. 1995). Possible impacts of sea level rise will also be discussed.

Cropping

Elevated CO_2 concentrations

Scientific studies and laboratory tests focusing on individual plant responses have shown that enhanced CO_2 concentrations lead to accelerated rate of photosynthesis, increased water use efficiency, increased above- and below-ground productivity, and decreased stomatal conductance and transpiration. C_3 crops (such as wheat, barley, rice and potatoes) seem to be more responsive than C_4 crops (maize, millet, sorghum and sugarcane) (Allen-Diaz 1994). The total effect of the CO_2 fertilization is however debated; it is uncertain to what extent experiments in controlled environments are able to include the whole range of interactions affecting yield output in real-world agriculture (cf. Hulme et al. 1995).

Sinha (1994) suggests that an increase in growth rate does not necessarily result in increased grain yield. Rice plants were exposed to 900 ppm CO_2 before and after heading at near-optimum temperature. The observed increase in yield was 28% and 11%, respectively, though the crop growth rate increased about 50%. An experiment on winter wheat crops indicates that the effect of CO_2 fertilization may be offset by increased temperature. The increase in yield caused by a doubling of CO_2 (between 14% and 36%) was offset by the reduction in yield caused by a rise of only 1°C during grain growth (Semenov and Porter 1994). Furthermore, crops grown under high CO_2 concentrations (in laboratory) have shown to be of lower food quality due to high carbohydrate content and low nitrogen content (Kellogg and Schware 1981).

It has also been suggested, without further scientific evidence, that a potential increase in productivity may be offset by the concomitant growth in weeds (Karekezi and Majoro 1994), and that rapid biomass growth may provoke depletion of soil nutrients and water, such that artificial fertilizers and irrigation would become necessary (Claude et al. 1994).

Changes in temperature and precipitation

The anticipated increase in atmospheric CO_2 concentration will lead to a general increase in temperature and a variable change in precipitation (Chapter 2). Drought is the most important factor limiting agricultural and livestock production in the drier regions of Africa (Nyabundi and Njoka 1991). Increased rainfall would thus be welcome over the large expanses of semi-arid and arid regions. The model predictions indicate, however, that for the most part the present precipitation trends will be enlarged, namely wetter and warmer in the tropics and drier and warmer in the northern and southern parts of Africa. As pointed out in chapter 2, there may however be great differences in the type, magnitude and direction of impacts on the regional and local level.

Figure 3.1

A selection of global and regional*) case studies on climate change located in Sub-Saharan Africa

Subject	Starting date (length in months)	Location	Author/Organizations
• Methodological Framework for National GHG Abatement Costing Studies	10/93 (28)	Senegal, Zimbabwe	UCCEE
• Country Case Studies on Sources and Sinks of GHGs, Phase I	11/92 (28)	Gambia, Nigeria, Senegal, Tanzania, Uganda	UNEP, GEF
• Country Case Studies on Sources and Sinks of GHGs, Phase II	06/95 (18)	Burkina Faso, Cameroon, Seychelles	UNEP, GEF
• Country Case Studies and Training Material on Climate Change Impacts and Adaptations Assessment, Phase I	04/95 (18)	Benin, Cameroon, Ethiopia, Senegal, Uganda	UNEP, GEF
• Training Programme to Promote the Implementation of the UNFCC	07/93 (15)	Zimbabwe	UNITAR, Interim Secretariat of the UNFCCC, UNDP, UNEP, GEF
• Implications of Climate Change and Sea Level Rise and Vulnerability Assessment of Selected Coastlines	(12)	Kenya, Mauritius, Nigeria	
• Building Capacity in Sub-Saharan Africa to Respond to the UNFCCC	04/94 (24)	Ghana, Kenya, Mali, Zimbabwe	UNDP, GEF
• Greenhouse Gas Mitigation in Southern Africa	10/94	Botswana, Tanzania, Zambia, Zimbabwe	UCCEE
• Climate Change and vulnerable places		Senegal, Zimbabwe, Kenya	Downing (1992)
• Global Climate Change and Agricultural Productivity in Southern Africa		South Africa, Lesotho, Swaziland	Schulze et al. (1993)
• Climate Change Effects in Burkina Faso	1995	Burkina Faso	UFCCEE, Govt. of Burkina Faso, Govt. of Denmark
• Water resources in the Nile Basin		Sudan, Ethiopia	Conway (1993)
• Vulnerability of coastal cities to sea level rise		Tanzania, Nigeria, Gambia	Chidi Ibe (1991)
• The possible impact of sea-level rise on the Diep/Ritvlei system, Cape Town		South Africa	Hughes et al. (1993)

Main sources: CC:INFO (1994), Hulme et al. (1995)

*) Updated information on *national* case studies can be found in the Climate Change Information Exchange Programme, CC:INFO.

Where moisture is a limiting factor, a net increase in water availability will have a positive effect on crop growth. However, elevated temperatures also increase soil processes (mineralization) and decomposition rates. Increased rainfall may thus lead to increased loss of soil organic matter (with corresponding negative effects on soil structure) and loss of soil fertility through leaching of soil nutrients and soil erosion. The overall effect is determined by the cropping system (including the extent of ground cover), and the intensity and annual distribution of rainfall. Generally, precipitation is expected to occur more in the form of convective (high intensity) rainfall. Increased rainfall intensity commonly followed by floods will be destructive to crops and result in increased soil erosion and nutrient leaching.

Due to increased temperatures, thermal crop limits will be moved from present ranges. In the Sahel this move is expected to go south, extending the desert area, and toward higher elevations. This would mean that present crops and cropping systems become less appropriate to the environmental conditions, and a situation similar to the concept of "drought follows the plow" could occur: In times of great population pressure on land, new settlers attempt to grow crops in increasingly marginal lands with the same cropping systems as in more fertile areas. The result is a decrease in yields, not because of changes in climate but because of the inappropriate agricultural practices (Glantz and Degefu 1991). This situation may also be illustrative for Africa. It underlines the need for appropriate agricultural practices, including the selection of crops and livestock that are adapted to local environmental conditions. The importance of conserving the diversity of genetic resources should therefore be a major concern. This will be discussed further in the biodiversity section below.

However, the most significant effects of changes in temperature and precipitation in Africa will probably be changes in the timing and length of the growing season and increased moisture stress (Hulme et al. 1995). A crop like millet is particularly sensitive to reduced rainfall during reproductive stages of growth (Sivakumar 1992). The timing of rainfall events is also important for local decisions on when to till the land and when to plant crops. It will also influence weeding and crop harvesting pattern. Montieth (1991, cited by Rockström 1995) reports that in the semi-arid Sudano-Sahelian region, the present problem of attaining livelihood security is not a shortage of annual rainfall *per se*, but rather the large spatial and temporal fluctuations in rainfall and the high rate of evaporation loss. As a consequence, the irrigation potential in these regions is low. Irrigation in dryland areas is also problematic due to the high energy consumption and salinization problems.

Figure 3.2

Some experiences from past climatic fluctuations in Africa

Given the limited number of case studies on climate change in Africa, looking at past experiences may be a useful approach to predicting potential future impacts.

Cameroon: the droughts of the seventies and eighties

Claude et al. (1994) outlines the main impacts of the droughts in the seventies and eighties (with emphasis on the 1982/83 drought):

1) Depletion of inland surface waters and water scarcity, resulting in prevalence of water-borne diseases such as typhoid and cholera
2) Lowering of crop yields: In 1982/83, the overall loss in crop production was evaluated at 15-20%.
3) Animal breeding suffered from low production of feed from agricultural residues and shortage of water. Increases in animal diseases were also recorded as a result of the drought. In the North-West Province, where cattle rearing is the main speciality, 10% loss of cattle was recorded, with low yields in beef production.
4) Migration and increased pressure on arable lands: Mountain dwellers have migrated towards the lowlands in search of waters in the western plateaus. At the same time, intensification of grain farmlands in the altitudes have led to an increase in conflicts of land ownership between farmers and grazers. The occupation of marginal lands were intensified.
5) Disruption of the distribution and marketing of food
6) Difficulties for farmers to fulfill their financial engagements

Uganda, Rwanda and Kenya: Increase in malaria and plant pests due to warming?

In recent times it has been observed an increase in the incidences of malaria in the highlands of Kabale, Uganda, a region where malaria was unknown 30 years ago. It is now believed, and yet to be confirmed by research; that the apparent warming in the area has increased the habitat of the malaria mosquito in the region. Incidences of recent droughts have also influenced the remarkable increase in plant pests, especially the cassava mosaic which has effected most parts of Central, Eastern and Northern Uganda. (Excerpted from Otiti 1994).

Ecologist Michael Loevinsohn of the International Development Research Centre in New Dehli, India, has linked a 1-degree-Celsius increase in the average temperature in 1987 to a 337% rise in the incidence of malaria that year. The mountainous areas, in which malaria had been "rare or absent", were found to be especially vulnerable. (*The Lancet* 343:714, cited by Stone 1995). These data is reported to coincide with findings from other tropical countries, including Costa Rica, Colombia, India and Kenya, showing that one of the prime carriers of the diseases dengue and yellow fever, the *Aedes aegypti* mosquito, has extended its range higher into the mountains than before (Stone op.cit.).

Zimbabwe: the 1991/92 drought

The catastrophic drought of 1991/92, which probably was linked to an El Niño/Southern Oscillation (ENSO) event, offered valuable insight into Zimbabwe's vulnerabilities to changes in climate. During the drought, temperature reached record heights, rainfall fell to 40% of normal, the water table dropped by 100-200 m, ground water (including shallow wells and boreholes) dried up, and numberless rivers, lakes, reservoirs, and their related ecosystems disappeared.

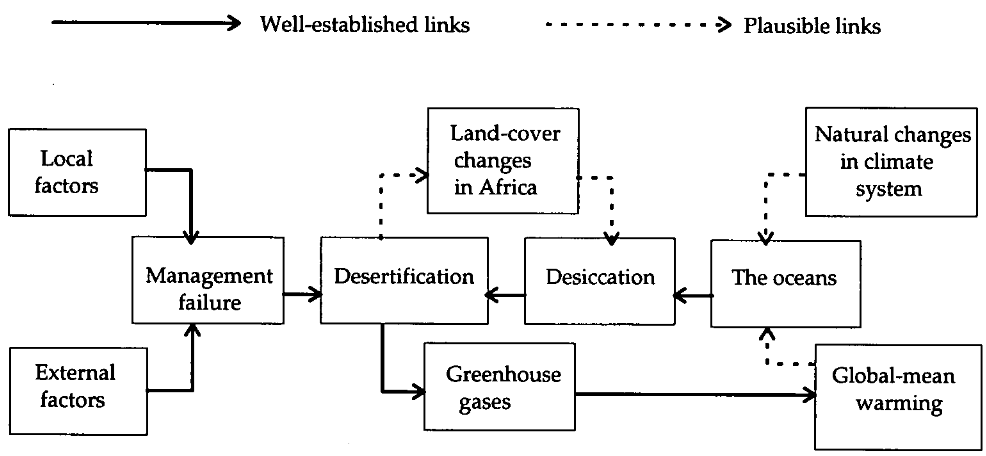
1) Water resources: People in remote areas often walked 10-15 km for their daily supplies, and rural services were threatened with closure.
2) Agricultural system: the southern limit of grain production shifted northwards, and the national herd was reduced by up to 50%. The drought recovery programme cost over Z$200 million (US$40 million).
3) Energy sector: Productivity in the Lake Kariba dam (where some 80% of the country's energy comes from) dropped to 40% of capacity. To maintain Zimbabwe's structural adjustment programme, power had to be imported at great expense from Zaïre, Zambia, and South Africa.
4) Forestry sector: Most of the rural population uses fuelwood and other biomass for its domestic energy needs. The drought caused such harsh conditions that a number of indigenous and exotic tree species actually perished.
5) Human health: During the drought, new and drug-resistant strains of malaria and diarrhoea were reported in all districts. Logistical problems plagued the delivery of essential drugs to rural clinics and hospitals.
6) Economic development: Diversion of funds to emergency relief weakened investment in the country's industrial reform programme.

The drought highlighted the vulnerability of various economic sectors, and thereby created widespread awareness among policy-makers and the general public of the need to address the country's dependence on climatic conditions. (Excerpted from IUCC 1994).

Droughts, desiccation and desertification

Drought is a period of two or more years with below-average rainfall, while *desiccation* is the process of aridification resulting from a dry period lasting a decade or more (Warren and Khogali 1992, cited by Hulme and Kelly 1993). Experiences from past drought periods in vulnerable regions in Africa have shown a set of impacts on the agricultural systems that may be multiplied by future climate changes (See also figure 3.2). Among the effects of drought have been intensification of existing farming systems, farming extending into unstable marginal lands, crop destruction, declines in production, disruption of food distribution and marketing, and problems in animal husbandry. Consequently, droughts increase the risks for food shortage and economic problems for farmers, as well as conflicts about land ownership between farmers and grazers. Temperature increases, coupled with rainfall decreases, may also result in increased bushfire frequency, with long-term negative impacts on organic soil matter and nitrogen availability in addition to a potential for increasing GHG emissions.

The term *desertification* is defined as "land degradation in arid, semi-arid and dry sub-humid areas resulting from a variety of factors, including climatic variations and human activities" (UN Conference on Environment and Development, Rio 1992). There is a complex link between drought, desiccation, desertification, and human-induced climate change, illustrated by the figure below.



Note: Desertification is the result of resource management failure, the product of both local factors, such as population pressure and inequity, and external factors , such as the state of the global economy, commodity prices, and the burden of debt. Desertification is aggravated by climate change—desiccation—which may be the result of natural mechanisms with the climate system, such as ocean-atmosphere feedback; by desertification itself through, for example, surface-atmosphere interaction; or possibly by global-mean warming. Finally, desertification contributes to global-mean warming through its effect on the sources and sinks of greenhouse gases, such as carbon dioxide. Many uncertainties affect assessment of the relative role of these various factors.

Figure 3.3. The matrix of cause and effect surrounding desertification and the role of climate change. Source: Hulme and Kelly (1993).

There has been considerable debate about the extent of desertification in Africa (see e.g. Nelson 1988; Warren and Agnew 1988). There is also great uncertainty connected to the relative role of the factors in the figure (3.3) above.

As described in chapter 2, the link between sea surface temperature (SST) anomalies and rainfall patterns is considered to be a major factor concerning the Sahelian drought/desiccation (Folland et al. 1986; Hulme and Kelly 1993) and hence the climatic factor in the desertification process. To what extent *human-induced* climate change may affect this system is not clear. Kadomura (1993) points out that there have been dramatic climatic changes in the Sudano-Sahelian region throughout history, and these changes may contain possible keys to understanding the causes for present land degradation and for predicting future climatic changes.

Desertification may also contribute to global warming, in two ways: 1) If vegetation is removed on a permanent basis, the desertification process reduces potential carbon sinks and increases CO_2 emissions. Emissions of other GHGs may however change in either directions (Hulme and Kelly 1992). Williams and Balling (1994) suggests that the *global* degradation of drylands probably contributes less than 5 per cent of the GHG forcing. However, these emissions may nonetheless be significant on the regional or national scale, and slowing desertification could therefore offset growth in other greenhouse gas emissions (Williams and Balling op.cit.; Hulme and Kelly op.cit.). 2) Desertification is likely to cause reductions in surface soil moisture, thereby making more energy available to increase air temperature. It has been noted that desertified areas have been warming faster than non-desertified areas over the past century (cf. Balling 1993), but it is debated how important this effect is on global warming records (Balling 1991; Hulme and Kelly 1993).

It must be remembered that drylands are areas where people are adapted to large temporal and spatial fluctuations, but where there is insufficient knowledge about thresholds of the ecosystems to regional deficits in soil moisture, temperature extremes and salinity (Williams and Balling 1994). However, the fragility of soils and instability of water supply imply that dryland areas should receive particular attention in climate change discussions.

Crop production and food supply

Globally, only small decreases in crop production may be expected because of climate change (Rosenzweig and Parry 1994). Still, the distribution of crop production is likely to be uneven; Fischer et al. (1994) found that all studied scenarios suggest a relative change in agriculture in favor of developed countries. Developing countries, of which African countries are among the poorest, are expected to receive a noticeable loss in agricultural production, increasing the number of persons at risk of hunger. However, there are many uncertain factors, including the magnitude and spatial characteristics of climate change, range and efficiency of adaptation possibilities, the long-term aspects of technological change and agricultural productivity, and future demographic trends (Fischer et al. op.cit.).

Pest damage

Many pests and diseases are controlled by climatic factors (cf. Hulme et al. 1995). Generally, reduced rainfall is expected to decrease pest damage. Increases in temperature (and rainfall) may on the other hand lead to lengthening of breeding seasons or increased geographical ranges, or new pests may emerge. The authors op.cit. mention the possibility for increased incidence of disease early in the growing seasons due to better conditions for overwintering. It is also reasonable to believe that a combination of other environmental stresses, like droughts, will increase the crop susceptibility to pests and diseases. Ultimately, it has been assumed that climate change may increase post-harvest spoilage and putrefaction of animal products such as meat and milk (Nyabundi and Njoka 1991).

Sea level rise

An anticipated rise in sea level due to global warming will increase the intrusion of saline water in deltas and coastal low lying lands and rivers, and impact on coastal crop and rangelands. In the river Zambezi, sea water has been traced to 80 km upstream. A further sea level rise will worsen this problem and may render longer stretches of Africa's main rivers unsuitable for irrigation use (Nyabundi and Njoka 1991). A sea level rise may also increase saltwater intrusion into aquifers, thus reducing water availability. (See also water resources section).

In spite of all these potential risks to agricultural productivity from the gradual increase in atmospheric CO_2, technological change through the use of irrigation and breeding of drought-resistant varieties could ameliorate some impacts over time. However, developing countries in Africa may not readily benefit because of their lack of economic and scientific flexibility (Odingo 1994). If a shift in agro-climatic zones occurs, farmers might not have adequate resources to adjust and adapt accordingly, and major crops could go out of production. The situation will be most serious for the poorest segments of society who live in marginal environments that are sensitive to changes.

Livestock

Livestock production is likely to be impacted in similar ways as agriculture, and because livestock and agriculture are commonly associated, impacts on livestock will affect agriculture and vice versa. Plant growth response to CO_2, as well as the importance of conserving genetic resources, were mentioned above. The main impact of climate change would probably be an increase in existing problems.

Higher temperatures may increase water demand, as well as increase lignification of grazing plant material with corresponding lower digestibility. However, it is unclear how significant this effect would be, considering the relatively low temperature increases predicted by the models.

Past droughts in Africa have led to problems in animal breeding due to low production of animal feed and scarcity of water, as well as an increase in animal diseases. Climate change with reduced precipitation will increase land degradation problems in vulnerable areas, which are often enlarged by overgrazing.

With an increase in rainfall caused by climate change, there may be an increase in fodder availability in areas where rainfall normally is the limiting factor. On the other hand, lower fodder quality (dilution of nutrients in grazing plants, more pests) may be a problem. Increased rainfall may mean increased suitability for cropping in

Vegetation Change Predicted by the Modified Budyko Model

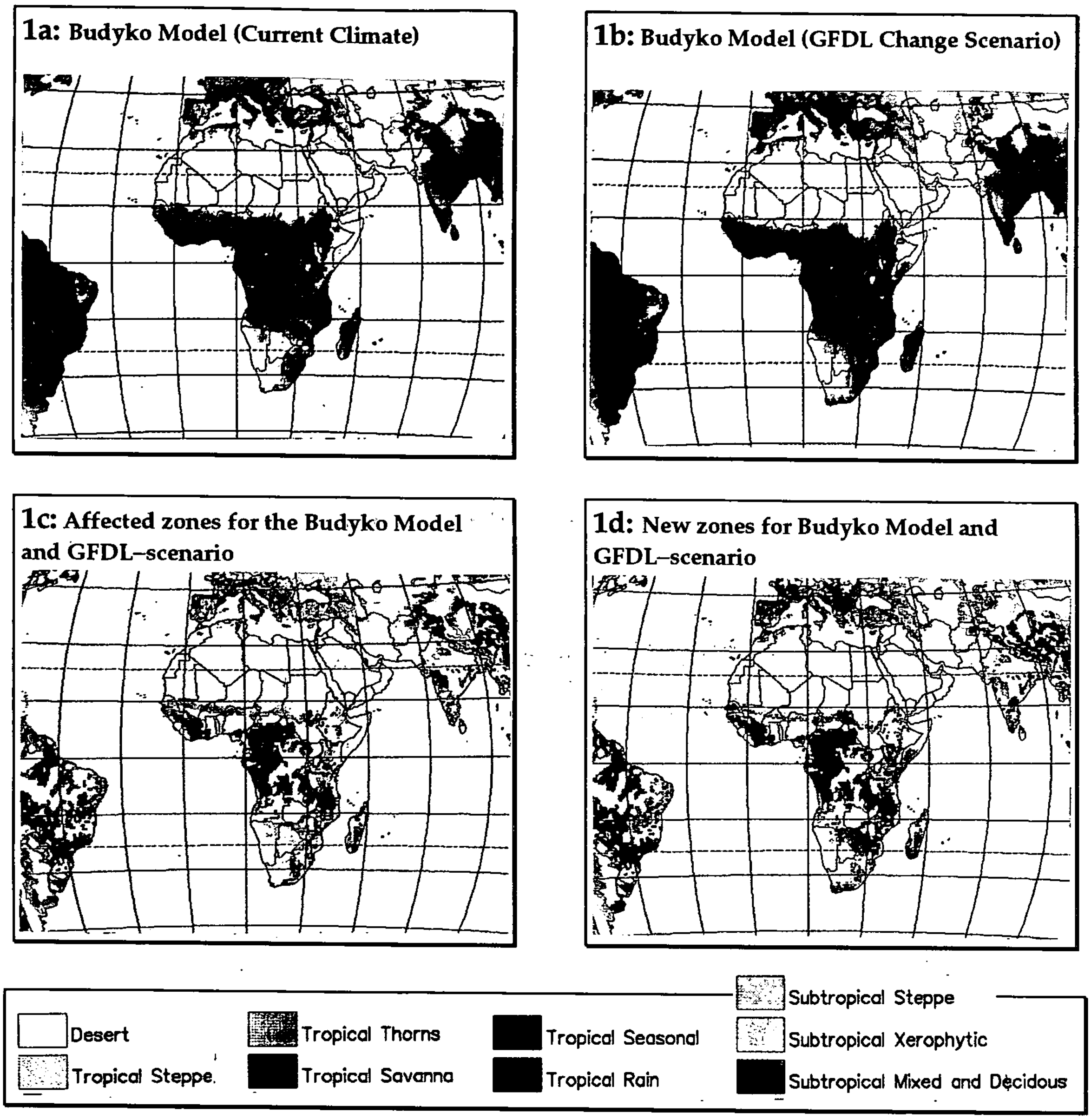


Figure 3.4. The modified Budyko model map predictions for Africa. Source: Monserud et al. (1993). **1a** = Current climate. **1b** = Climate change: This map is derived from a double CO_2 climate scenario as predicted by the GFDL general circulation model. **1c** = Locations on the current climate map (1a) that are changed ('affected zones') on the GFDL climate change map (1b). The blank white locations are the same in both maps ('stable'). **1d** = Locations on the climate change map (1b) that have changed ('new zones') from the current climate map predictions (1a). The blank white locations are the same in both maps ('stable').

rangelands and result in land use conflicts. Rangeland ecosystems are found to be very sensitive to conventional tillage, and do not recover in predictable ways or time frames from loss of organic matter and interruption of nutrient cycles (Allen-Diaz 1994).

Forestry

The impact of climate change on the forestry sector in Africa must be related to the other stressors affecting the structure and composition of forest ecosystems. As for plant species, the effect of CO_2 on forests is highly uncertain (Brown 1994). Increased temperatures would probably be of significance mostly by exacerbating the severity and duration of droughts for forests at the dry-margin of their range.

When considering forests in the tropical zone, Brown (op.cit.) emphasizes the effect on the water balance. Particularly vulnerable could be the moist evergreen forests (which contain the least drought-tolerant species), and forests already growing at the limit of water availability, such as the dry forests and woodlands. In areas experiencing warmer and drier climate, climate change would, as mentioned above, lead to higher risks for forest fires and bushfires at the forest edge. Forest fires are already a considerable problem in Africa. A sea level rise may lead to deforestation of low-lying forest areas as well as the destruction of the mangrove forests. This will be discussed further below. The forecasted increase in the frequency of extreme weather events, such as storms, floods and droughts, may have severe impacts on the coastal forest resources and coast stabilization.

The climate change models (GCMs) produce conflicting results about whether the forested area in the tropics will shrink or expand. BIOME 1.0 projects an increase in area suitable for tropical forests, while MAPPS shows little or no net change (Brown 1994). Monserud et al. (1993), using the modified Budyko model, concluded that most vegetation classes in the tropics are expected to expand. Nearly all future changes in vegetation were found to occur south of the Sahara. Any shift favoring forest over savanna, or vice versa, will, according to the authors, op. cit., be determined by the precipitation patterns accompanying global warming. See figure 3.4. Other process models, such as IMAGE 2.0, that incorporate additional effects of humans (population growth with increasing pressure on forest lands), suggests that, by 2050, under a "business as usual" scenario, 50% of the present tropical forests will be lost, with most loss occuring in tropical Africa (Brown op.cit.). Such a loss will have significant implications for fuelwood production and supply, commercial tropical hardwood production, and the considerable amount of other market and non-market forest goods and services. Deforestation, if it leads to permanent land use change, is also a significant source of CO_2 emissions, see chapter 4.

Fish resources

Fish make up a significant part of the food supply in Africa. FAO (1993, cited by Hersoug 1995) estimates the total fish harvest potential at around 10.5 millon tons; 7.8 million in saltwater and 2.7 million in fresh-water fisheries. In a densely populated country such as Nigeria, as much as 1/3 of the protein supply comes from fish (Hersoug 1995). Consequently, any fluctuation of the fish stock will impact on planning and management. A reduction in fish stocks will have the greatest effect on developing countries that are 1) heavily dependent on fisheries and 2) not able to diversify easily into other activities. Examples of African countries with these characteristics are Mauritania, Namibia and Somalia (Clarke 1993).

According to Everett (1994), the potential impacts of elevated temperatures on coastal fisheries include: 1) A shift in centers of production and the composition of fish species as ecosystems move geographically (polewards) and change internally. Freshwater fish species, particularly in small, shallow rivers and lakes, will have limited possibilities to adapt to the changes by migration. 2) Current ranges of important commercial fish species may shift: Rapid changes due to physical forcing favors smaller, low-priced opportunistic species that discharge large numbers of eggs over long periods. Thus the economic values can be expected to fall until long-term stability is reestablished. 3) Where ecosystems shift position, national fisheries will suffer if institutional mechanisms are not in place that enable fishermen to move within and across present exclusive economic zone boundaries. Subsistence and other small-scale fishermen (who dominate in Africa) will probably suffer disproportionally from changes.

Temperature increases also lead to increased evaporation. If the increased evaporation is not offset by an increase in rainfall, this will mean that lakes and rivers and consequently fish habitats will shrink.

A rise in sea level may seriously affect fish- and crustacean-producing coastal ecosystems. Mangroves, coastal wetlands, marshes and shallows may be lost or relocated and subsequent increases in coastal erosion may occur, impacting on fish stocks and replenishments (cf. Hulme et al. 1995).

If the climate becomes more variable, local fish populations may more often experience extreme events such as those that produce lethal conditions for short periods of time. Fishery yields are often heavily dependent on the occasional strong year class (Richey 1994). Thus even small variations in the environment have shown to have great impact on the abundance, distribution and availability of fish populations (Glantz 1994c).

Glantz (op.cit.) regards model scenarios as inadequate and possibly misleading for providing a basis for policy making at regional and local levels. Instead, the author suggests that one should use a "forecasting by analogy" approach. By looking at how societies have responded to climatic changes in the past, one could gain valuable insight about societal strengths and weaknesses and tactical responses to future disasters. The response strategy would hence be that societies evaluate and strengthen their ability to cope with unexpected changes.

Biodiversity resources

For African countries, biodiversity represents wealth with respect to the present and potential future goods and services it may provide, including genetic variation and varieties useful for development of the agricultural sector, forest products, medicines, tourism income, and a heritage of unique species and ecosystems. The convention on biological diversity (UNEP 1992c) aims at conservation and sustainable use of biodiverse resources, as well as equitable sharing of the benefits.

African ecosystems have always been subject to changes and are adapted to changes. However, in terms of ecological adaptation processes, the present changes in the natural environment are very rapid. Little is known about the different ecosystems' thresholds to changes or extreme events from which they could no longer be able to adapt. Climate change is one of many stress factors which may increase the risk for reaching those limits, directly and indirectly leading to irreversible loss of species and ecosystems. Globally, the current global decline in biodiversity may lead to one of the great extinction events of Earth history (Raven 1994).

The potential biological responses of species and ecosystems to climate change are reviewed by (among others) Gates (1993), Peters and Lovejoy (1992) and Kristiansen (1993). The impacts of climate change on African ecosystems are complex and highly uncertain, and one thus has to use general principles in order to assume possible impacts. The uncertainties involved in plant responses to elevated CO_2 concentrations were discussed above. The projected temperature increases are relatively low in Africa compared with higher latitudes, but relatively little is known about the African species' physiological tolerances. Some scientists believe that organisms inhabiting relatively unvarying environment (as opposed to temperate climates) have a narrow tolerance range (Kristiansen 1993). The forecasted regional precipitation changes may also lead to substantial disruptions. It is anticipated that the changes in occurence of extreme events like droughts and floods will affect the species distribution more than changes in average conditions *per se* (Walker 1991; Peters 1992).

In addition to first order responses to changes in CO_2, temperature and precipitation patterns, second-order effects may occur. Many scientists share the view that each species will respond differentially, affecting a number of intra- and interspecific interactions and leading to a reshuffling of species into new aggregations and ecosystems. This occured during Pleistocene oscillations (Lovejoy and Peters 1994).

A possible outcome of climate change is latitudinal and longitudinal shifts in the habitat suitability for plant and animal species. This is caused both by direct effects on physiology, and indirect effects caused by other species which themselves are affected by climate changes. Generally, adaptation to climate change occurs either through evolution, acclimatization, or migration (DN 1994). Historic evidence indicates that the major response to climate change has been migration (Kristiansen 1993). The principle impacts will be on plants, where the inherent ability to migrate varies greatly between species. Animals are generally more mobile and have a more rapid response time, but many animals depend on particular plants, and their migration rate will thus be restricted by the migration rate of those plants.

Thus, the critical factors for adaptation are 1) the rate of migration and 2) a suitable migration environment. Problems arise when species are not able to migrate rapidly enough, or migrations are blocked by either natural barriers (oceans, mountains) or human imposed barriers such as urban settlements and wide stretches of agricultural land (Lovejoy and Peters 1994). Furthermore, there might not be suitable habitats at the places species are forced to move to. Species with strict habitat requirements will be more vulnerable than species able to colonize a wide range of habitats.

A major part of the natural biodiversity in Africa is today confined to reserves and national parks which may prove too small for the movements that will become necessary. Hence, the challenge is to provide corridors along which species may move, either in flat terrain or on mountain slopes. Concerning temperature increases, corridors along altitudinal gradients are likely to be most practical, because they can be relatively short compared with the longer distances necessary to accomodate latitudinal shifting (Peters 1992). The problem, however, is that migration to higher altitudes leads to a concomitant reduction in the total area of any habitat type (Dobson et al. 1989, cited by Kristiansen 1993).

A diversity of domesticated crop and livestock genetic resources is a prerequisite for sustainable agricultural development as well as adaptation to changing conditions. Domesticated species have evolved from wild species and have adapted to local conditions through selection, both natural and from the influence of farmers (Berg et al. 1991). Crop and livestock genetic resources in Africa are threatened by a combination of several factors such as persistent droughts, land degradation, introduction of new varieties, and land use changes. Thus, climate change may be a potential additional threat to crop and livestock biodiversity, while the current loss of genetic resources may make it more difficult to adapt to any changes, including climate change.

By using paleontological records, Magadza (1991) found that changes in precipitation patterns in the African semi-arid savannahs in the past have created corresponding changes in vegetation and animal communities. Western (1991) states that a future precipitation increase in these areas would mean that wildlife reserves and parks could be suitable for agriculture which in turn could compound the already serious problem of encroachment on the national parks and reserves. A shift from savannah grasslands to thick bushlands could occur if rainfall increases in the arid regions where most of the wildlife reserves and national parks are located. This will disrupt the existing ecosystem, as species are affected differentially. In case of an overall drier climate, lands become more marginal, agricultural areas shrink, and there will be increased pressure on remaining areas.

On islands and in the coastal zones, a sea level rise could threaten the ecosystems in a similar manner as temperature rise: The inherent adaptation capability must be able to keep up with the changes and there must be suitable migration routes. The productive mangrove forests will be threatened by a sea level rise because migration inland is often blocked by human habitation. Mangrove forests serve a number of valuable functions: They sustain important fish habitats, provide coastal stabilization, are important habitats for invertebrates and birds, and are valuable sources of timber and fuel (Soulé 1986). Still, many places in Africa they have been subject to pollution and excessive harvesting of timber and fuelwood, and are today endangered ecosystems.

As discussed above, fisheries and freshwater ecosystems could suffer from elevated temperatures and changes in precipitation patterns. Especially endemic species in lakes and rivers would be in danger. Marine ecosystems are expected to experience less pronounced impacts due to the high mobility, large ranges, high fecundity, and rapid growth rates of most marine organisms (Ray et al. 1992, cited by Kristiansen 1993). The effects on biodiversity are likely to be larger in coastal areas than in the open sea because near shore organisms are more constrained by the physical features of the shore (Kristiansen op.cit.).

Pollution, overharvesting and habitat degradation may reduce the ability for species and ecosystems to adapt to climate changes. Small remaining populations resulting from fragmentation means that fewer colonists can be sent out, and consequently there are less probabilities for successful colonization of the new habitat. Many tropical deep-forest birds do not cross even small unforested areas (Diamond 1975, cited by Peters 1992). Healthy coral reefs may keep pace with a sea level rise of as much as 1 centimeter a year (Haq 1994), which exceeds the rates for sea level rise predicted by IPCC. At present, however, African coral reefs face multiple threats due to population pressure, commercial exploitation and pollution, and as a result, the growth rate may no longer be rapid enough (Haq op.cit.).

Water resources

Africa is experiencing a dramatic decline in water resources. By the end of the century, the available amount of freshwater per inhabitant is estimated to be only 25% of that in 1950 (Obasi 1994). Falkenmark and Rockström (1993) separate genuine and man-made water scarcity. Clark (1991) reports that the major problem is not the total amount, but rather the distribution, as most of the water drains west into the Atlantic. The current high population growth in Africa will further increase the demand for water at the same time as the supply situation is worsened. In densely populated coastal areas, such as the Nile and Niger deltas, excessive water extraction from aquifers has lowered the water table leading to intrusion of saltwater (Haq 1994). Pollution is another major problem. In addition, climate change may affect both quantity and quality of the water resources.

Water for agriculture and domestic supply

Increased CO_2 levels may increase the efficiency of water use by crops and vegetation, as noted above. Temperature increases will however add to both potential and actual evapotranspiration, which may be critical for regions and ecosystems already stressed by water scarcity. In the Sahel region, around 50% of the rainfall is "lost" to the atmosphere through evapotranspiration (Rockström 1995). The demand side must also be considered. Increased demand for water is a natural consequence of temperature increase.

In areas where precipitation is decreased or where the increase is less than increased evapotranspiration demands due to higher temperatures, dams and lakes used to irrigate crops and supply urban areas will shrink.

In dry areas such as the Sahelian zone, runoff is very sensitive to precipitation. A study from Senegal, Niger and Shari River basins showed an increase in runoff of 30-50% due to an increase in precipitation of 20-30% and similarly 15-59% decrease in runoff due to 9-24% increase in annual precipitation (Sircoulon 1987, cited by Lins et al. 1991).

A lowering of groundwater recharge will affect the groundwater table and the population's water supply, especially shallow wells. Desalinization is very costly and very energy consuming, and is thus beyond many African countries' capability. Decreased water availability could also increase pollution levels, with possibly serious sanitary and ecological consequences.

The fact that many African countries depend on shared water resources makes them vulnerable to any changes in river flows. Gleick (1992) points out that political rivalry over water is likely to grow as scarcity increases. In Egypt, Botswana and Sudan the share of water originating outside their borders is 97%, 94% and 77%, respectively (Gleick op.cit.). Only small changes in rainfall, and to a lesser extent temperature, may have major impacts on the timing and amount of runoff and in turn water supply to rivers.

In those parts of Africa where most of the rainfall is dependent on the monsoon flow (western and eastern Africa), an increase in frequency and severity of storms is anticipated, along with an increase in rainfall amount and intensity (Obasi 1994). The probable effect of this is an increase in floods. The gain in water availability could give local benefits, but these may well be outweighed by the damages caused by increased erosion and flooding (e.g. damage to human settlements, crop damage, loss of soil fertility, spread of water-borne diseases), exacerbated by the lack of flood forecasting and warning systems in most African countries.

Sea level rise, in combination with subsidence due to excessive withdrawals of aquifer water and hydrocarbons, will also provoke the intrusion of salty and brackish water into river deltas and groundwater, thus lowering fresh water supplies for coastal regions and islands. In Africa, this is a major concern for the Niger and Nile delta, with potentially significant socio-economic implications.

Hydro power dams

The potential for hydro-electricity production would also be affected by climate change. Evaporation from hydro power dams and basins is a major problem today, and any increase in temperatures may aggravate this effect. A decrease in rainfall will naturally have an adverse effect on the water supply to hydro power installations. The Kossou dam in Côte d'Ivoire and the Aswan dam in Egypt illustrate this: Both were constructed on the basis of rainfall observations before the drought in the Sahel began in 1968-70, and both have experienced severe problems. For the Aswan dam, only the exeptional rainfall which caused catastrophic floods in Khartoum in August 1988 saved the dam from closing (Sircoulon 1991).

Although an increase in rainfall may offset the evaporation effect and even increase the potential for electricity production, it is also probable that an increase in rainfall amounts and intensity will lead to more erosion and consequently increased sedimentation in the basins. Climate changes leading to greater intra- and interannual fluctuations in water volumes will also have negative effects on natural water management and hydroelectric schemes.

Social, political and economic impacts

Climate change may have significant indirect effects, but considering the great uncertainties involved, "downstream" predictions of climate change impacts on social, political and economic sectors should be treated with caution. In this section, emphasis is put on potential *direct* impacts of climate change.

Sea level rise and extreme weather events

The potential damage of sea level rise will depend upon- 1) the number of inhabitants in the affected area, 2) the amount of coastal land used for agriculture and mariculture, and 3) the extent of coastal infrastructure, including urban development, industries, ports, tourist facilities, sea defences and tidal controls, cf. Clarke (1993).

A joint study by UNEP and Delft Hydraulics of The Netherlands identified Egypt, Senegal, Nigeria, Kenya and Mozambique among the countries most vulnerable to sea-level rise in terms of the extent of the potential impacts and the countries' ability to prevent or minimize them (UNEP/Delft Hydraulics 1989, cited by Clarke 1993). In addition, sea level rise may pose a significant threat to the small island states, some of which are coral reefs and atolls (Haq 1994).

A global sea level rise is likely to be modified by regional characteristics and vertical land movements. In densely populated river deltas and coastal urban centers in Africa the global rise in sea level may be combined with local subsidence, which is commonly accelerated due to excessive withdrawals of aquifer water and hydrocarbons. The total relative sea level rise could lead to significant losses of land available for human habitation, as well as the earlier mentioned reduction in fishing and agricultural potential, and biodiversity losses. A study from the Nile delta in Egypt projects a total relative sea-level increase of more than 1 meter, which is estimated to inundate as much as 15 percent of productive land that produces 13 percent of Egypt's GDP (Haq 1994). Saltwater intrusion in aquifers represents a serious threat to the water supply for growing populations. These estimates are based on little or no further increase in the rates of local subsidence or eustatic sea level increase. A study from the Niger delta in Nigeria shows similar figures: a relative sea level rise of over 1 meter could force up to 80% of the delta's population to seek higher ground (Haq op.cit.). In both cases the situation is worsened by reduced fresh-water flow due to damming upstream.

The impacts from an increased frequency of extreme weather events, such as droughts and floods, have been discussed above. The damage caused to the natural resources sectors is likely to be followed by an increase in the numbers of "eco-refugees", as well as high economic costs due to damage to infrastructure and construction of storm-resistant facilities.

Any changes in the ecosystems which reduce biodiversity could have a significant impact on the potential for an increased tourism industry in Africa. Changes caused by a rise in sea level or increases in extreme weather events will likely alter beach structures and hence the attractiveness of the coastal zone for tourist activities (Hulme et al. 1995).

Human health

Health impacts has up to now been a "curious blind spot" in global warming studies, but there are indications that this field will receive more attention in the time to come (Stone 1995). Impacts on food supply and water quality, as discussed earlier in this chapter, will of course influence on human health. Moreover, as noted in figure 3.2 above, there are research findings in Africa that link higher temperatures and droughts to increased frequency of common diseases. The present scientific consensus, published in the draft of the Health Impacts chapter for the IPCC Second Assessment report, is summarized by McMichael (1994):

Generally, it is stated that sustained human health at an acceptable level depends on the stability of the biosphere's protective and productive natural systems. Disturbance of these and of dependent ecological relationships by changes in the climate would therefore pose risks to human health.

Any increase in frequency of heatwaves would cause a significant increase in the number of heat-related diseases or deaths, even in populations undergoing acclimatization. Furthermore, net increases in the geographic distribution of "vector" organisms of infectious diseases (e.g. malarial mosquitos, schistosome-spreading snails) and changes in life-cycle dynamics of vector and infectious parasites would increase the potential transmission of these vector-borne diseases.

Other climate-induced health impacts could include exacerbation of respiratory disorders, deaths and injuries from extreme weather events, enhanced transmission of contagious diseases (e.g. cholera), and increases in food shortages (on a regional basis). Climate change may also influence the viability, range, and activity of disease pathogens and food-consuming pests. Moreover, climate changes may (as mentioned above) reduce biodiversity, and may alter predator-prey relationships.

Vulnerability to climate-related impacts would differ due to natural, technical and social resources of the populations. For example, the impact of a climate-related increase in exposure to infectious agents would depend on prior contact, general biological resilience, population density, and patterns of interpersonal contact. Adaptive options include improved 1) monitoring of health-risk indicators, 2) environmental management, 3) disaster preparedness, 4) protective technology, 5) public education directed at personal behaviors, and 6) appropriate professional training.

Chapter 4

African priorities

African policies to meet the threat of climate change

African priorities are clearly related to general development and this has been stated at all climate conferences held in Africa: the 1990 Nairobi Declaration which was based on a conference held by ACTS and the Woods Hole Research Center; the Victoria Falls Conference of 1993, and the ACTS/SEI conference held in Nairobi december 1994. The statement of this last conference sets forth the following: "Although African countries are willing to contribute to international efforts to mitigate Climate Change, this should not deviate them from pursuing their development targets". African priorities will in terms of the climate question be concentrated on capacity building in the following areas: formulating national and regional inventories and programmes; developing effective negotiation skills; conduct research; formulate national policies, conduct cost-benefit analyses; build capacity in the area of technology assessment and transfer.

As is to be expected few if any African countries have national policies explicitly aimed at combatting the consequences of climate change. They are according to the convention not required to develop such plans until 1997. They are, however, eligible under the convention for support for the development of inventories climate policies and plans, and a number of countries are using this access to funding. Several countries have single legal acts and chapters under other policies and pieces of legislation that have relevance to climate issues.

A useful review of African climate policies would need to involve an evaluation of existing development strategies and plans, especially energy and forest management plans, and their indirect consequences for climate change concerns. Such a review would reveal the future and potential relevance of policies for climate change, but is not within the confines of this limited study.

Almost all of Africa, but especially the Sahel, is very vulnerable to the potential impacts of climate change. African countries' dependence on natural resources and systems make them vulnerable to natural disasters such as floods, droughts, violent storms and rising sea levels. The 1994 Nairobi conference recommended therefore that "The issues of vulnerability and adaptation to the adverse effects of climate change and variability retain a legitimate position as global obligations under the Convention."

Some African countries have begun to formulate options and possible strategies to mitigate climate change. Yet given the dearth of reliable information on a number of sectors and areas, it will be some time before African countries will be able to meet their reporting commitments under the convention, and thus devise development strategies consonant with the objectives of the convention.

Given that Africa, despite its size, on the one hand contributes only about 7% percentage of the world's total emissions, and Africa's potential vulnerability on the other hand, it is to be expected that African policies will concentrate on combatting that vulnerability. Energy efficiency gains could substantially contribute to mitigating effects of climate change just as they are in other parts of the world. Energy efficient development strategies would thus be beneficial from the perspective of mitigation, and be an important aspect of general development. The great challenge will be to devise energy policies that are both environmentally sound and consistent with development priorities.

To date, African priorities are focused on poverty alleviation, improvement in agricultural performance, food security, ensuring political stability, strengthening local capacity and human resources, and improve educational facilities. It should, however, be pointed out, that most of these priorities are not reflected in African budgets at this point in time. None of these priorites need be in conflict with global environmental aims, as a matter of fact, all of them may contribute significantly to the improvement of present environmental degradation tendencies in Africa.

The ability to meet the threat of climate change depends both on the existence of institutional infrastructures and on natural ecosystems. Even though African countries today put great emphasis on their vulnerability, there is no doubt that a general improvement in planning capacity and governance would improve their resilience to eventual climate changes. Investment in human resources and capacity building on all levels will thus have beneficial effects on countries ability to handle global issues as well.

Future energy scenarios

In an analysis of different energy scenarios and also of mitigation and adaptation measures, an extraordinary long time perspective is necessary. A doubling of the concentrations of carbon dioxide in the atmosphere might be a reality in the middle or the end of the next century. The level of development in Africa at that time is impossible to estimate with any degree of reasonable probability. The fact that development has shown limited progress in most of Africa during the last decades, does not give factual evidence to assume that this will be typical of Africa in the next century.

An outline of the energy sector in Africa today

Traditional fuels such as firewood, animal and plant waste, and charcoal are the most common energy sources in Africa and are primarily used for cooking, food preservation, and heating. Modern commercial sources of energy are mainly consumed by industrial and transport sectors in urban areas. Electricity is generally not supplied to households in the rural areas, while the electrification rate in the urban areas was about 38 percent in 1990 (IENPD 1994).

Supply often meets or exceeds demand in rural areas, given the low density of the rural population and the large stock of available low-grade woody biomass. The collection of wood in the rural areas for household use is therefore usually a sustainable activity which does not lead to deforestation. The traditional use of woodfuels in the rural areas is nevertheless often inefficient, and poorly designed stoves also cause harmful indoor air pollution. Woodfuels used by households in rural areas usually bypass the market place, and are collected directly by the households. The total use of this energy source is therefore difficult to estimate and often not included in international statistics.

While woodfuels are the main energy source for cooking, households in the rural areas spend considerable amounts of money on kerosene and dry-cell batteries to satisfy their lighting and radio needs. Photovoltaic cells are becoming increasingly competitive in rural areas, and are appropriate for households not connected to an electricity grid (Yager and Salvador 1994).

Households in the urban areas are more energy intensive than rural areas. Higher incomes and more common access to grid-based electricity makes it possible for households in urban areas to enjoy a wider choice of fuels. However, only relatively well-to-do consumers can afford to use LPG[1], electricity and kerosene on a substantial scale. Charcoal is therefore the most common energy source in the urban areas.

Harvesting of woodfuels, production of charcoal and the transportation of the fuels to urban areas are important sources of employment, but are often the cause of depletion of forests. The efficiency in traditional charcoaling production is very low, but may however be increased significantly by small investments in improved technology and training of unskilled charcoalers.

The burning of woodfuels does not lead to accumulation of carbon dioxide in the atmosphere as long as it does not cause deforestation. Africa is therefore so far, as discussed in Chapter 2, a relatively modest contributor to global warming. The continent's emissions of carbon dioxide from fossil fuels are small due to the low level of industrialized production and motorized transport. More than 40 percent of the African emissions of carbon dioxide from fossil fuels originates in South Africa. In contrast to the rest of the world, land degradation in Africa constitutes a more

[1] Liquid Petroleum Gas

important contribution to the greenhouse heating effect than emissions from the use of fossil fuels[2].

On the basis of an anticipated demographic and economic development, one may construct greenhouse gas emissions projections for Africa. The value of such projections are however limited because of the uncertainty about the political, technological, economic and demographic development in the region. It is likely that, parallel to a possible economic development in Africa, the emissions of carbon dioxide from fossil fuels may increase relative to emissions of methane which is closely related to agricultural activities.

Development and sustainability

To accentuate the importance of promoting economic development as the most meaningful mitigation measure against global warming in Africa, table 4.1 gives figures for three different energy scenarios for the continent in the long-term. The highest priority in the climate policy in Africa today is to avoid the course that scenario 1 represents. Falling fertility rates and demographic transition will be a result of economic development. In a global warming perspective, it is important that the transition starts as soon as possible because the momentum of high population growth is difficult to change.

So far, econometric studies show positive correlations between economic growth and rising emissions of carbon dioxide (Shafik 1994). Nevertheless, enhanced economic growth in Africa, together with rapid population growth, does not necessarily require a corresponding rise in future emissions of carbon dioxide. The difference between scenario 2 and 3, is the use of energy sources. There is a vast economic literature that focuses on the large substitution possibilities, especially in the long run (Cavendish and Anderson 1994). Crucial factors that are decisive in the choice of scenarios here are public policy and availability and competitiveness of alternative energy technology.

Population growth and demographic transition

The future emissions of greenhouse gases in Africa must be seen in the context of the demographic situation on the continent. Africa is expected to continue to have the most rapid population increase: According to World Population Projections (UN 1992), the population of Africa will stabilize at 3.2 billion in 2150, nearly five times its 1990 population size of about 640 million. As a consequence of this rapid growth, Africa's share of world population will increase from 12 percent in 1990 to 23 percent in 2050.

The demographic development in Africa is the most uncertain element in the long-term population growth projections of the world (UN 1992). According to the

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[2] According to World Resource Institute, 1992. There is considerable scientific debate regarding the accuracy of these estimates. New knowledge about deforestation and desertification in Africa might change this picture.

medium-fertility assumption, the world's population will reach 11.5 billion in 2150[3]. This assumption is especially sensitive to the estimated fertility rates in Africa, cf. table 4.2.

The rapidly growing population in Africa will constitute a force towards higher emissions of greenhouse gases. Nevertheless, one should *not* overemphasize the concern of population growth. There are no linearities in the relationship between GNP per capita and greenhouse gas emissions per capita.

Since 1950, fertility rates have declined substantially all over the world, except in Africa, where the total fertility rate is still above six births per woman. Since 1980, the total fertility rate has also declined in some countries in Africa, but in several of the low income countries the fertility rate has actually increased after 1980. Improved living standards are necessary to reduce the fertility rates and thereby reduce population growth. Especially improved levels of education and better health among women are essential. As is emphasized in the World Development Report 1992, there is no conflict between the need for economic development in Africa and a sustainable environmental policy where mitigation measures against the greenhouse effect will play an important role.

Future energy supply and demand

The investments in energy systems that probably will increase in decades to come will have long lasting consequences for the greenhouse gas emissions from the continent. At an early stage in the process the costs of substitution are lower. The challenge is first of all to secure that the relevant decision makers are aware of the no-regret options which the renewable energy, perhaps especially solar energy, represent. In the context of table 4.1, it is important to secure that development with the characteristics of scenario 3 is favored over scenario 2.

Recent technological developments have created new possibilities for choosing renewable energy sources. The most promising future energy technologies are photovoltaic cells, high temperature solar thermal collectors, and in some cases wind turbines. The fact that households usually have no access to an electricity grid, because of the dispersed rural population, solar power (photovoltaic cells) is especially suited to African rural areas. This may be particularly true when solar energy systems are used in connection with other energy supply systems that together create a reliable 'stand alone system'.

In Africa, hydropower to some extent represents another important low emission energy source for the future, especially in central Africa. Only a small part of the total exploitable hydropower potential in Africa has been harnessed. One should nevertheless be aware of the social and environmental problems (deforestation and disturbance of river basins, fauna and flora) in connection with the exploitation of hydro power in Africa. Forests and agricultural land might be lost and farmers

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[3] These projections do not fully take into account the increasing death rates due to the AIDS epidemic. The social and economic impacts of the epidemic might, however, delay the demographic transition. In total, the AIDS epidemic therefore probably will not represent a very significant force towards lower population growth.

might be forced to move. The exploitation of hydro power is usually more area-demanding than solar power (Anderson and Ahmed 1993).

Table 4.1. Three energy scenarios for Africa

	Scenario 1 Stagnation	Scenario 2 Growth based on fossil fuels	Scenario 3 Sustainable growth
Basic scenario characteristics	Slow economic development. This causes fertility to stay high (delayed demographic transition). Slow transformation of traditional societies.	A successful development policy. Emphasis on the education and health of women. Accelerating economic growth and rapidly falling fertility rates (a rapid demographic transition).	
Population	High growth rate, 3.0 - 5.2 billion in 2100	Rapidly falling fertility rate, slow population growth. 1.6 - 3.0 billion in 2100.	
Energy	Basically woodfuels and charcoal used in households for cooking. Gradual introduction of other energy sources.	Large investments in energy supply, mainly based on fossil fuels	Large investments in energy supply to a great extent based on renewable energy sources
Land management and deforestation	Weak governmental institutions are not able to revise land tenure systems, or to yield any other protection to natural resources. Agricultural practices are not developing efficiently. High population growth gives a rising demand for woodfuels and puts pressure on scarce and often vulnerable resources.	Strong governmental institutions are able to introduce and secure property rights and in other ways make societies take care of their resources in a sustainable way.	
Vulnerability	High. The traditional societies are highly vulnerable to climate changes.	Lower. Modern societies are less vulnerable to climate changes, because they are in continuous change and are therefore able to adapt to changes in the environment: See also Chapter 5, section "Adaptation measures".	
GHG emissions	When development is delayed, the high population growth makes it more difficult to initiate effective abatement measures.	High but declining population growth provides opportunities for abatement measures.	Low emissions due to low population growth and the use of non-fossil fuels in energy production.
Total contribution to the global warming	High due to a large population and natural resources degradation.	High due to the use of fossil fuels, but not necessarily higher than in Scenario 1 because of lower population and good land management.	Low due to low population, the use of renewable sources of energy, and proper land management.

Table 4.2. Estimated and projected population in Africa 1990-2150. Different fertility assumptions. Millions.

Year	Medium	Medium-high	High	Low
1990	642	644	644	640
2000	867	881	881	847
2025	1597	1807	1807	1375
2050	2265	2891	2896	1675
2075	2727	3904	4043	1717
2100	2931	4652	5158	1549
2125	3021	5186	6369	1358
2150	3090	5640	7819	1181

Source: Long-range World Population Prospects, UN 1992.

Conclusions

Economic development is essential for the reduction of the fertility rate. And the development of the fertility rate decides whether there will be around 1.6 or more than 5 billion Africans demanding energy in 2100, a result that will influence greenhouse gas emissions. It is, however, imaginable that new technologies will have made fossil fuels less important at that time. Nevertheless, land use changes and degradation will continue to cause unacceptable greenhouse gas emissions in Africa for a long time to come.

When economic development in Africa accelerates, it is probably inevitable that the emissions of greenhouse gases increase. There are, however, rapid and promising developments in technology for using alternative energy resources, and it is important that the African countries get support in taking advantage of these new technologies.

Mitigation measures against global warming in low-income African countries should be quite different from the mitigation measures in the more developed countries in other regions of the world. In the developed countries, greenhouse gas emissions are high and necessary mitigation measures that have to be taken will, from a national point of view, to some extent create inefficient economic behavior that reduces welfare.

The low-income African countries' contribution to the greenhouse effect is mainly connected to deforestation and agricultural practices. Mitigation measures in African low-income countries should therefore concentrate on improved natural resource management and population growth control. Because deforestation activities to a great extent are inefficient economic activities due to market failures, the short-run mitigation measures will not reduce welfare in the low-income African countries affected by deforestation and desertification.

Measures towards forcing the demographic transition might be cost-effective mitigation measures in the low-income countries in Africa. Such policies should not be in conflict with national interests, as the high population growth is causing a lot of other problems. While effective mitigation measures against greenhouse gas emissions in the developed countries most probably will mean some reductions in welfare, the mitigation measures in the low-income countries in Africa in contrast will reinforce qualified national policies.

To be more specific, while the mitigation measures in the developed countries will concentrate on changing established production structures and consumption patterns, the mitigation measures in Africa, generally speaking, should concentrate on combatting poverty forcing economic growth. World Development Report 1992 for instance underlines that improving education for girls may be the most important long-term environmental policy measure in the low-income countries in Africa. Educated women have fewer children, and their children tend to be healthier and better educated. Improving education for girls could therefore be an important contribution to bringing the low-income countries in Africa into the third stage in the demographic transition and thus, in the long-term, be a mitigation measure against global warming.

It is likely that even the least-developed countries in Africa will at some stage experience accelerating economic growth. If fossil fuel at that time still is the dominant energy source, such growth will induce rising emissions of greenhouse gases. But on the other side, such a development will probably bring the countries into the third stage in the demographic transition. It is important to take seriously that effective mitigation measures against global warming in Africa must reinforce a national economic policy which enhance the welfare of households.

Chapter 5

Response strategies

Abatement measures

It is assumed that all countries, and developing countries in particular, have access to so-called no-regret measures. These are measures that reduce the emissions of greenhouse gases, or enhance sinks, and are expected to give a positive net economic benefit as well. In other words, these are measures that should be carried out regardless of the concern for climate change. United Nations Environment Program (UNEP 1994a) suggests that no-regret options in Egypt may contribute to a 50 percent reduction in their emissions of CO_2. The corresponding estimate for Zimbabwe is nearly 30 percent, the bulk of which stems from more efficient household stoves. If more efficient stoves is a no-regret option, it is likely that a significant reduction in emissions of greenhouse gases can be carried out as no-regret options for the whole of Africa. This indicates that abatement measures may be carried out as part of a development strategy, or at least that they may be initiated with marginal funding and as part of the prioritized national development strategies, irrespective of the GEF.

The question arises, however, of why these no-regret options have not been carried out already. In the case of Africa, there are a number of reasons of high relevance for the design of an abatement strategy. The two most important are:

(i) It is highly questionable whether all advantages and disadvantages of a measure can be adequately assessed in terms of benefits and costs. Since the "market" is far from being perfect in most of the economies, prices fail to reflect the real value of a measure. To remove people in subsistence economies from their area in order to build a dam, for instance, may seem like a no-regret option: After having moved, they have to integrate into the economy somehow, and may thereby increase the national product at "no cost". In spite of the measured positive economic effect, the negative welfare effect is indisputable ("hidden cost"). More generally, the effects of measures are not equally evaluated among those affected, because the valuation of effect reflects the welfare of some people better than that of others. This problem of incidence is present in all economies, but it is probably more significant in most African countries than elsewhere.

(ii) There are national constraints to the economy which are not reflected in prices, such as access to the international credits market. If a country fails to obtain credits for investing in no-regret measures, it is of little help to believe that the project would have yielded a net positive economic benefit. A limitation on loans will lead to a rejection of many expected no-regret options. Climate measures constitute only a minor part of potential measures, thus, if a country receives extra loans which they are free to use for any purpose, it is not evident that the no-regret option for climate effects will be chosen. Moreover, extra loans are often conditioned upon economic reforms. Those measures that may support such reforms may therefore be given priority.

This suggests that apparent no-regret options to abate climate change may need additional funding in order to be carried out, e.g. as a joint agreement with industrialized countries that need "emission-credits". In such cases, measures for which the "hidden costs" are expected to be low, or at least transparent, should be given priority. Thus one should focus on measures that have limited impacts on activities "outside" the market economy, such as the introduction of new technologies in economic production activities. Projects that aim at replacing existing facilities in order to reduce emissions of greenhouse gases will often have impassable "hidden costs". The importance of such costs will usually be less when comparing different alternatives in a development process, for instance to choose between alternative investment options.

A main explanation for the rejection of developing countries in the international credits market is clearly uncertainty, often related to political risks. However, the economic risk of e.g. investments may also be significant *inter alia* because the economic outcome may be dependent on the ability to operate new technology. Therefore, hesitance towards further loans can partly be regarded as a risk premium. In some cases the concern about climate effects of measures may change the evaluation of the total uncertainty of the project. The reduction in emissions in terms of enhanced sinks from a forestation program, for instance, may be assessed with reasonable accuracy, although the economic outcome of the program is uncertain. In such cases, the attention to climate effects could cause no-regret climate projects to advance in the queue of potential projects.

In this context, particular concern should be given to the comparison between alternatives with high investments and low operating costs and alternatives with low investments and high operating costs. High investments mean that capital costs may accrue for a number of years, regardless of the economic success of the project. With low investments, the cost of closing down in order to avoid a huge economic loss is lower. The investor thereby runs a smaller risk. For financial reasons, therefore, the latter should be chosen. For environmental reasons, however, the first one may be more attractive. If the "abatement effect" is more or less certain, it may be beneficial to pay the "risk premium" for the economic prospects as a cost of mitigation. Thus, the concern for climate change may make the support of new technology in Africa more attractive.

A policy in industrialized countries that aims at supporting no-regret projects may bias developing countries' preferences for projects by enhancing the probability of getting a project with positive climate effects funded. By neglecting its own preferences for other positive side effects, the developing country may require a higher funding than necessary for carrying out the project. This calls for the use of incentive contracts when funding climate measures. Incentive contracts aim at preventing agent countries from exaggerating their needs.

Adaptation measures

The effects of an increasing concentration of greenhouse gases in the atmosphere are highly uncertain, both regarding the kinds of effects and their strength. To outline a strategy for adaptation must therefore to some extent be speculative. As pointed out in Section 2, however, it is likely that climate change can result in more extreme weather conditions, such as a higher frequency of droughts and local changes in the precipitation patterns. This makes Africa vulnerable to climate change, as even small changes in these factors may have significant impacts. The vulnerability relates to many different factors:

The dependency on bio-fuel constitutes a main problem for energy management in Africa. The problem is clearly reinforced if climate change leads to deforestation. Thus, increasing the range of substitution possibilities for the energy consumption of households will also provide an adaptation measure. The reason for the dependency on fuelwood is, however, that it is an open access good. Substitutes will have to be bought in a market. The ability to extend the range of possibilities thus requires a transition towards a money economy in many rural areas.

The importance of agriculture. As pointed out in Section 3, agriculture contributes 34 percent of the total GDP in Africa and employs about 60 percent of its population. According to the World Bank (1994c), its contribution to GDP is well above 50 percent in many countries. For different reasons, relatively small climatic changes may have large effects on farming capacity and thereby affect a lot of people. To create new sources of income as a result of a development strategy might therefore serve as an effective assurance against the negative impacts of climate change.

Mobility. The vulnerability of the people increases by the fact that many of them have no alternatives to rural farming. There is usually no alternative for them to move to other areas in order to start up farming there, and because of the lack of education there are small chances of getting work in other sectors. To make them less vulnerable to climate change, therefore, one may prepare for mobility, first and foremost through education.

*Physical health.*Vulnerability to climate changes also relates to the health of people. Better health makes people more resistent to short-term fluctuations in weather conditions. Climate change may also affect health, for instance by further limitations to the supply of drinking water. Thus, health policy is also adaptation policy and vice versa.

Population growth. As pointed out in Section 4, a description of the African future is highly dependent on population growth. A high birth rate will not only imply that Africa's contribution to climate change will increase, it may also drastically increase the vulnerability of the people. It imposes a heavier burden on already heavily exploited resources, and thereby restricts the ability to achieve social and economic development.

Material standards. Material damages caused by e.g. extreme weather conditions can be reduced significantly by better material standards, such as better houses, etc. Better material standards may similiarly save lives. It is therefore important to see general development as an important, perhaps the most important, means to adapt to climate change.

These examples show that one cannot make clear distinctions between abatement and adaptation measures in the case of Africa, and that social and economic development are necessary in order to prepare the continent for adaptation. The effects of development, adaptation, and abatement may also support each other, although they may be in conflict in certain cases. The overall response strategy for Africa, therefore, would be to sort out measures and design them in such a way as to minimize the potential conflicts among the concerns and priorities for development, adaptation and abatement. This may imply a country-wise examination of development plans to figure out whether the concern for climate change may change the priorities or design of development measures. There are two general issues that may be of importance. Firstly, the attention to adaptation suggests that measures to be taken should be directed against the most vulnerable people. This may be in conflict with those who argue that development policy in general should aim at supporting potential "locomotives" in the economy. Secondly, it was shown that the concern for climate change might change the over-all uncertainty of measures. In particular, measures that require relatively large investments may turn out to be more attractive if the expected benefits from the abatement and adaptation points of view are taken into account.

The ability to deal with adaptation and abatement measures

The ability to cope with a changing climate depends both on political and socio-economic conditions as well as on natural ecosystems. African countries must bear the costs of adapting to climate change as well as cover the economic losses which incur once efficient adaptation has occured. As was pointed out above, African countries will put great emphasis on their vulnerability rather that their contributions to emission. This attitude is prevalent because their capacity to implement large-scale adaptation measures, such as introducing drought resistant species or making coastal zone infrastructure investments, may be limited.

To illustrate the close relation between development, adaptation and abatement measures, the impacts of three potential measures will be discussed below. The discussion below might be viewed as a very general input to an action impact matrix, as suggested by Munasinghe (1993). Technological improvements are expected to be carried out mainly for development purposes. To make Africa less dependent on biomass fuels is mainly regarded as an adaptation measure, and a forestation policy is taken to be mainly an abatement measure.

a) Technological improvements in a broad sense include a variety of measures, such as supporting new machinery, building infrastructure and introducing new methods e.g. in agriculture. Common to these measures is that the introduction of new technology requires education, and their success is thereby dependent on the success of the education programs. Introduction of new technology usually aims at economic growth. The social and economic impacts of technological improvements depend on the kind of measure.

Apart from the fact that economic growth in itself makes a country less vulnerable to climate change, the adaptation aspect of introducing new technologies is of particular importance within agriculture. The possible effects of climate change is dependent on how easy it is for the farmers to adapt to new ecological surroundings. Whether the introduction of new technologies and methods in agriculture facilitates or obstructs the ability to adapt is not always clear. More intensive farming may impoverish the soil, thereby making people more vulnerable to climatic change. However, an ecological sustainable development strategy within agriculture will support adaptation.

Rijbersmann and Scwart (1990) suggest that, compared with a "business as usual" scenario for Africa, a scenario that combines a low share of coal consumption, a modest increase in population and a halt in deforestation will reduce the expected increase in global temperature by only 1/10 around year 2025.

Africa possesses a considerable potential for solar and hydro power whose further development might be encouraged. These are typical examples of measures with high investment costs and with uncertain economic outcomes. The alternative to hydro plants are plants based on fossil fuels where investments are lower, but costs are higher to operate them. From the point of view of economic risk management, therefore, the fossil fuel alternative is advantageous. However, in a total evaluation, the environmental effects should be taken into account, and thus favors the utilization of renewable energy sources. Hydro power projects may, however, have considerable "hidden costs" because of water regulation.

Energy supply in Africa divides naturally into Southern and Northern Africa. Northern Africa posesses large amounts of natural gas. Exporting gas to e.g. Europe at low prices may initiate substitution from coal and oil to gas in Europe and thereby have a positive environmental effect on local pollutants as well as emissions of climate gases. The global effect of higher gas exports may be positive although the emissions from the exporting countries may increase if they boost extraction of petroleum. A similiar effect of higher coal exports from South Africa may be obtained because the emissions from South African coal is lower than much of the domestically extracted coal in other parts of the world. In both cases, however, there is a "leakage" effect due to the fact that the world price of energy may decrease as a result.

b) Lower dependency on biomass fuels is attained by increasing the energy efficiency in households and by making alternatives to biomass available. The possibilities of energy management in Africa are clearly restricted because of poverty and the pattern of energy use in households. Biomass represents between 80 and 95 percent of total energy consumption in most of the countries south of Sahara. Moreover, the household sector consume between 75 and 90 percent of total energy consumption.

This pattern of energy use means that deforestation and soil erosion have impacts on the supply of energy. To reduce dependency on biofuels is therefore an adaptation measure. Means to enhance energy efficiency include introducing more efficient stoves and making substitution possibilities available to the households, for instance by solar power or applying more efficient methods for the production of charcoal. An additional benefit from such a strategy relates to the reduction of local pollutants. A main problem of using economic measures, or in changing energy technology within the household sector in Africa, is that it is required that the households have financial means to buy new equipment.

This problem also applies to the potential for increasing the use of electricity, which could increase energy efficiency and expand substitution possibilities. In order to enhance the use of electricity, for instance, development of a transmission and distribution system is needed. This implies rather significant public investments and social and economic changes. To develop a modern energy supply system should therefore be regarded only as a long-term development strategy for which adaptation to climate change is only a part of the motivation.

c) Reforestation programs are important abatement measures through sequestration of carbon, and may be promoted in rural areas by a more efficient extension service and better land management e.g. by establishing clear property rights.

As mentioned, afforestation may also contribute to lowering the vulnerability to climate change by safeguarding biodiversity, ensuring supplies of fuelwood, and building materials. Deforestation reduces the carbon sinks and is thereby forcing global warming.

Conclusions

Measures to encourage economic and social development on the one hand and abatement and adaptation to climate change on the other may often support each other. In a response strategy, one should emphasize an integrated evaluation of alternatives in order to avoid choices that seem advantageous from one perspective, but imply extra costs from another.

In some cases, however, conflicts between development, abatement and adaptation occur. Since Africa's contribution to the problem of global warming is limited, abatement measures have limited effects on the problem. It is important to prepare the African continent for the effects of global warming, a strategy that is closely related to social and economic development. There may be conflicts between these two aspects as well, but in most cases these can be overcome.

Annex

References and selected bibliography[4]

Abu-Zeid, M. and Biswas, A.K. 1991. Some major implications of climatic fluctuations on water management. Water Resources Development 7:74-81.

Achebe, C., Okeyo, A.P., Gorna Hyden, C., and Magadza, C. (eds.) 1990. Beyond hunger in Africa: Africa 2057, an African vision. Heinemann, Nairobi.

Adams, W.M. 1992. Wasting the Rain: Rivers, People and Planning in Africa. Earthscan, London. 256 pp.

African Centre for Technology Studies (ACTS) and Stockholm Environment Institute (SEI). 1995. African Conference on Policy Options and Responses to Climate Change: Conference Statement. Nairobi, Kenya: ACTS Press. A Statement from the African Conference on Policy Options and Responses to Climate Change, Nairobi, Kenya, 5-8 December 1994. 4 pp.

African Centre for Technology Studies and Woods Hole Research Center. 1990. The Nairobi Declaration on Climate Change. International Conference on Global Warming and Climate Change: African Perspectives, Nairobi. ACTS Press, African Centre for Technology Studies, Nairobi. 33 pp.

African Energy Policy Research Network (AFREPREN). 1990. African energy: issues in planning and practice. Zed Books, London. 157 pp.

Agnew, C. 1990. Spatial aspects of drought in the Sahel. Journal of Arid Environments 18:279-293.

Agnew, C. and Anderson, E. 1992. Water resources in the Arid Realm. London: Routledge.

[4] References are marked with *

Ahlcrona, E. 1988. The impact of Climate and Man on Land Transformation in Central Sudan: Applications of Remote Sensing. Lund University Press. 140 pp.

Ahmad, M.U. 1989. Hydrologist plan to combat greenhouse effect. International Geological Congress, Washington D.C., July 9-19 1989. Abstracts. 28. (1). p. 19.

Akong'a, J., Downing, T.E., Konijn, N.T., Mungai, D.N., Muturi, H.R., and Potter, H.L. 1988. The Effects of Climatic Variations on Agriculture in Central and Eastern Kenya, pp. 123-270 in: Parry, M.L., Carter, T.R. and Konjin, N.T. (eds.), The Impact of Climatic Variations on Agriculture. Volume 2: Assessments in Semi-arid Regions. IIASA/UNEP. Kluwer, Dordrecht.

Albaret, J.J. and Ecoutin, J.M. 1990. Seasonal Effects and Climate Variations on the Fish Population in a Tropical Lagoon of West-Africa. Acta Oecologica-International Journal of Ecology 11 (4):557-583.

Allen, S.J., Wallace, J.S., Gash, J.H.C., and Sivakumar, M.V.K. 1994. Measurements of albedo variations over natural vegetation in the Sahel. International Journal of Climatology, in press.

Allen-Diaz, B. 1994. Sensitivity of Rangeland Ecosystems to Climate Change. pp. 39-41 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp. *

Alusa, A. 1993. World Climate Impacts Assessment and Response Strategies Programme (WCIP) - Past and Planned Activities in Africa. A paper presented at the First Conference of the African Meteorological Society. Nairobi.

Alusa, A. and Ogallo, L. 1992. Implications of Expected Climate Change in the East African Region: An Overview. United Nations Environment Programme, Regional Seas Reports and Studies No. 149.

Ammous, A. 1993. Methodological framework for national greenhouse gas abatement costing studies: cas du Sénégal.

Amous, S. 1994. Climate and Africa: Northern Africa Regional Report. Paper presented at the African Conference on Policy Options and Responses to Climate Change, Nairobi. ACTS/SEI. 49 pp.

Ampadu-Agyei, O., Manful, G.A., Fleischer, E., Opam, M., and Ameyaw, A.M. 1994. Climate and Africa: Country Report, Ghana. Paper presented at the African Conference on Policy Options and Responses to Climate Change, Nairobi. ACTS/SEI. 42 pp. + app.

Anderson, D. and Ahmed, K. 1993. Where We Stand with Renewable Energy, Finance and Development, June 1993, 40 - 43. *

Anyadike, R.N.C. 1992. Regional variations in fluctutations of seasonal rainfall over Nigeria. Theoretical and Applied Climatology 45:285-292.

Anyadike, R.N.C. 1993. Seasonal and annual rainfall variations over Nigeria. International Journal of Climatology 13:567-580.

Arbuthnot, J.D. 1992. The Impact of Environmental Change on Southern African Agriculture. Report to the Interdepartemental Co-ordinating Comittee for Global Environmental Change (ICC) Task Group on the Terrestrial Environment. Department of Environment Affairs, Pretoria.

Arrhenius, E. and Waltz, T.W. 1990. The Greenhouse Effect: Implications for Economic Development. World Bank Discussion Papers No. 78, The World Bank, Washington, D.C. 18 pp.

Atkinson, D. (ed.) 1993. Global Climate Change: Its Implication for Crop Protection. BCPC Monograph No. 56. Proceedings of a Symposium organised by the British Crop Protection Council, held at The Brighton Metropole Hotel on 22. November 1993. 102 pp.

Avenard, J.M. and Michel, P. 1985. Aspects of present-day processes in the seasonally wet tropics of West Africa, pp. 75-92 in: Douglas, I., Spencer, T.(eds.), Environmental change and tropical geomorphology. Univ. Manchester, Sch. Geogr., Manchester, United-Kingdom. p.. A publ. of the Br. Geomorph. Res. Group. George Allen & Unwin, London. 378 pp.

Ballantyne, M. 1993. Small island states seek specific mandate. Tiempo-Global Warming and the third world. Issue 10. December. International Institute for Environment and Development (IIED) and the university of East Anglia. London.

Balling, R.C. Jr. 1991. Impact of desertification on regional and global warming. Bulletin of the American Meteorological Society, 72:232-234. *

Balling, R.C. Jr. 1993. Interactions of Desertification and Climate: Some Key Concepts. Arizona State University, Arizona. July 1993. 10 pp. *

Bartels, G.B., Norton, B.E., and Perrier, G.K. 1993. An examination of the carrying capacity concept, pp. 89-104 in: R.H. Behnke, I. Scoones and C. Kerven (eds.), Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas. London, Overseas Development Institute, London.

Batidzirai, B., Nziramasanga, N., and Gavaza, P. 1994. Climate and Africa: Country Report, Zimbabwe. Paper presented at the African Conference on Policy Options and Responses to Climate Change, Nairobi. ACTS/SEI. 38 pp.

Behnke, R.H. and Scoones, I. 1993. Rethinking range ecology: Implications for rangeland management in Africa, pp. 1-30 in: R.H. Behnke, I. Scoones and C. Kerven (eds.), Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas. London, Overseas Development Institute, London.

Benson, C. and Clay, E. 1994. The impact of drought on sub-Saharan African economies: a preliminary examination. ODI Research Paper, Regent's College, London.

Berg, T., Bjørnstad, Å., Fowler, C., and Skrøppa, T. 1991. Technology options and the gene struggle. NORAGRIC Occasional Papers Series C, No. 8. Ås, Norway. 146 pp. *

Berry, L., Campbell, D., and Olson, J.M. (eds.) 1992. Alternative and Sustainable Systems of Production and Livelihoods in Marginal Lands. New York, United Nations Sudano-Sahelian Office.

Bhagavan, M.R. and Karekezi, S. (eds.) 1992. Energy Management in Africa. London: Zed Books.

Bie, S.W. and Imevbore, A.M.A. (eds.) 1994. Biological Diversity in the Drylands of the World. Preliminary and Incomplete Version. International Panel of Experts, Subgroup on Biodiversity (IPED), UN, Geneva. 220 pp.

Bijlsma, L. 1994. Sensitivity of Coastal Zones to Climate Change. pp. 43-44 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp.

Biodiversity Support Programme. 1993. Central Africa Global Climate Change and Development. Technical Report. Biodiversity Support Program Africa. Washington D.C.: World Wildlife Fund.

Biot, Y. 1993. How long can high stocking densities be sustained ? , pp. 153-172 in: R.H. Behnke, I. Scoones and C. Kerven (eds.), Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas. London, Overseas Development Institute, London.

Bohle, H.G., Downing, T.E. and Watts, M.J. 1994. Climate change and social vulnerability: towards a sociology and geography of food insecurity. Global Environmental Change 4:37-48.

Bolin, B., Döös, B.R., Jäger J., and Warrick, R.A. (eds.) 1986. The Greenhouse Effect, Climate Change, and Ecosystems. John Wiley, Chichester, UK.

Bonnefille, R., Roeland, J.C., and Guiot, J. 1990. Temperature and rainfall estimates for the past 40,000 years in equatorial Africa. Nature 346:347-349.

Bounova, L. and Krishnamurti, T.N. 1993a. Influence of soil moisture on the Sahelian climate prediction I. Meteorology and Atmospheric Physics 52:183-203.

Bounova, L. and Krishnamurti, T.N. 1993b. Influence of soil moisture on the Sahelian climate prediction II. Meteorology and Atmospheric Physics 52:205-224.

Bradley, D.J. 1993. Human tropical diseases in a changing environment, pp. 146-162 in: Lake, J.V., Bok, G.R., and Ackrill, K. (eds.), Environmental Change and Human Health. Chichester: John Wiley & Sons.

Branchu, P., Faure, H., Ambrosi, J.P., van-Zinderen-Bakker, E.M., and Faure-Denard, L. 1993. Africa as source and sink for atmospheric carbon dioxide. Global and Planetary Change 7 (1-3):41-49.

Brown, S. 1994. Response of Tropical Forests to Climate Change. pp. 37-38 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp. *

Buchanan-Smith, M., Davies, S. and Petty, C. 1994. Food security - let them eat information. IDS Bulletin 25:69-80.

Burckle, L.H. and Abrams, N. 1985. Biotic response to the two late Neogene intervals of global climatic change; evidence from the deep-sea record. South African Journal of Science 82 (2):69.

Buret, J., Agoumi, A., and Senhaji, F.A. 1994. Climate and Africa: National Report, Morocco. Paper presented at the African Conference on Policy Options and Responses to Climate Change, Nairobi. ACTS/SEI. 32 pp. + app.

Cable, V. and Juma, C. 1992. Shaping Our Common Future: Sustainable Development in a Changing World Order. Report for the Centre for Our Common Future, Geneva. 55 pp.

Cahoon, D.R., Jr., Stocks, B.J., Levine, J.S., Cofer, W.R., III, and O'Neill, K.P. 1992. Seasonal distribution of African savanna fires. Nature 359:812-815.

Calder, J.H. 1992. Response of tropical continental peat formation to climate change and tectonism; examples from the Late Carboniferous of Euramerica and the Holocene of Africa, in: Anonymous. GAC/AGC - MAC/AMC joint annual meeting; abstracts volume. Program with Abstracts Geological Association of Canada; Mineralogical Association of Canada; Canadian Geophysical Union, Joint Annual Meeting. 17. p. 14. Halifax, Canada.

Carpenter, S.R., Fisher, S.G., Grimm, N.B., and Kitchell, J.F. 1992. Global Change and Freshwater Ecosystems. Annual review of ecology and systematics 23:119-139.

Carter, T.R., Parry, M.L., Nishioka, S., and Harasawa, H. 1992. Preliminary Guidelines for Assessing Impacts of Climate Change. Working Group II of the IPCC, WMO/UNEP. The Environmental Change Unit, Oxford, and Center for Global Environmental Research, Tsukuba. 28 pp.

Cavendish, W. and D. Anderson. 1994. Efficiency and Substitution in Pollution Abatement. Oxford Economic Papers 46:774-799. *

CC:INFO 1994. Country Activities on Climate Change. Report-August 1994. Prepared by The UNFCCC/UNEP Climate Convention Information Exchange Programme (CC:INFO). Geneva, Switzerland. *

Chang-Ko, L. 1993. Vulnerability of the Seychelles Islands to Sea Level Changes as a Consequence og Global Warming and Climate Change. A paper presented at the IPCC Eastern Hemisphere Workshop on Vulnerability to Sea Level Rise and Coastal Zone Management. Tsukuba, Japan.

Chesworth, P. 1990. History of water use in Sudan and Egypt, pp. 40-58 in: Howell, P.P. and Allan, J.A. (eds.), The Nile, Conference at RGS 2-3 May, SOAS, London, 40-58.

Chidi Ibe, A. 1991. Vulnerability of African coastal cities to the impact of increased sea level rise: case studies of Lagos, Banjul and Dar Es Salaam. Abstract in: Frassetto, R. and Editori, M. (eds.), Impact of sea level rise on cities and regions. Venice, 239 pp.

Clark, R. 1991. Water: The International Crisis. Earthscan, London. 193 pp. *

Clarke, H. 1993. The Impact of Climate Change. UNEP/GEMS Environment Library No. 10, Nairobi. 40 pp. *

Claude, L.M., Tapamo, D., Blaise, B., Maurice, T., Etouman, E., Ekobo, S., and Effa, E. 1994. Climate and Africa: Country Report Cameroon. Paper presented at the African Conference on Policy Options and Responses to Climate Change, Nairobi. ACTS/SEI. 71 pp. *

Climate Network Africa. 1992. Impact. No.7, December 1992, Newsletter of Climate Network Africa. Climate Network Africa, Nairobi.

Conway, D. 1993. The development of a grid-based hydrological model of the Blue Nile and the sensitivity of Nile River discharge to climate change. Unpublished Ph.D.Thesis, University of East Anglia, Norwich. 311 pp.

Coppock, D.L. 1993. Vegetation and pastoral dynamics in the Southern Ethiopian rangelands: implications for theory and management, pp. 42-61 in: R.H. Behnke, I. Scoones and C. Kerven (eds.), Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas. London, Overseas Development Institute, London.

Cowling, R.M., Esler, K.J., Midgley, G.F., and Honig, M.A. 1994. Plant Functional Diversity, Species-Diversity and Climate in Arid and Semiarid Southern Africa. Journal of Arid Environments 27 (2):141-158.

Cox, J.R., Fourie, J.H., Rethman, N.F.G., Martin, M.H., Ibarra, F.A., and Wilcox, D.G. 1988. The Influence of Climate and Soils on the Distribution of 4 African Grasses. Journal of Range Management 41 (2):127-139.

Crutzen, P.J. and Andreae, M.O. 1990. Biomass burning in the tropics: Impact on atmospheric chemistry and biogeochemical cycles. Science 250:1669-1678.

Darkoh, M.B.K. 1993. Desertification: The Scourge of Africa. Tiempo. Global Warming and the Third World. Issue 8, April 1993. International Institute for Environment and Development, London and University of East Anglia, Norwich. *

de Leeuw, P.N. and Tothill, J.C. 1993. The Concept of Rangeland Carrying capacity in Sub-Saharan Africa- myth or reality? pp. 77-78 in: R.H. Behnke, I. Scoones and C. Kerven (eds.), Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas. London, Overseas Development Institute, London.

de Leeuw,P.N., Diarra, L. and Hiernaux, P. 1993. An analysis of feed demand and supply for pastoral livestock: the Gourma region of Mali, pp. 136-152 in: R.H. Behnke, I. Scoones and C. Kerven (eds.), Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas. London, Overseas Development Institute, London.

Debenay, J.P., Pages, J. and Guillou, J.J. 1994. Transformation of a subtropical river into a hyperhaline estuary; the Casamance River (Senegal); paleogeographical implications. Palaeogeography, Palaeoclimatology, Palaeoecology. 107 (1-2):103-119.

Diamond, J.M. 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural preserves. Biological Conservation 7:129-146. *

Diaz, H.F. and Markgraf, V. (eds.) 1992. El Niño: Historical and Paleoclimatic Aspects of the Southern Oscillation. Cambridge, England: Cambridge University Press.

Direktoratet for Naturforvaltning (DN). 1994. Kritiske utviklingshastigheter for klimaendringer. DN-rapport 1994-4. Directorate for Nature Management, Trondheim, Norway. *

Dixon, C. 1990. Rural Development in the Third World. London: Routledge.

Dobson, A., Jolly, A. and Rubinstein, D. 1989. The greenhouse effect and biological diversity. TREE 4:64-68. *

Dolzer, R. 1994. The Legal Status of the Commitments in the Convention on Climate Change and the Need for Future Revisions, pp. 131-145 in: Hanisch, T. (ed.), Climate Change and the Agenda for Research. Westview Press, Boulder & Oxford. 222 pp.

Downing, E., Gitu, K.W. and Kamau, C.M. (eds.) 1989. Coping with Drought in Kenya. Lynne Rienner Publishers, Boulder & London.

Downing, T.E. 1991. Vulnerability to hunger in Africa: A climate change perspective. Global Environmental Change 1 (5):365-380.

Downing, T.E. 1992. Climate Change and vulnerable places: global food security and country studies in Zimbabwe, Kenya, Senegal and Chile. Research Report No. 1, Environmental Change Unit, University of Oxford, Oxford. 54 pp.

Downing, T.E. and Parry, M.L. 1991. Climatic change, agriculture and food security, pp.127-139 in: Ominde, S.H. and Juma, C. (eds.), A Change in the Weather. African Perspectives on Climate Change. ACTS Press, Nairobi. 210 pp.

Dregne, H.E. and Tucker, C.J. 1988. Desert encroachment. Desertification Control Bulletin 16:16-19.

Druyan, L.M. 1991. The sensitivity of Sub-Saharan precipitation to Atlantic SST. Climatic Change 18:17-36. *

Druyan, L.M. and Hastenrath, S. 1991. Modelling the differential impact of 1984 and 1950 sea-surface temperatures on Sahel rainfall. International Journal of Climatology 11:367-380.

Druyan, L.M. and Hastenrath, S. 1992. GCM simulation of the Sahel 1984 drought with alternative specifications of observed SSTs. International Journal of Climatology 12:521-526.

DuPisani, A.L. and Partridge, T.C. 1990. Effects of global warming on crop production in South Africa. South African Jounal of Science 86:306-311.

Duxbury, J.M., Harper, L.A. and Mosier, A.R. 1993. Contribution of agroecosystems to global climate change in agriculture. Ecosystem effect on trace gases and Global Climate Change. Special pub. No. 55 American Soc. Agron. Madison, Wl pp. 1-18.

Eddy, J.A. et al. (eds.) 1991. Global Change System for Analysis, Research and Training (START) : report of a meeting at Bellagio, December 3-7, 1990. IGBP Secretariat, Stockholm. IGBP global change report no.15. 40 pp.

Eleri, E.O. 1993. Africa's response to climate change: the role of governments, societies and external actors. The The Fridtjof Nansen Institute, Oslo, Report 1993/6.

Eleri, E.O. 1994. Africa's Decline and Greenhouse Politics. International Environmental Affairs 6 (2):133-148.

Ellery, W.N., Scholes, R.J., and Mentis, M.T. 1991. An Initial Approach to Predicting the Sensitivity of the South-African Grassland Biome to Climate Change. South African Journal of Science 87 (10):499-503.

Ellis, J. and Galvin, K.A. 1994. Climate Patterns and Land-Use Practices in the Dry Zones of Africa. Bioscience 44 (5):340-349.

Ellis, J.E., Coughenour, M.B. and Swift, D.M. 1993. Climate variability, ecosystem stability, and the implications for range and livestock development, pp. 31-41 in: R.H. Behnke, I. Scoones and C. Kerven (eds.), Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas. London, Overseas Development Institute, London.

Ellis, J.E., Coughnoun, M.B., and Swift, D.M. 1993. Climate variability, ecosystem stability and the implication for range and livestock development, pp. 31-41 in: : R.H. Behnke, I. Scoones and C. Kerven (eds.), Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas. London, Overseas Development Institute, London.

ENDA-ENERGY. 1994. Climate and Africa: West and Central Africa, Regional Report. Paper presented at the African Conference on Policy Options and Responses to Climate Change, Nairobi. 35 pp.

ENVI-R-O. 1994. Climate and Africa: National Report, Seychelles. Paper presented at the African Conference on Policy Options and Responses to Climate Change, Nairobi. ACTS/SEI. 87 pp.

Erskine, J.M. 1992. Vetiver grass: its potential use in soil and moisture conservation in southern Africa. South African Journal of Science 88:298-299.

Everett, J. 1994. Sensitivity of Fisheries to Climate Change. pp. 45-47 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp. *

Falkenmark, M. 1991. Rapid population growth and water scarcity: The predicament of tomorrow's Africa, pp. 81-94 in Davis, K. and Bernstam, M.S. (eds.), Resources, Environment and Population: Present Knowledge, Future Options. Population and Development Review, Oxford University Press, Oxford.

Falkenmark, M. and Chapman, T. (eds.) 1989. Comparative Hydrology. Unesco, Paris.

Falkenmark, M. and Rockström, J. 1993. Curbing Rural Exodus from Tropical Drylands. Ambio 22 (7):427-437. *

FAO 1986. Atlas of African Agriculture: African Agriculture: the Next 25 Years. Rome: FAO.

FAO 1993. Selected aspects of African fisheries: a continental overview. FAO Fisheries Circular No 810 Revision 1, FAO, Rome. *

Firth, P. and Fisher, S.G. (eds.) Global Climate Change and Freshwater Ecosystems. Springer-Verlag, New York. 321 pp.

Fischer, G., Frohberg, K., Parry, M.L., and Rosenzweig, C. 1994. Climate change and world food supply, demand and trade: Who benefits, who loses? Global Environmental Change, 4 (1): 7-23. *

Flannery, B. and Clarke, R. 1992. Global Climate Change: A petroleum industry perspective. IPIECA, London.

Folland, C.K., Karl, T.R., Nicholls, N., Nyenzi, B.S., Parker, D.E. and Vinnikov, K.Y. 1992. Observed climate variability and change, pp. 135-170 in: Houghton, J.T, Callander, B.A., and Varney, S.K. (eds.), Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment. Cambridge, England: Cambridge University Press. *

Folland, C.K., Palmer, T.N., and Parker, D.E. 1986. Sahel rainfall and worldwide sea temperatures, 1901-85. Nature 320:602-607. *

Fontaine, B. and Bigot, S. 1993. West African rainfall deficits and sea surface temperatures. International Journal of Climatology 13:271-285.

Fontaine, B. and Janicot, S. 1992. Wind-field coherence and its variations over West Africa. Journal of Climate 5:512-524.

Fournier, A. 1991. Phénologie, croissance et production végétale dans quelques savanes d'Afrique de l'Ouest. Variation selon un gradient climatique. ORSTOM, Etudes et Thèses, Paris. 312 pp.

Frankhauser, S. 1994. Valuing Climate Change: An Economic Assessment of Global Warming Impacts, pp. 105 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp.

Fuglestvedt, J., Hanisch, T., Isaksen, I., Selrod, R., Strand, J., and Torvanger, A., 1994. A Review of Country Case Studies on Climate Change. Global Environment Facility, Working Paper No. 7, UNDP, UNEP, The World Bank. Washington D.C. 61 pp + app.

Garanganga, B.J. 1994. Climate Change and Possible Impacts on Water Resources over Zimbabwe. A paper presented at the UNFCCC/UNITAR National Workshop held in Harare, May 9-11 1994.

Gates, D.M. 1993. Climate Change and Its Biological Consequences. Sinauer, Sunderland, Massachusetts. 280 pp. *

Glantz, M. H. 1992. Global Warming and Regional Environmental Change: Winners and Losers in Africa. Working Papers in African Studies No. 162, African Studies Center, Boston University. 30 pp.

Glantz, M.H. (ed.) 1987. Drought and hunger in Africa: denying famine a future. Cambridge University Press, Cambridge. 457 pp.

Glantz, M.H. (ed.) 1994a. Drought follows the plow: cultivating marginal areas. New York: Cambridge University Press.

Glantz, M.H. (ed.) 1994b. The Role of regional organizations in context of climate change. Berlin: Springer. 208 pp.

Glantz, M.H. 1992. Global warming and environmental change in sub-saharan Africa. Global Environmental Change 2:183-204.

Glantz, M.H. 1994c. The Impacts of Climate on Fisheries. UNEP Environment Library No. 13, Nairobi. 36 pp. *

Glantz, M.H. and Degefu, W. 1991. Drought issues for the 1990s, pp. 253-263 in: Jäger, J. and Ferguson, H.L. (eds.), Climate Change: Science, Impacts and Policy. Proceedings of the Second World Climate Conference. University Press, Cambridge. 539 pp. + app. *

Gleick, P.H. 1989. Climate change, hydrology and water resources. Reviews of Geophysics 27:329-344.

Gleick, P.H. 1991. The vulnerability of runoff in the Nile Basin to climatic changes. The Environmental Professional 13:66-73.

Gleick, P.H. 1992. Effects of Climate Change on Shared Fresh Water Resources, pp. 127-140 in: Mintzer, I.M. (ed.), Confronting Climate Change: Risks, Implications and Responses. Cambridge University Press, Cambridge. 382 pp. *

Grainger, A. 1990. The Threatening Desert: Controlling Desertification. Earthscan, London and UNEP, Nairobi.

Grainger, A. 1992. Characterization and assessment of desertification processes, pp. 17-33 in: Chapman, G.P. (ed.), Desertified Grasslands: Their Biology and Management. Linnean Society Symposium Series Number 13. London: Academic Press Limited.

Gray, W.M. 1990. Strong association between West African rainfall and U.S. landfall of intense hurricanes. Science 249:1251-1256.

Gupta, J. and Karani, P. 1994. Case study in Climate Change Politics, Department of International Relations and Public International Law. University of Amsterdam, 1994.

Gupta, S. and Pachauri, R.K. (eds.) 1989. Proceedings of the International Conference on Global Warming and Climate Change: Perspectives from developing countries. New Dehli, 21-23. February 1989. Tata Energy Research Institute, New Dehli. 294 pp.

Hamilton, A.C. and Taylor, D. History of Climate and Forests in Tropical Africa During the Last 8 Million Years. Climatic Change 19 (1-2):65-78.

Haq, B.U. 1994. Sea Level Rise and Coastal Subsidence: Rates and Threats. ENVLW Technical Note No.1,The World Bank, Environment Department. Draft. 34 pp. *

Harrison, P. 1987. The Greening of Africa: Breaking Through in the Battle for Land and Food. IIED-Earthscan. Paladin Grafton Books, London. 380 pp.

Hassan, F.A. 1981. Historical Nile floods and their implications for climatic change. Science 212 (4499):1142-1145.

Hassan,F.A. and Stucki, B.R. 1987. Nile floods and climatic change, pp. 37-46 in: Rampino, M.R., Sanders, J.E., Newman, W.S., Konigsson, L. K. Climate; history, periodicity, and predictability. Van Nostrand Reinhold Co., New York, NY.

Hastenrath, S. and Kruss, P.D. 1992. Greenhouse indicators in Kenya. Nature 355:503-504.

Heal, O.W., Menaut, J.C., Steffen, W.L. (eds.) 1993. Towards a global terrestrial observing system (GTOS): detecting and monitoring change in terrestrial ecosystems: report of a workshop, Fontainebleau, France (27-31 July 1992) / sponsored by: Observatoire du Sahara et du Sahel (OSS), Global Change and Terrestrial Ecosystems (GCTE) Core Project of the International Geosphere-Biosphere Programme (IGBP), UNESCO - Man and Biosphere (MAB) Programme. IGBP global change report no.26. Unesco, Paris. 71 pp.

Hellden, U. and Eklundh, L. (eds.) 1988. National drought impact monitoring: a NOAA NDVI and precipitation data study of Ethiopia. Lund: Lund University Press, Sweden. 55 pp.

Hersoug, B. 1995. Fiskeriene, pp. 297-312 in: Stenseth, N.C., Paulsen, K., and Karlsen, R. (eds.), Afrika - natur, samfunn og bistand. Ad Notam Gyldendal/Prosjekt Alternativ Framtid. Oslo. 664 pp. *

Hiernaux, P. 1993. The crisis of Sahelian pastoralism: ecological or economic? ILCA, Addis Ababa, Ethiopia. 15 pp.

Hobson, S. and Short, R. 1993. A perspective on the 1991-92 drought in South Africa. Drought Network News 5 (1):3-6.

Holdgate, M. 1989. Climate Change: Meeting the Challenge. Report by the Commonwealth Group of Experts. London: Commonwealth Secretariat.

Holligan, P. (ed.) 1990. Coastal ocean fluxes and resources : report of a CP2 ad hoc workshop, Tokyo, Japan, 19-22 September 1989. IGBP global change report no.14. IGBP Secretariat, Stockholm. 53 pp.

Holligan, P.M. and de Boois, H. (eds.) 1993. Land-Ocean Interactions in the Coastal Zone (LOICZ) : science plan. Land-Ocean Interactions in the Coastal Zone. IGBP global change report no.25. IGBP Secretariat, Stockholm. 49 pp.

Hollis, G.E. 1992. Implications of climatic changes in the Mediterranean Basin: Garaet el Ichkeul and Lac de Bizerte, Tunisia, pp.602-665 in: Jeftic, L., Milliman, J.D., and Sestini, G. (eds.), Climatic change and the Mediterranean. Edward Arnold, London.

Hughes, P., Brundrit, G.B., Swart, D.H., and Bartels, A. 1993. The possible impact of sea-level rise on the Diep River/Ritvlei system, Cape Town. South African J. of Science 89:488-493.

Hulme, M. 1989. Is environmental degradation causing drought in the Sahel? An assessment from recent empirical research. Geography 74:38-46.

Hulme, M. 1992. Rainfall changes in Africa: 1931-60 to 1961-90. International Journal of Climatology 12:685-699. *

Hulme, M. 1994. Regional climate change scenarios based on IPCC emissions projections with some illustrations for Africa. Area 26:33-44.

Hulme, M. and Kelly, P.M. 1992. Linkages between climate change and desertification with particular emphasis on the African Sahel. A Briefing Paper prepared for the Overseas Development Administration. Climatic Research Unit (CRU), University of East Anglia, Norwich, UK. 22 pp. *

Hulme, M. and Kelly, P.M. 1993. Exploring the links between desertification and climate change. Environment 35 (6):4-11 & 39-45. *

Hulme, M., Conway, D., Kelly, P.M., Subak, S., Downing, T.E. 1995. The Impacts of Climate Change on Africa. CSERGE Working Paper GEC 95-04. University of East Anglia, Norwich and University College London, UK. 60 pp. *

Hulme, M., Raper, S.C.B., and Wigley, T.M.L. 1994. An integrated framework to address climate change (ESCAPE) and further developments of the global and regional climate modules (MAGICC), pp. 289-308 in: Nakicenovic, N., Nordhaus, W.D., Richels, R. and Töth, F. (eds.), Integrative assessment of mitigation, impacts and adaptation to climate change. IIASA Collaborative Paper Series CP-94-9, Laxenburg, Austria. 669 pp.

Hutchinson, P. 1992. The Southern Oscillation and prediction of "Der" season rainfall in Somalia. Journal of Climate 5:525-531.

Ibe, A.C. and Awosika, L.F. 1991. Sea Level Rise Impact on African Coastal Zones, pp. 105-111 in: Ominde, S.H. and Juma, C. (eds.), A Change in the Weather: African Perspectives on Climate Change. African Centre for Technology Studies, Nairobi. 210 pp.

IEA 1994. World Energy outlook, 1994 edition. OECD/IEA. *

IENPD 1994. Energy Sector Development Revisited: The Case of Low Income African Countries, A Discussion Paper, draft. 20 pp. *

IGADD 1993. IGADD Experience in Combating Desertification in the Sub-region. Paper presented at INCD meeting, UNEP, Nairobi, Kenya.

Impact team. 1993. Biodiversity and climate change: Africa's vanishing wealth. Impact No. 9, June 1993, pp. 1-9. Newsletter of the Climate Network Africa (CNA), Nairobi.

International Geosphere-Biosphere Programme. 1994. Africa and global change : report from a meeting at Niamey, Niger, 23-27 November, 1992, arranged by the Global Change System for Analysis Research and Training (START) on behalf of the International Geosphere-Biosphere Programme (IGBP)A Study of Global Change (IGBP) of the International Council of Scientific Unions (ICSU). IGBP global change report no.29. 45 pp.

International Geosphere-Biosphere Programme. 1994. IGBP in action : work plan 1994-1998. IGBP global change report no.28. The Programme, Stockholm. 151 pp.

International Union for Conservation of Nature and Natural Resources. 1990. Biodiversity in Sub-Saharan Africa and its Islands, Conservation, Management and Sustainable Use. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.

IPCC 1990a. Climate change: The IPCC Scientific Assessment. Edited by Houghton, J.T., G.J. Jenkins and J.J. Ephraums. WMO/UNEP. Cambridge University Press. 339 pp. + app. *

IPCC 1990b. Impacts Assessment of Climate Change. The Policymakers' summary of the Report of Working Group II to IPCC, Canberra, WMO/UNEP. 32 pp.

IPCC 1991. Climate change: the IPCC response strategies. WMO/UNEP/IPCC. 270 pp.

IPCC 1992. Climate change: The supplementary report to the IPCC Scientific Assessment Edited by Houghton J.T., B.A. Callander and S.K. Varney. WMO/UNEP. Cambridge University Press. 170 pp. + app. *

IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp. *

IUCC 1994. Zimbabwe's vulnerability to climate change. Fact sheet prepared by the Department of Meteorology, Harare, Zimbabwe and the Information Unit on Climate Change (IUCC) , UNEP, Châtelaine, Switzerland. *

IUCN 1989. Etude de l'UICN sur le Sahel 1989. IUCN, Gland, Switzerland. 152 pp.

Jacks, B. 1994. Living Conditions and Nutrition of Some Tamasheq Groups in Mali under the Influence of Drought. Ambio 23 (7):438-445.

Jacobberger, P.A. 1988. Drought-related changes to geomorphologic processes in central Mali. Geological Society of America Bulletin. 100 (3):51-361.

Janicot, S. 1992. Spatiotemporal variability of West African rainfall. Part II: Associated surface and airmass characteristics. Journal of Climate 5:499-511.

Ji, J., Petit-Maire, N., and Yan, Z. 1993. The last 1000 years; climatic change in arid Asia and Africa. Global and Planetary Change 7 (1-3):203-210.

Jones P.D. and Briffa K.R. 1992. Global surface air temperature variations during the 20'th century: Part 1, spatial, temporal and seasonal details. The Holocene, 2, 165-179. *

Juma, C., Ojwang, J.B., and Karani, P. 1994. Equity Consideration in the Climate Debate: Technology Transfer, paper prepared for IPCC Working Group III, Workshop on Social Equity Consideration, Nairobi, Kenya.

Justice, C., Scholes, B. and Frost, P. (eds.) 1994. African savannas and the global atmosphere: research agenda: report of a joint IGBP/START/IGAC/GCTE/GAIM /DIS workshop on African savannas, land use and global change: Interactions of climate, productivity and emissions, 2-5 June 1993, Victoria Falls, Zimbabwe. IGBP global change report no.31. Stockholm. 51 pp.

Jutro, P.R. 1991. Biological diversity, ecology, and global climate change. Environmental Health Perspectives 96, 1991.

Kadomura, H. 1984. Natural and man-induced environmental changes in tropical Africa; case studies in Cameroon and Kenya; a preliminary report of the Tropical African Geomorphology and Late Quaternary Palaeoenvironments Research Project 1982/83. Special Publication Laboratory of Fundamental Research, Hokkaido University. 177 pp.

Kadomura, H. 1984. Problems of past and recent environmental changes in the humid areas of Cameroon, pp. 3-20 in: Kadomura, H. Natural and man-induced environmental changes in tropical Africa; case studies in Cameroon and Kenya; a preliminary report of the Tropical African Geomorphology and Late Quaternary Palaeoenvironments Research Project 1982/83. Special Publication Laboratory of Fundamental Research, Hokkaido University. 177 pp.

Kadomura, H. 1993. Climatic Changes, Droughts, Desertification and Land Degradation in the Sudano-Sahelian Region - A Historico-Geographical Perspective. Preliminary Version, Tokyo. 21 pp. *

Karekezi, S. 1994. Aide Memoire - Seychelles Mission of January, 1994. Climate and Africa Programme - AFREPREN sub-project for Eastern Africa. SEI/ACTS. AFREPREN, Nairobi.

Karekezi, S. and Mackenzie, G.A. 1993. Energy options for Africa : environmentally sustainable alternatives. Zed Books, London. 184 pp.

Karekezi, S. and Majoro, L. 1994. Climate and Africa: Eastern Africa Regional Report. Paper presented at the African Conference on Policy Options and Responses to Climate Change, Nairobi. ACTS/SEI. 31 pp.+ app. *

Katz, R.W. an Brown, B.G. 1992. Extreme Events in a Changing Climate: Variability is More Important Than Averages. Climatic Change 21:289-302.

Kellogg, W.W., and Schware, R. 1981. Climate Change and Society: Consequences of Increasing Atmospheric Carbon Dioxide. Westview, Boulder, Colo. 178 pp. *

Kelly, P.M. and Hulme, M. 1992. Climate Scenarios for the SADC Region. University of East Anglia, School of Development Studies.

Kelly, P.M. and Hulme, M. 1993. Desertification and climate change. Tiempo. Global Warming and the Third World. Issue 9, August 1993. International Institute for Environment and Development, London and University of East Anglia, Norwich.

Khennas, S. and Gaid, A. 1994. Climate and Africa: Country Report, Algeria. Paper presented at the African Conference on Policy Options and Responses to Climate Change, Nairobi. ACTS/SEI. 52 pp. + app.

Khogali, M.M. 1991. Famine, desertification and vulnerable populations: the case of Umm Ruwaba District, Kordofan Region, Sudan. Ambio 20 (5):204-206.

King, J.M. 1983. Livestock water needs in pastoral Africa in relation to climate and forage.ILCA research report, 7, Addis Ababa. 95 pp.

Kinyamairio, J.I. and Mwendwa, H.A. 1992. Kenya Country Study on Biodiversity-In Situ Conservation: Savannas, Grasslands, Arid/Semi Arid Areas and Deserts. Ministry of Environment and Natural Resources, Nairobi, Kenya.

Kite, G. 1989. Use of time series analysis to detect climatic change. Journal of Hydrology 111 (1-4):259-279.

Kozloff, K. and Dower, R.C. 1993. A New Power Base: Renewable Energy Policies for the Nineties and Beyond. World Resources Insitute.

Krattiger, A.F., McNeely, J.A., Lesser, W.H., Miller, K.R., Hill, Y.St. and Senanayake, R. (eds.) 1994. Widening Perspectives on Biodiversity. IUCN, Gland, Switzerland & International Academy of the Environment, Geneva, Switzerland. xvi & 473 pp.

Kristiansen, G. 1993. Biological effects of climate change. An introduction to the field and survey of current research. Report 1993:3, Center for International Climate and Energy Research - Oslo (CICERO) and International Geosphere-Biosphere Programme (IGBP). 190 pp. *

Lamb, P.J. 1978. Large-scale tropical Atlantic surface circulation patterns associated with sub-Saharan weather anomalies. Tellus 30:240-251.

Lamb, P.J. and Peppler, R.A. 1991. West Africa, pp. 121-189 in: Glantz, M., Katz, R.W. and Nicholls, N. (eds.), Teleconnections Linking Worldwide Climate Anomalies. Cambridge: Cambridge University Press.

Lamb, P.J. and Peppler, R.A. 1992. Further case studies of tropical Atlantic surface atmospheric and oceanic patterns associated with sub-Saharan drought. Journal of Climate 5:476-488.

Lamprey, H.F. 1975. Report on the desert encroachment reconnaissance in northern Sudan, 21 Oct. to 10 Nov., 1975. UNESCO/UNEP. (mimeo.), 16 pp.

Landsea, C.W. and Gray, W.M. 1992. The strong association between western Sahelian monsoon rainfall and intense Atlantic hurricanes. Journal of Climate 5, 435-453.

Langaas, S. 1992. Temporal and spatial distribution of savanna fires in Senegal and the Gambia, West Africa, 1989-90, derived from multi-temporal AVHRR night images. International Journal of Wildland Fire 2 (1):21-36.

Langaas, S. 1993a. Senegalese fire activity during the 1989-90 dry season deduced from NOAA AVHRR night time images. International Journal of Remote Sensing 14 (12):2241-2244.

Langaas, S. 1993b. A parameterised bispectral model for savanna fire detection using AVHRR night images. International Journal of Remote Sensing 14 (12):2245-2262.

Langaas, S. 1993c. Diurnal cycles in savanna fires. Nature 363:120.

Lapenis A.G. and Shabalova, M.V. 1994. Global climate changes and moisture conditions in the intracontinental arid zones. Climatic Change 27:283-297. *

Lare, A.R. and Nicholson, S.E. 1990. A climatonomic description of the surface energy balance in the central Sahel. Part I: Shortwave radiation. Journal of Applied Meteorology 29:123-137.

Larsson, J.E. 1992. SADC Conference on Climate Change. Splash 8, No. 1. Maseru, Lesotho.

Le Houerou, H.N. 1985. The impact of climate on pastoralism, pp. 155-186 in: Kates, R.W., Ausubel, J.H. and Berberian, M. (eds.), Climate Impact Assessment. SCOPE, Study no. 27, John Wiley and Sons, New York.

Le Houerou, H.N. 1988. Interannual variability in rainfall and its ecological and managerial consequences on natural vegetation and crops, pp. 323-346 in: Di Castri, F., Floret, Ch., Rambal, S., and Roy, J. (eds.), Proceedings 5th Internat. Conf. of Mediterran. Ecosyst. (MEDECOS V). Internat. Union of Biolog. Sces., Paris.

Le Houérou, H.N. 1992. Outline of the biological history of the Sahara. Journal of Arid Environments 22:1-30.

Leggett, J., Pepper, W.J. and Swart, R.J. 1992. Emissions scenarios for the IPCC: an update, pp. 75-95 in: Houghton, J.T., Callander, B.A. and Varney, S.K. (eds.), Climate change 1992: the supplementary report to the IPCC scientific assessment. Cambridge University Press, Cambridge. 200 pp.

Lindesay, J.A. 1994. Present climates of southern Africa. In: Hobbs, J.E. (ed.), Southern Hemisphere Climates: Present, Past and Future. Belhaven Press, London.

Lins, H.F., Shiklomanov, I.A., and Stakhiv, E.Z. 1991. Impacts of hydrology and water resources, pp. 87-97 in: Jäger, J. and Ferguson, H.L. (eds.), Climate change: Science, impacts and policy. Proceedings of the Second World Climate Conference. Cambridge University Press, Cambridge. *

Littmann, T. and Schmidt, K.H. 1989. The response of different relief units to climatic change in an arid environment (southern Morocco). In: Anonymous. Selected papers of the Fourth Benelux colloquium on Geomorphological processes. Catena (Giessen). 16. (4-5). p. 343-355. Ruhr-Univ. Bochum, Germany.

Livingstone, D.A. 1992. Climatic Change and its impact on Biodiversity in Africa. In: Conservation of Biodiversity in Africa, Local Initiatives & Institutional Roles, Conference Programme & Abstracts, The National Museums of Kenya, Nairobi, 30 August - 3 September 1992.

Lough, J.M. 1980. Atlantic sea surface temperatures and weather in Africa. Unpublished Ph.D. Thesis, University of East Anglia, Norwich.

Lovejoy, T., and Peters, R. 1994. Climate Change and Biodiversity. pp. 85-86 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp. *

Maboyi, B. 1994. Climate and Africa: Southern Africa, Regional Report. Paper presented at the African Conference on Policy Options and Responses to Climate Change, Nairobi. ACTS/SEI. 33 pp.

MacKenzies, J.J. 1993. Electric and Hydrogen Vehicles: Transportation Technologies for the Twenty-first Century. World Resources Institute.

Magadza, C.H.D. 1991. Some Possible Impacts of Climate Change on African Ecosystems, pp. 385-390 in: Jäger, J. and Ferguson, H.L. (eds.), Climate Change: Science, Impacts and Policy. Proceedings of the Second World Climate Conference. University Press, Cambridge. 539 pp. + app. *

Magadza, C.H.D. 1994. Climate change: some likely multiple impacts in Southern Africa. Food Policy 19 (2):165-191.

Magalhaes, A. 1994. Maintaining Sustainable Development while Restricting Climate Change, pp. 107-111 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp.

Mailu, G. 1994. Assessing the Impacts of Climate Change on Water Resources. pp. 97-98 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp.

Maitima, J.M. 1991. Vegetation response to climatic change in central Rift Valley, Kenya. Quaternary Research (New-York) 35 (2):234-245.

Martens, W.J.M., Rotmans, J. and Niessen, L.W. 1994. Climate change and malaria risk - an integrated modelling approach. RIVM, National Institute of Public Health and Environmental Protection, Global Report Series No. 3, Bilthoven, Netherlands, 37 pp.

Maya, R.S. 1994. Issues on the assessment of costs and benefits of activities to reduce GHG emissions. Climate and Africa Project SEI/ACTS. Southern Centre for Energy and Environment. 21 pp.

McKenzie, J.A. 1993. Pluvial conditions in the eastern Sahara following the penultimate deglaciation; implications for changes in atmospheric circulation patterns with global warming. In: van Hinte, J. E., Guiot, J., Meulenkamp, J. E., Sarnthein, M. 200 ka of global change. Vrije Universiteit, Instituut von Aardwetenschappen, Amsterdam, Netherlands. Palaeogeography,-Palaeoclimatology, -Palaeoecology. 103. (1-2). p. 95-105.

McMichael, A. 1994. Assessing the Health Impacts of Global Climate Change. pp. 93-96 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp. *

Meadows, M., Washington, R., Baxter, A., and Wynberg, R. 1993. Global warming; the importance of the past in understanding the future. South African Geographical Journal 75 (2):41-45.

Medina, E. and Huber, O. 1992. The role of biodiversity in the functioning of savanna ecosystems, pp. 139-158 in: Biodiversity and Global Change. IUBS Monograph No. 8, Paris.

Melillo, J. 1994. Global Ecosystem View: Responses to Environmental Change and Feedbacks to Climate. pp. 99-100 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp.

Melillo, J.M., McGuire, A.D., Kicklighter, D.W., Ill, B.M., Vorosmarty, C.J., and Schloss, A.L. 1993. Global climate change and terrestrial net primary production. Nature 363 (6426):234-240.

Mendelsohn, R. 1994. Property Rights and Tropical Deforestation. Oxford Economic Papers 46:750-756.

Messerli, B. and Winiger, M. 1992. Climate, Environmental Change, and Resources of the African Mountains from the Mediterranean to the Equator. Mountain Research and Development 12 (4):315-336

Mintzer, I.M. (ed.) 1992. Confronting Climate Change: Risks, Implications and Responses. Cambridge University Press, Cambridge. 382 pp.

Monserud, R.A., Tchebakova, N.M., and Leemans, R. 1993. Global vegetation change predicted by the modified budyko model. Climatic Change 25 (1):59-84. *

Montieth, J.L. 1991. Weather and water in the Sudano-Sahelian zone, pp. 11-29 in: Sivakumar, M.V.K., Wallace, J.S., Renard, C., and Giroux, C. (eds.), Soil Water Balance in the Sudano-Sahelian Zone, (Proceedings of the Niamey Workshop, February 1991) IAHS Publication No. 199. *

Mooney, H.A. 1993. Biodiversity components in a changing world, pp. 30-33 in: Sandlund, O.T. and Schei, P.J. (eds.), Proceedings of the Norway/UNEP Expert Conference on Biodiversity, 24-28 May 1993. The Directorate for Nature Management, Trondheim, Norway.

Moyo, S., O'Keefe, P., and Sill, M. 1993. The Southern African Environment: Environmental Profiles of the SADC Countries. Earthscan, London.

Muller, M.J., Posnik, S.J., and Levin, M. 1990. Long-term climatic effects on the national radioactive waste disposal facility; a reconstruction of the palaeoenvironments of Bushmanland, South Africa. In: Maud, R.R. Palaeoecology of Africa and the surrounding islands. Univ. Natal, Dep. Geol., Durban, South-Africa. Palaeoecology of Africa and of the Surrounding Islands. 21. p. 295-309.

Munasinghe, M. 1993. The Economist's Approach to Sustainable Development. Finance and Development, Vol. 30, no. 4. 16-19. *

Mylne, M.F. and Rowntree, P.R. 1992. Modelling the effects of albedo change associated with tropical deforestation. Climatic Change 21:317-343. *

Naiman, R. (in press). The Freshwater Imperative: A Research Agenda. Island Press.

Nduwayo, M. 1992. Global warming and Biodiversity in East Africa: Implications for Sustaining a Tourist Economy. University of Albany, New York: Department of Geography and Planning.

Nelson, R. 1988. Dryland Management: The "Desertification" Problem. Environment Working Paper No. 8., The World Bank, Policy Planning and Research Staff, Environment Department. *

Ngoile, M. and Horrill, C. 1993. Coastal ecosystems, productivity and ecosystem protection: coastal ecosystems management. Ambio 22 (7):461-467.

Niang, I. 1990. Responses to the Impacts of Greenhouse-Induced Sea Level Rise on Senegal. In Changing Climate and the Coast, Vol. 2. Pp. 67-83 in: Report to the IPCC from the Miami Conference on Adaptive Responses to Sea Level Rise and Other Impacts of Global Climate Change. US Environmental Protection Agency, Washington D.C.

Nicholson, S.E. and Lare, A.R. 1990. A climatonomic description of the surface energy balance in the central Sahel. Part II: The evapoclimatonomy model. Journal of Applied Meteorology 29:138-146.

Nicholson, S.E. and Palao, I.M. 1993. A re-evaluation of rainfall variability in the Sahel. Part I. Characteristics of rainfall fluctuations. International Journal of Climatology 13:371-389.

Nicholson, S.E., Davenport, M.L. and Malo, A.R. 1990. A comparison of the vegetation response to rainfall in the Sahel and East Africa, using Normalized Difference Vegetation Index from NOAA AVHRR. Climatic Change 17:209-241.

Njoka, T.J. 1989. Possible impact of climate change on agriculture and forests–with special reference to East Africa coastal areas. UNEP, Nairobi.

Nyabundi, J.O. and Njoka, T.J. 1991. Impact of climate change on agriculture and forests in Africa, pp. 79-85 in: Ominde, S.H. and Juma, C. (eds.), A Change in the Weather. African Perspectives on Climate Change. ACTS Press, Nairobi. 210 pp. *

O'Keefe, P. and Munslow, B. 1984. Energy and development in Southern Africa: SADCC country studies, The Scandinavian Institute of African Studies, The Beijer Institute, Stockholm.

Obasi, G.O.P. 1994. Climate Change: A challenge to sustainable development in Africa. Keynote address presented to the African Conference on Global Climate Change, Nairobi, 5/12/94. WMO, Geneva. 18 pp. *

Odingo, R. 1994. The Impact of Climate Change on Global Maize Farming and Production Ecosystems. pp. 55 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp. *

Ogallo, L.A. 1993. Dynamics of the East-African Climate. Proceedings of the Indian Academy of Sciences-Earth and Planetary Sciences 102 (1):203-217

Ogallo, L.A. 1994. Greenhouse gas emission and the Climate Change issue for Africa: An introductory review, report prepared for ACTS, Climate and Africa project. Nairobi. 34 pp.

Ogallo, L.J. 1988. Relationships between Seasonal Rainfall in East Africa and the Southern Oscillation. Journal of Climatology 8:31-43.

Ogunlade, D. 1992. Transport Energy in Sub-Saharan Africa: Options for a Low-Emissions Future. The Centre for Energy and Environmental Studies. Princeton: Princeton University.

Ojwang, J.B. and Karani, P. 1994. The Climate Convention: Joint Implementation of Greenhouse Gas Abatement Commitments. ACTS. 34 pp.

Okeyame, A.A. 1991. Debts, forests and climate change, pp. 97-103 in: Ominde, S.H. and Juma, C. (eds.), A Change in the Weather. African Perspectives on Climate Change. ACTS Press, Nairobi. 210 pp.

Okoth-Ogendo, H.W.O. 1994. Global Climate Change and Environmental Governance: Setting an African Agenda for Policy Responses to the United Nations Framework Convention on Climate Change. Concept paper for the SEI/ACTS project on Climate and Africa: An Assessment of African Policy Options and Responses.

Olaniran, O.J. 1991. Evidence of climatic change in Nigeria based on annual series rainfall of different daily amounts, 1919-1985. Climatic Change 29:319-340. *

Olindo, P.M. 1991. Climate, Tropical Ecosystems and the Survivability of Species, pp. 379-384 in: Jäger, J. and Ferguson, H.L. (eds.), Climate Change: Science, Impacts and Policy. Proceedings of the Second World Climate Conference. University Press, Cambridge. 539 pp. + app.

Olsson, K. and Rapp, A. 1991. Dryland degradation in central Sudan and conservation for survival. Ambio 20 (5):192-195.

Olsson, L. 1993. On the causes of famine - drought, desertification and market failure in the Sudan. Ambio 22 (6):395-403.

Ominde, S.H. and Juma, C. (eds.) 1991. A Change in the Weather: African Perspectives on Climate Change. African Centre for Technology Studies, Nairobi. 210 pp.

Omorinbola, E.O. 1987. Climatic variability and regolith groundwater regime in southwestern Nigeria, pp. 525-534 in: Solomon, S. I., Beran, M., Hogg, W. The influence of climate change and climatic variability on the hydrologic regime and water resources; proceedings of an international symposium held during the XIX general assembly of the International Union of Geodesy and Geophysics. Univ. Waterloo, Dep. Civ. Eng., Waterloo, ON, Canada. IAHS-AISH-Publication. 168.

Otiti, T. 1994. Climate and Africa: Country Report, Uganda. Paper presented at the African Conference on Policy Options and Responses to Climate Change, Nairobi. ACTS/SEI. 49 pp. *

Ottichilo, W.K.; Kinuthia, J.H.; Ratego, P.O., and Nasubo, G. 1990. Weathering the Storm: Climate Change and Investment in Kenya. SEI/ACTS, Nairobi. 91 pp.

Paepe, R., Fairbridge, R.W., and Jelgersma, S. (eds.) 1990. Greenhouse Effect, Sea Level and Drought. NATO ASI Series, Series C: Mathematical and Physical Sciences, Vol. 325. Kluwer Academic Publishers, Dordrecht, Boston, London. xix + 718 pp.

Panel on Policy Implications of Greenhouse Warming. 1992. Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base. National Academy Press, Washington D.C. 918 pp.

Parry, M. 1990. Climate Change and World Agriculture. Earthscan, London. 157 pp.

Parry, M. 1994. A Note on Critical Levels of Climate Change for Global and Regional Food Supply. pp. 97-98 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp.

Parry, M. 1994. Climate change and the world economy. London: Earthscan.

Parry, M., Magalhaes, A. and Ninh, N. (eds.) 1991. The potential Socio-Economic Effects of Climate Change: A Summary of Three Regional Assessments. United Nations Environment Programme, Nairobi.

Parry, M.L. and Swaminathan, M.S. 1992. Effects of Climate Change on Food Production, pp. 113-126 in: Mintzer, I.M. (ed.), Confronting Climate Change: Risks, Implications and Responses. Cambridge University Press, Cambridge. 382 pp.

Parry, M.L., Carter, T.R. and Konjin, N.T. (eds.) 1988. The Impact of Climatic Variations on Agriculture. Volume 2: Assessments in Semi-arid Regions. IIASA/UNEP. Kluwer, Dordrecht. 764 pp.

Peters, R.L. 1992. Consequences of Global Warming for Biological Diversity. pp. 99-118 in: Wyman, R.L. (ed.), Global Climate Change and Life on Earth. Routledge, Chapman and Hall, New York & London. 282 pp. *

Peters, R.L. and Lovejoy, T.E. (eds.) 1992. Global warming and biological diversity. Yale University Press, New Haven & London. xxi + 386 pp. *

Petit-Maire, N. 1990. L'effet de serre pourrait-il faire reverdir le Sahara meridional? (The effect of restrictions; could it revegetate the southern Sahara?). In: Anonymous: 15(e) colloque de geologie. Publication Occasionnelle Centre International Pour la Formation et les Echanges Geologiques. 20. p. 233. Marseilles, France.

Petit-Maire, N. 1990. Will greenhouse green the Sahara? Episodes 13 (2):103-107.

Petit-Maire, N., Faure, M., Gayet, M., and Guerin, C. 1991. Importance des donnees aleontologiques pour l'etude des changements climatique globaux; macropaleontologie et paleoclimat sahariens (The importance of paleontologic data in studying global climate change; macropaleontology and Saharan paleoclimate). Bulletin de la Societe eologique de France, Huitieme-Serie 162 (4):707-711.

Pokras, E.M. and Mix, A.C. 1987. Influence of the Earth's precession cycle on climatic changes in North Equatorial Africa. Technical Report Marine Geoscience Unit, Joint Geological Survey/University of Cape Town. 17. pp. 3-6.

Polcher,J and Laval, K. 1994. The Impact of African and Amazonian Deforestation on Tropical Climate. Journal of Hydrology 155 (3-4):389-405.

Potter, T.D. 1984. World-Meteorological-Organization Expert Group Meeting on the Climatic Situation and Drought in Africa, Held at Wmo Headquarters in Geneva, Switzerland, During 6-7 October 1983. Environmental Conservation 11 (1):85-86.

R.H. Behnke, I. Scoones and C. Kerven (eds.) 1993. Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas. London, Overseas Development Institute, London.

Raven, P. 1994. Why it matters. Our Planet, 6 (4):5-8 *

Ray, G.C., Hayden, B.P., Buler, A.J. jr., and McCormick-Ray, M.G. 1992. Effects of global warming on the biodiversity of coastal-marine zones, pp. 91-104 in Peters, R.L. and Lovejoy, T.E. (eds.), Global warming and biological diversity. Yale University Press, New Haven & London. *

Reid, W.V. and Trexler, M.C. 1991. Drowning the National Heritage: Climate Change and Coastal Biodiversity in the United States. World Resources Institute.

Reilly, J.M. and Anderson, M. (eds.) 1992. Economic Issues in Global Climate Change: Agriculture, Forestry, and Natural Resources. Westview Press, Boulder. 460 pp.

Richey, J. 1994. Sensitivity of Freshwater Systems to Climate Change. pp. 49-52 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp. *

Riebsame, W.E. 1989. Assessing the Social Implications of Climate Fluctuations: A Guide to Climate Impact Studies. UNEP, Nairobi.

Rijbermann, F.R. and Scwart, R.J. 1990. Targets and indicators of Climate Change. J. Jaeger (ed.), Stockholm Environment Institute, Stockholm. *

Rockström, J. 1994. Agrohydrological diagnosis of potential food production in dry tropical landscapes: Linkages between water use efficiency, soil- and water management, and socio-economic development. Licentiate i Philosophy Thesis, Natural Resources Management Institute, Stockholm.

Rockström, J. 1995. "On-farm" diagnosis of water use efficiency in the sahelian agriculture: An indispensable tool for achieving livelihood security. Presentation of research proposal to SAREC. Stockholm University. *

Rognon, P. 1991. Les secheresses au Sahel replacees dans l'evolution climatique des vingt derniers millenaires (Sahel droughts as seen through climatic change over the past twenty millenia). Secheresse (Montrouge) 2 (3):199-210.

Rosenzweig, C. and Parry, M.L. 1994. Potential impact of climate change on world food supply. Nature 367:133-138. *

Rowell, D.P., Folland, C.K. Maskell, K., Owen, J.A., and Ward, M.N. 1992. Causes and predictability of Sahel rainfall variability. Geophys. Res. Lett. 19:905-908.

Scholes, R.J. and van der Merwe, M.R. 1994. Greenhouse gas inventory for South Africa. Report No. FOR DEA-774.

Schulze, R.E. 1990. Climate Change and Hydrological Response in Southern Africa - Heading Towards the Future. South African Journal of Science 86 (7-10):373-381.

Schulze, R.E. and Kunz, R.P. 1993. Climate Change Scenarios for Southern Africa: Report to South African Global Climate Change Comittee, Department of Agricultural Engineering, University of Natal, Pietermaritzburg.

Schulze, R.E., Kiker, G.A., and Kunz, R.P. 1993. Global climate change and agricultural productivity in southern Africa. Global Environmental Change 3 (4):330-349. *

Sebagenzi, M.N., Vasseur, G., and Louis, P. 1992. Recent warming in southeastern Zaire (Central Africa) inferred from disturbed geothermal gradients. Global and Planetary Change 6 (2-4):209-217.

Selrod, R., Torvanger, A., Karani, P., and Ojwang, J.B. 1995. Joint Implementation under the Convention on Climate Change: Opportunities for Development in Africa. African Centre for Technology Studies (ACTS) and Center for International Climate and Energy Research - Oslo (CICERO). ACTS Research Memorandum 12, Nairobi. vii + 86 pp.

Semenov, M. and Porter, J. 1994. The Wheat Ecosystem and Climate Change. pp. 57-60 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp. *

Sestini, G. 1992. Implications of climatic changes for the Nile Delta, pp. 535-601 in: Jeftic, L., Milliman, J.D., and Sestini, G. (eds.), Climatic change and the Mediterranean. Edward Arnold, London.

Shafik, N. 1994. Economic Development and Environmental Quality: An Econometric Analysis. Oxford Economic Papers 46:757-773. *

Shah, N.J. 1994. Seychelles National Report: Coastal Erosion, Sea Level Changes and their Impacts. IOC/UNESCO/SAREC.

Shine, K.P., Derwent, R.G., Wuebbles, D.J. and Morcrette, J.-J. 1990. Radiative forcing of climate, pp. 41-68 in: Houghton, J.T., Jenkins, G.J., and Ephraums, J.J. (eds.), Climate Change: The IPCC Scientific Assessment, Cambridge, England: Cambridge University Press.

Shinoda, M. 1990a. Long-term Sahelian drought from the late 1960s to the mid-1980s and its relation to the atmospheric circulation. Journal of the Meteorological Society of Japan 68:613-624.

Shinoda, M. 1990b. Long-term variability of the tropical African-rain belt and its relation to rainfall in the Sahel and northern Kalahari. Journal of the Meteorological Society of Japan 68:19-35.

Silveira, S. (ed.). 1994. African voices on climate change: policy concerns and potentials. Stockholm Environment Institute (SEI). vii+ 39 pp.

Sinha, S. 1994. Potential Impact of Climate Change on Rich and Rice-Based Cropping System, pp. 53-54 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp. *

Sircoulon, J. 1991. Climate, Water and Development. pp. 243-252 in: Jäger, J. and Ferguson, H.L. (eds.), Climate Change: Science, Impacts and Policy. Proceedings of the Second World Climate Conference. University Press, Cambridge. 539 pp. + app. *

Sircoulon, J.H. 1987. 'Variation des débits des cours d'eau et des niveaux des lacs en Afrique de l'ouest depuis le début 20 ème siecle'. In Solomon, S. et al. (eds.) The Influence of Climate Change and Climatic Variability on the Hydrological Regime and Water Resources. IAHS Publication No. 168, p. 13-25. *

Sivakumar, M.V.K. 1992. Climate Change and Implications for Agriculture in Niger. Climatic Change 20:297-312. *

Smith, B.J. 1982. Effects of climate and land-use change on gully development; an example from northern Nigeria. In: Douglas, I. and Spencer, T. Applied geomorphology in the tropics. Zeitschrift fuer Geomorphologie. Supplementband. 44. p. 35-51. Queens Univ., Dep. Geogr., Belfast BT7 1NN, UK.

Smith, E.A. and Sohn, B.-J. 1990. Surface forcing of interannual variation in the radiation balance over North Africa. Part I: Partitioning the surface and cloud forcing. Climatic Change 17:147-192.

Soulé, M.E. (ed.) 1986. Conservation Biology: The Science of Scarcity and Diversity. Sinauer, Sunderland Massachusetts. 584 pp. *

South African Journal of Science (Vol. 86,7). 1990. Studies of Global Change in Southern Africa. Papers from the Conference on Geosphere - Biosphere Change in Southern Africa, University of Cape Town, 4-8 December 1989.

Southern Centre for Energy and Environment. 1992. UNEP Greenhouse Gas Abatement Costing Studies: Zimbabwe Country Study - Phase One and Two. Harare.

Stone, R. 1995. If the Mercury Soars, So May Health Hazards. Science 267:957-958. *

Street-Perrott, F.A. and Perrott, R.A. 1990. Abrupt climate fluctuations in the tropics. The influence of Atlantic Ocean circulation. Nature 343:607-612.

Strong, M. and Arrhenius, E. 1993. Closing Linear Flows of Carbon through a Sectoral Society: Diagnosis and Implementation. Ambio 22 (7):414-416.

Strzepek, K.M., Onyeji, S.C., Saleh, M. and Yates, D.M. 1994. An assessment of integrated climate change impacts in Egypt. IIASA Working Paper WP94-48, Laxenburg, Austria.

Stuart, S.A., Adams, R.J., and Jenkins, M.D. 1990. Biodiversity in sub-Saharan Africa and its Islands: Conservation, Management and Sustainable Use. Gland, Switzerland: IUCN Species Survival Occasional Paper.

Stuart, S.N., Adams, R.J., and Martin (eds.) 1990. Biodiversity and its Status in Africa. International Union for Conservation of Nature and Natural Resources, Geneva, Switzerland.

Suliman, M. (ed.) 1990. Greenhouse Effect and its Impact on Africa. Institute for African Alternatives, London. 90 pp.

Surridge, A.D., Fauconnier, C.J., Grobbelaar, C.J., and Thamm, A.G. 1994. Coal, energy and research: A South African perspective. NACA conference, Cape Town, Nov. 24-25, 1994.

Surridge, A.D., Thamm, A.G., and Grobbelaar, C.J. 1994. A scenario of coal/energy production in the RSA and impacts on the global environment. The 10th International Committee on Coal Research, Brisbon, Australia, Oct. 9-11, 1994.

Sutcliffe, J.V., Knott, D.G. 1987. Historical variations in African water resources. In: Solomon, S. I., Beran, M., Hogg, W. The influence of climate change and climatic variability on the hydrologic regime and water resources; proceedings of an international symposium held during the XIX general assembly of the International Union of Geodesy and Geophysics. Univ. Waterloo, Dep. Civ. Eng., Waterloo, ON, Canada. IAHS-AISH-Publication. 168. p. 463-475.

Tandoh, S.E. 1991. Climate Patterns and Changes of the West Africa region from 1951-1990. Accra, Ghana.

Tapson, D. 1993. Biological sustainability in pastoral systems: The Kwazulu case, pp. 118-135 in: R.H. Behnke, I. Scoones and C. Kerven (eds.), Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas. London, Overseas Development Institute, London.

Temba, T.C. 1994. Climate Change Scenarios for Southern Africa. A paper presented at the UNFCCC/UNITAR National Workshop held in Harare, May 9-11 1994.

The Group for Environmental Monitoring. 1994. Climate and Africa: National Report, South Africa. Paper presented at the African Conference on Policy Options and Responses to Climate Change, Nairobi. 49 pp.

The World Resources Institute (1992): World Resources 1992-1993, New York.

Titus, J.G. 1990. Changing climate and the coast, Volume 2: Western Africa, the Americas, the Mediterranean Basin, and the Rest of Europe. US Environmental Protection Agency, Washington D.C., 105 pp.

Torn, M.S. and Fried, J.S. 1992. Predicting the Impacts of Global Warming on Wildland Fire. Climatic Change 21:257-274.

Torvanger, A., Fuglestvedt, J.S., Hagem, C., Ringius, L., Selrod, R., and Aaheim, H.A. 1994. Joint Implementation Under the Climate Convention: Phases, Options and Incentives. Report 1994:6, Center for International Climate and Energy Research - Oslo (CICERO). 72 pp. *

Touche Ross and Ewbank Preece. 1992. The Economic Implications of Limiting CO_2 Emissions in Zimbabwe. Harare.

Touche Ross. 1991. Global Climate Change: The Role of Technology Transfer. London.

Tucker, C.J., Dregne, H.E., and Newcomb, W.W. 1991. Expansion and contraction of the Sahara Desert from 1980 to 1990. Science 253:299-301.

Turner II, B.L., Moss, R.H. and Skole, D.L. (eds.) 1993. Relating land use and global land-cover change : a proposal for an IGBP-HDP core project : a report from the IGBP/HDP Working Group on Land-Use/Land-Cover Change. IGBP/HDP Working Group on Land-Use/Land-Cover Change. IGBP global change report no.24. IGBP Secretariat, Stockholm. 65 pp.

Turner, K., Subak, S., Adger, W.N., and Parfitt, J. 1994. How are socio-economic systems affected by climate-related changes in the coastal zone? A report to IPCC Working Group II, Subgroup B, CSERGE, UCL/UEA. 57 pp.

Tyson, P.D. 1986. Climate change and variability in Southern Africa. Oxford University Press, UK. 220 pp.

Tyson, P.D. 1990. Modeling Climatic Change in Southern Africa - A Review of Available Methods. South African Journal of Science 86 (7-10):318-330.

Tyson, P.D. 1991. Climatic Change in Southern Africa: Past and Present Conditions and Possible Future Scenarios. Climatic Change 18:241-258.

Tyson, P.D. 1993. Recent Developments in the Modeling of the Future Climate of Southern Africa. South African Journal of Science 89 (10):494-505.

UN 1992. Long-range World Population Projections: Two Centuries of Population Growth, 1950-2150. Department of International Economic and Social Affairs. United Nations, New York. 35 pp. *

UNCED 1992. Earth Summit Agenda 21: Programme of Action for sustainable development. New York: United Nations Department of Public Information. *

UNDP 1994. Human Development Report 1994. United Nations Development Programme, New York: Oxford University Press.

UNEP 1990. Report of the ad-hoc consultative meeting on the assessment of desertification. Nairobi: United Nations Environment Programme.

UNEP 1992a. Regional Seas, Potential Impacts of Expected Climate Change on Coastal and Near Shore Environment. United Nations Environment Programme Regional Seas Reports and Studies No. 140. United Nations Environment Programme, Nairobi.

UNEP 1992b. Status of desertification and implementation of the United Nations Plan of Action to Combat Desertification. Report of the Executive Director. Nairobi: United Nations Environment Programme.

UNEP 1992c. The Convention on Biological Diversity. Nairobi: UNEP. *

UNEP 1992d. World Atlas of Desertification. Editorial Commentary by N.Middleton and D.S.G. Thomas, London: Edward Arnold.

UNEP 1994a. GHG abatement costing studies. Phase II, Country Studies. UNEP, Nairobi. *

UNEP 1994b. UNEP Environmental Management Guidelines for Halophytes for Livestock, Rehabilitation of Degraded Land and Sequestering Atmospheric Carbon. UNEP, Nairobi.

UNEP Collaborating Centre on Energy and Environment. 1994. Climate Change Mitigation in Southern Africa: National studies and regional collaboration.

UNEP-IGBP. 1993. Implications of Sea Level rise in some Selected areas of Kenyan Coast. UNEP/IGBP (Kenya), UNEP/OCAPAC.

UNEP-IGBP. 1993. Implications of Sea Level rise in some Selected areas of Kenyan Coast. UNEP/IGBP (Kenya), UNEP/OCAPAC.

UNEP/Delft Hydraulics. 1989. Criteria for assessing vulnerability to sea-level rise: a global inventory to high risk areas. Delft Hydraulics. *

Urbiztondo, B.I., Rose, W.R., and Restrepo, P. 1991. Potential climate change impacts in the middle Zambezi River Basin. Report prepared for the US Environmental Protection Agency, University of Colorado, Boulder. 33 pp.

Usher, P. The perspective from Africa. Geotimes 34 (8):14-16.

Vellinga, Pier. 1994. Extreme Weather Events, Climate Change and Critical Thresolds for Society: An Exploration, pp. 101-103 in: IPCC 1994. IPCC Special Workshop on Article 2 of the UN Framework Convention on Climate Change. Fortaleza, State of Ceará, Brazil, October 17-21, 1994. 127 pp.

Villavicencio, A. 1994. Climate Change Effects in Burkina Faso. c2e2 News No.6 1994, pp. 8-9. Risø National Laboratory, Roskilde, Denmark.

Vogel, C.H. 1989. A Documentary-Derived Climatic Chronology for South-Africa, 1820-1900. Climatic Change 14 (3):291-307.

Walker, B.H. 1991. Ecological Consequences of Atmospheric and Climate Change. Climatic Change 18 (2-3):301-316. *

Walker, B.H. and Dickson, R.G. (eds.) 1989. Southern hemisphere perspectives of global change : scientific issues, research needs and proposed activities : report from a workshop held in Mbabane, Swaziland, 11-16 December, 1988. IGBP global change report no.9. IGBP Secretariat, Stockholm. 55 pp.

Walker, N.D. and Shillington, F.A. 1990. The Effect of Oceanographic Variability on South-African Weather and Climate. South African Journal of Science 86 (7-10):382-386.

Wallace, J.S., Gash, J.H.C., and Sivakumar, M.V.K., 1990. Preliminary measurements of net radiation and evaporation over bare soil and fallow bushland in the Sahel. International Journal of Climatology 10:263-270.

Walmsley, R.D. 1992. Stream Environments and Catchment Processes - A South African Perspective, pp. 45-57 in: Pigram, J.J. and Hooper, B.P. (eds.), Water Allocation for the Environment. Proceedings of an international Seminar and Workshop, The Centre for Water Policy Research, University of New England, Armadale 27-29 Nov. 1991.

Wandiga, S.O. 1994. Research, information, training and development. Climate and Africa: An Assessment of African Options and Responses. ACTS/SEI. 23 pp. + app.

Warren, A. and Agnew, C. 1988. An assessment of desertification and land degradation in arid and semi-arid areas. Drylands Programme, Issues Envelope, International Institute for Environment and Development, Paper No. 2. *

Warren, A. and Khogali, M. 1992. An Assessment of Desertification and Drought in the Sudano-Sahelian region 1985-1991. New York: United Nations Sudano-Sahelian Office (UNSO). xiii + 114 pp. *

Warrick, R.A., Barrow, E.M., and Wigley, T.M.L. 1993. Climate and sea-level change: observations, projections and implications. Cambridge University Press, Cambridge. 424 pp.

Western, D. 1991. Climate Change and Biodiversity, pp. 87-96 in: Ominde, S.H. and Juma, C. (eds.), A Change in the Weather. African Perspectives on Climate Change. ACTS Press, Nairobi. 210 pp. *

Whetton, P., Adamson, D. and Williams, M.A.J. 1990. Rainfall and river flow variability in Africa, Australia and East Asia linked to El Niño-Southern Oscillation events, pp. 71-82 in: Bishop, P. (ed.), Lessons for Human Survival: Nature's Record from the Quaternary. Geological Society of Australia.

Williams, M.A.J. and Balling, R.C., Jr. 1994. Interactions of Desertification and Climate. Prepared for WMO/UNEP (Geneva/Nairobi). 230 pp. *

World Bank. 1989. Sub-Saharan Africa: From Crisis to Sustainable Growth - A long term Perspective Study. Washington: The World Bank.

World Bank. 1994a. Adjustment in Africa. Reforms, Results, and the Road Ahead. Oxford University Press, New York.

World Bank. 1994b. Economywide Policies and the Environment: Emerging Lessons from Experience. Washington D.C. 118 pp.

World Bank. 1994c. World Development Report 1994: Infrastructure for Development. Washington D.C. *

World Resources Institute (WRI) 1989. World Resources 1988-1989. Basic Books Inc., New York.

World Resources Institute (WRI) 1992. World Resources 1992-1993. A guide to the global environment. Oxford University press. *

Yager, A. J. and N. J. Salvador. 1994. The Development of Photovoltaic Markets in the SADC Region. Paper presented at the 12th European Photovoltaic Solar Energy Conference. *

ZERO 1994. SADC Sub-regional Case Study on Drought and Desertification. (Unpublished Paper). Harare.

Zhou, P.P. 1994. Technological Transfer and Aquisition. Climate and Africa: An Assessment of African Policy Options and Responses. ACTS/SEI. 33 pp.

Zinyowera, M.C. and Unganai, S.L. 1992. Drought in Southern Africa: an update on the 1991-92 drought. Drought Network News 4:3-4.

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Updated list of African countries which ratified the Convention, in chronological order. 23 June 1995.

Country	Signature	Ratification (Type)	Entry into Force
1. Mauritius	10 Jun 92	04 Sep 92(R)	21 Mar 94
2. Seychelles	10 Jun 92	22 Sep 92(R)	21 Mar 94
3. Guinea	12 Jun 92	07 May 93(R)	21 Mar 94
4. Zambia	11 Jun 92	28 May 93(R)	21 Mar 94
5. Algeria	13 Jun 92	09 Jun 93(R)	21 Mar 94
6. Tunisia	13 Jun 92	15 Jul 93(R)	21 Mar 94
7. Burkina Faso	12 Jun 92	02 Sep 93(R)	21 Mar 94
8. Uganda	13 Jun 92	08 Sep 93(R)	21 Mar 94
9. Zimbabwe	12 Jun 92	03 Nov 92(R)	21 Mar 94
10. Sudan	09 Jun 92	19 Nov 93(R)	21 Mar 94
11. Mauritania	12 Jun 92	20 Jan 94(R)	20 Apr 94
12. Botswana	12 Jun 92	27 Jan 94(R)	27 Apr 94
13. Ethiopia	10 Jun 92	05 Apr 94(R)	04 Jul 94
14. Malawi	10 Jun 92	21 Apr 94(R)	20 Jul 94
15. Chad	12 Jun 92	07 Jun 94(R)	05 Sep 94
16. Gambia	12 Jun 92	10 Jun 94(R)	08 Sep 94
17. Benin	13 Jun 92	30 Jun 94(R)	28 Sep 94
18. Nigeria	13 Jun 92	29 Aug 94(R)	27 Nov 94
19. Kenya	12 Jun 92	30 Aug 94(R)	28 Nov 94
20. Senegal	13 Jun 92	17 Oct 94(R)	15 Jan 95
21. Cameroon	14 Jun 92	19 Oct 97(R)	17 Jan 95
22. Comoros	11 Jun 92	31 Oct 94(R)	29 Jan 95
23. Côte d'Ivoire	10 Jun 92	29 Nov 94(R)	27 Feb 94
24. Egypt	09 Jun 92	05 Dec 94(R)	05 Mar 95
25. Mali	22 Sep 92	28 Dec 94(R)	28 Mar 95
26. Zaïre	11 Jun 92	01 Jan 95(R)	09 April 95
27. Lesotho	11 Jun 92	07 Feb 95(R)	08 May 95
28. Togo	12 Jun 92	08 Mar 95(At)	06 Jun 95
29. Central Afr. Republic	13 Jun 92	10 Mar 95(R)	08 Jun 95
30. Cape Verde	12 Jun 92	29 Mar 95(R)	27 Jun 95
31. Eritrea		24 Apr 95 (Ac)	23 Jul 95
32. Namibia	12 Jun 92	16 May 95(R)	14 Aug 95
33. Sierra Leone	11 Feb 93	22 Jun 95(R)	20 Sep 95

Source: United Nations (UN), Framework Convention on Climate Change - Interim secretariat, Geneva, Switzerland.