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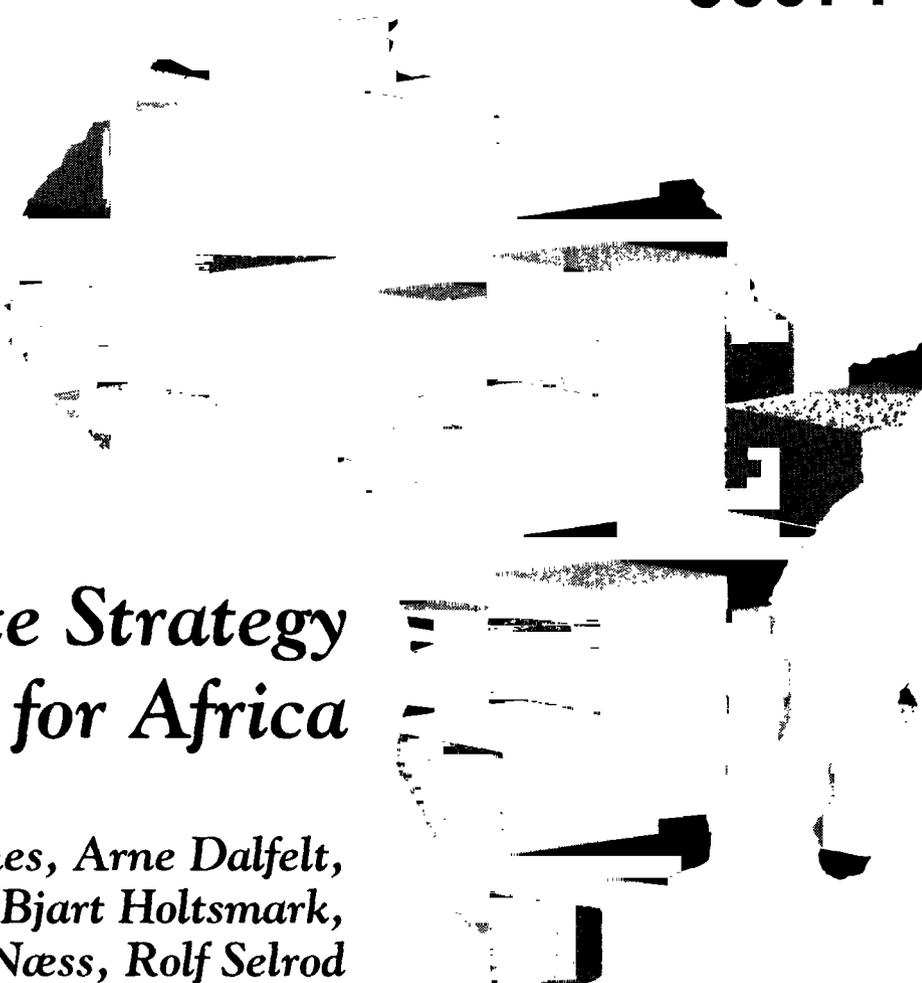
TOWARDS ENVIRONMENTALLY SUSTAINABLE DEVELOPMENT  
IN SUB-SAHARAN AFRICA

*Building Blocks for AFRICA 2025*

*Paper No. 10*

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***A Climate Strategy  
for Africa***

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Terje Berntsen, Bjart Holtsmark,  
Lars Otto Næss, Rolf Selrod  
and Asbjørn Aaheim*



Environmentally Sustainable Development Division • Africa Technical Department  
(AFTES)



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**Building Blocks for Environmentally Sustainable Development  
in Africa**

# A Climate Strategy for Africa

by

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The World Bank  
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## Foreword

Which environmental issues make development unsustainable in Sub-Saharan Africa, and how do African societies perceive and address these issues? How has the World Bank helped its Africa borrowers to integrate environment into their development strategies and programs? And what must the Bank do to help African countries achieve environmentally sustainable development (ESD)?

Inspired by the 1992 Earth Summit in Rio, the Bank has launched a reflection process to answer these questions. In its reflection the Bank is guided by the message of Rio: *without improved environmental management, development will be undermined, and without accelerated development in poor countries – which describes most of Sub-Saharan Africa – the environment will continue to degrade.*

This process seeks to define the Bank's medium-term agenda for helping its Sub-Saharan Africa borrowers attain ESD. It aims at enriching Bank staff's dialogue with African counterparts about improving the conception and implementation of Bank ESD programs. The process should also gain the interest of a much wider audience, including an array of prominent institutions—both African and non-African as well as public and private—universities, NGOs, and bilateral and multilateral agencies. It should encourage a debate on environmental issues which would forge wide support for new African initiatives toward ESD.

Space and time determine the process. Environmental issues are location-specific and therefore require integrating the *geographic dimension*. With respect to time, the process has focused on both past and future *historical perspectives*. The future time horizon is 2025, i.e., 30 years, corresponding roughly to a generation. Backward, the process focuses on the past decade, and the Bank's association with Africa, in order to measure the full magnitude of environmental issues.

Within this process, about 20 thematic "building blocks" have been compiled, each addressing a specific facet of ESD issues. These "blocks," prepared by specialists from inside and outside the Bank, fall into five categories: population, environmental knowledge, urban environment, natural resource management, and strategic instruments. The building blocks series has been the basis for the preparation of a World Bank discussion paper: *Toward Environmentally Sustainable Development in Sub-Saharan Africa – a World Bank Perspective*, which will be published in late 1995.

## Building Blocks for Environmentally Sustainable Development in Africa

sions from Africa (about 70 percent) 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 creating 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 to fund projects that do not meet normal lending criteria, that is, which are based on consideration of national costs and benefits rather than the global environment. In the case of cooperation between 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 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), believe that their financial global obligations towards developing countries should be covered by the GEF core fund.

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 also be considered 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**

Compared to emissions from other continents African GHG emissions are low. However, future climate changes may mean severe impacts to African countries because of their fragile natural resource base, weak economic foundation, and inadequate institutional preparedness. Programmes and projects related to climate should be aimed primarily 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 about climate issues, short-term climate variability, likely climate change impacts and possible “no regret” options to mitigate negative effects is limited. This may *inter alia* diminish opportunities to integrate low cost mitigation or adaptation measures into 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 which meet the FCCC's objectives 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 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 developing a programme for creating a new format for energy planning which includes maximum energy efficiency as well as the use of viable non-carbon forms of energy and less energy intensive technologies.
- 2.2 Support should be given to systems that improve 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 Mapping vulnerable areas and national/regional assessments of climate change effects need to be supported. This should be followed by preparation for reduced impacts and mitigation.

## Building Blocks for Environmentally Sustainable Development in Africa

2.4 African countries should be encouraged to participate in international coordinating activities where opportunities for cooperation and assistance can be demonstrated.

2.5 Preparation of national inventories should be supported (FCCC, Art. 4+12).

### 3. MEASURES TO MITIGATE GHG EMISSIONS

Identifying cost-effective measures with multiple social, economic, and environmental benefits ("win-win" situations) should be emphasized. Changes in national economic structures and mitigation measures may be grouped in three broad categories:

3.1 One should encourage switching to energy sources with lower carbon content. It is important not only to look at the capital costs of such investments, but also to be aware 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 planning stages. Such investments will be critical for the level of GHG emissions from this region in decades to come, and are in practical terms irreversible. This region can boast 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 available. As considerable financial resources are needed for large-scale investments, donors are probable sources of such funding. One should therefore make decisions about Africa's future energy scenario with regard to their climate impact.

a. Serious consideration should be given to providing incentives for countries or groups of countries to choose an environment friendly energy future. Cooperation with the GEF should be considered.

b. Dependency on fossil fuel is a serious problem for several African countries. In many cases, the price of fossil fuels has increased after an initial investment has been made. Switching fuel might in many cases be a "no-regret" opportunity, but may have institutional or other barriers for implementation.

c. There must be 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.

3.2 Policies and measures which increase energy efficiency and conserve energy nationally are needed. Waste or inefficient use of energy is not only costly, but often 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 kind of energy used).

3.3 It is important to decide how the measures might give incentives to local adoption and acceptance over time, thus helping to ensure the success of a project. Identifying barriers to energy efficiency improvements is one of the difficult, but promising, areas in formulating a mitigation policy. In this short paper we would only draw attention to two kinds of barriers, those arising from imperfections in the markets and the institutional barriers preventing companies from acting in a normal manner.

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

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

Third, 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 underground 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 Since national governmental institutions often have limited control over local land management, programmes which give incentives to local communities to consider climate issues in land management decisions should be encouraged.

3.10 Improved soil management practices 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 be strengthened. Increased resilience to climate change must also be a priority. 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. Therefore, development of flexible and resilient crops and crop systems should be a priority.

4.2 Biodiversity monitoring and conservation of crop genetic resources preservation are 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 delta, sand bank and coral reef protection—is essential for protection 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 Preparation for disasters caused by extreme weather should be supported, including plans, equipment and institutional responsibility allocation.

## 2. *General background*

### **African obligations and opportunities under the Climate Convention**

Any presentation of the specifically African aspects of the convention must begin with four of its basic principles:

1. that industrialized countries have accepted 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
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 become at most an aspect of developmental policies and strategies rather than a central concern.

The United Nations Framework Convention on Climate Change (FCCC) went into effect on March 24, 1994. Forty-nine African states have signed the Convention, but only 27 have so far ratified it (February 7, 1995). Ratification is important for two reasons—first it shows acceptance of the convention text; and, second, the first Conference of the Parties in Berlin will probably decide that only those countries which have ratified will be qualified for support under the FCCC.

The Framework Convention sets out principles and general commitments 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 must report on how they plan to return to their 1990 levels of GHG emissions through national action plans. The Convention has two kinds of commitments—general and specific. The general commitments obligate all countries party 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 of the convention’s taking effect. The least-developed countries may report at their own discretion.

The second type of commitments only relate to the industrialized countries and present an objective for these countries to return, individually or jointly, by the end of the

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<sub>2</sub> 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

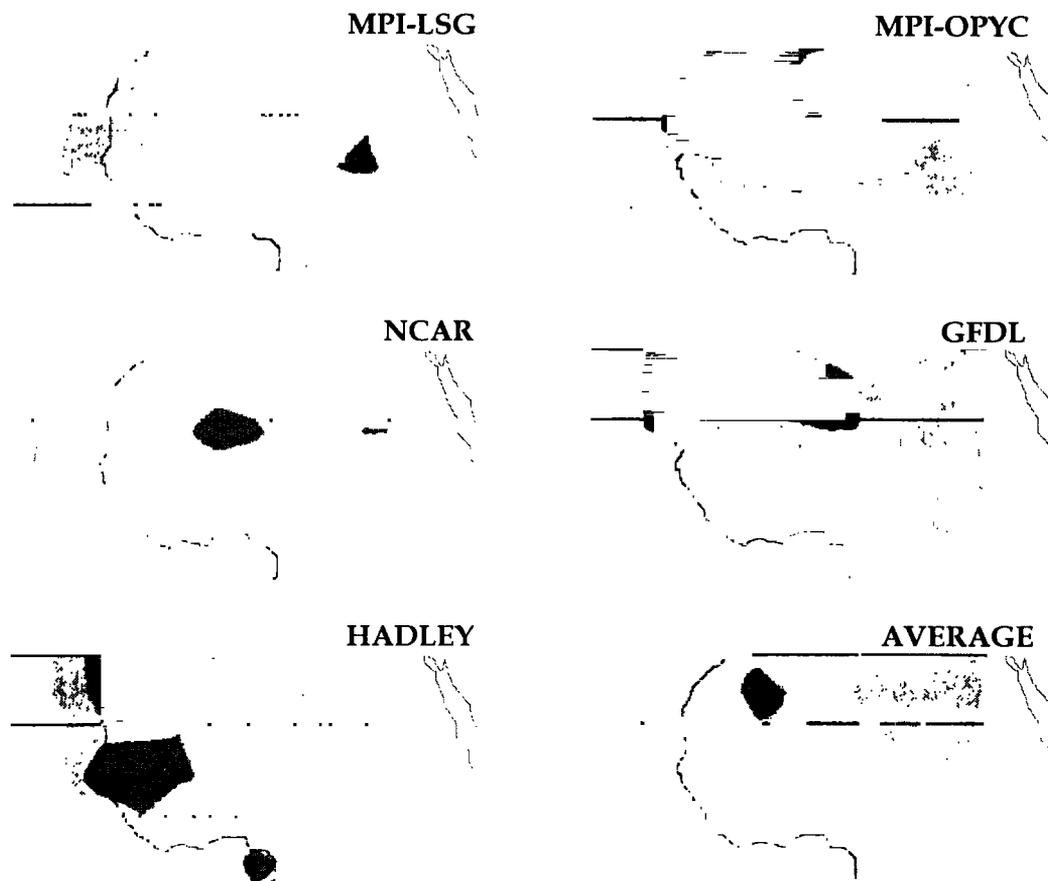
differences in radiative forcing as opposed to the spatial homogeneous forcing from well-mixed GHGs (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, CFCs etc.). The spatial variance in the forcing is likely to give rise to significant uncertainties in the regional climate estimates given by the climate 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 (Druryan 1991). The most recent model calculations of future climate change are based on transient 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.



5 4 -3 -2 -1 0 1 2 3 4 5 6 7  
Unit: °C

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>

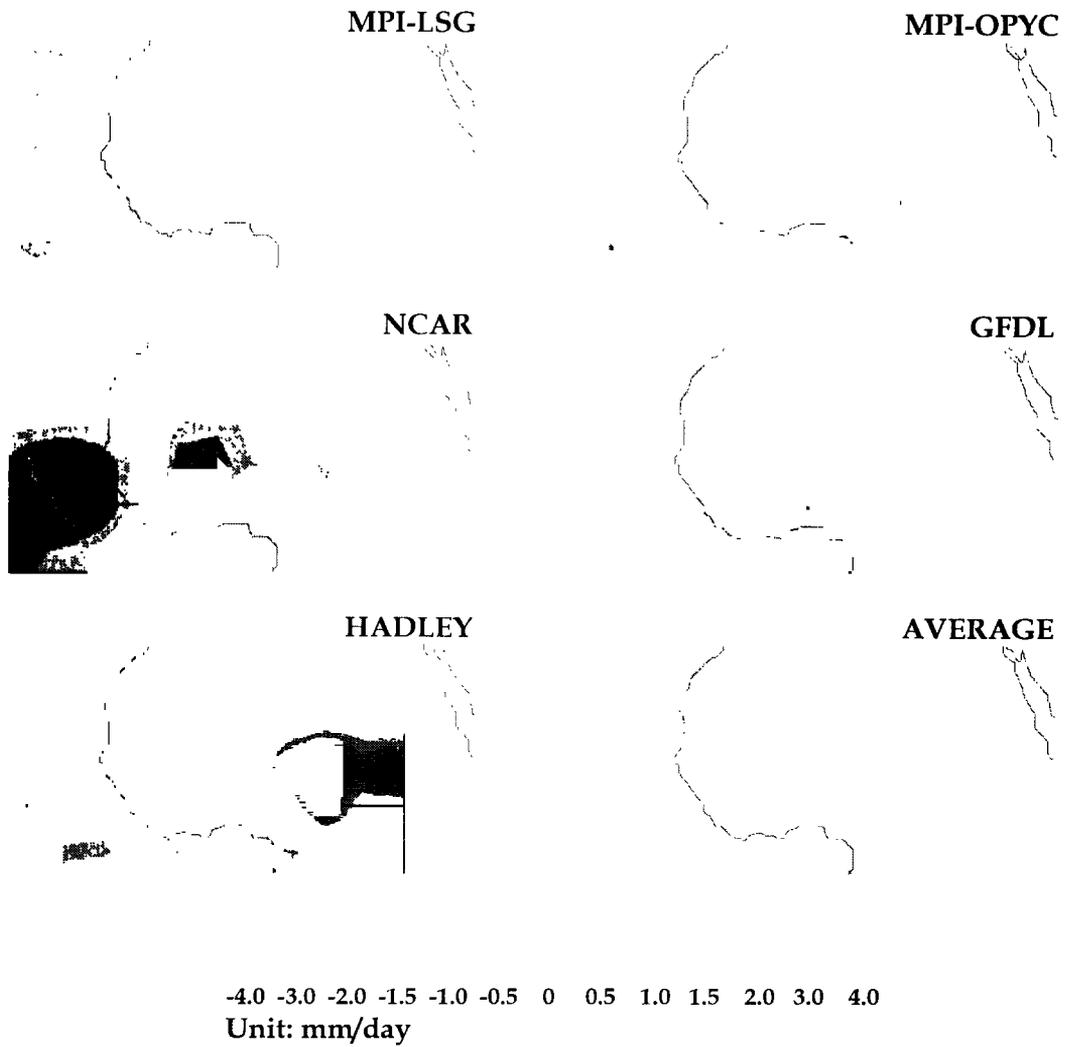
**Figure 2.1.** Calculated change in temperature for June-August at the time of CO<sub>2</sub> doubling in the atmosphere from 5 coupled atmosphere/ocean general circulation models. Average of the 5 models is shown in the lower right panel.

### IPCC 1990

- The first IPCC report (IPCC 1990a) discusses equilibrium climate changes resulting from a doubling of atmospheric concentrations of CO<sub>2</sub>.
- General agreement among models: Increase in surface temperature and increased radiative cooling of the atmosphere due to doubling of CO<sub>2</sub> 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 percent during winter, increases of 0-5 percent during summer. Soil moisture increases 0-10 percent during winter and decreases of 0-10 percent 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<sub>2</sub> 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 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<sub>2</sub> 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<sub>2</sub> doubling. IPCC-90 estimates up to a 65cm increase in sea level in year 2100. (This number will likely decrease to 40-45cm in the IPCC-95 report (Bert Bolin, private com.).



**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<sub>2</sub> doubling in the atmosphere from 5 coupled atmosphere/ocean general circulation models. Average of the 5 models is shown in the lower right panel.

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 percent 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 percent 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<sub>2</sub> in 1990 was estimated to be about 7 percent of the world's total anthropogenic emissions, if emissions from land use changes were included (WRI 1992). The African emissions of CO<sub>2</sub> from fossil fuel combustion in industrial processes (including transportation) constitutes only 2-3 percent 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<sub>2</sub> in Africa are presently from land use changes (~70 percent), while industrial sources and transportation constitutes about 30 percent. Table 2.2 shows contributions to CO<sub>2</sub> 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 percent of global emissions respectively).

**Table 2.1.** CO<sub>2</sub> Emissions from industrial sources and land use change (1990). 10<sup>6</sup> metric tons pr. year. Source: WRI 1992

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

#### OTHER GREENHOUSE GASES

The anthropogenic emissions of methane (CH<sub>4</sub>) in Africa is about 7 percent 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<sub>2</sub>O) 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 percent 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.

## Building Blocks for Environmentally Sustainable Development in Africa

**Table 2.2.** CO<sub>2</sub> emissions from Land Use Change (1990). 10<sup>6</sup> metric tons pr. year.

Source: WRI 1992. X: not available

Country	Emission	Country	Emission	Country	Emission	Country	Emission
Algeria	X	Djibouti	X	Madagascar	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	Mozambique	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	<b>Africa Total</b>	<b>1500</b>

### 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 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) eight country reports and four 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<sub>2</sub> 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 percent of the Gross Domestic Product (GDP), 40 percent of the exports and 60 percent of the employment (Obasi 1994). Climate change will affect the agriculture sector mainly through increased atmospheric CO<sub>2</sub> 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.

**Figure 3.1**

## A selection of global and regional<sup>1)</sup> 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 UNFCCC	07/93 (15)	Zimbabwe	UNITAR, Intern Secretariat of the UNFCCC, UNDP, GEF
• Implications of Climate Change and Sea Level Rise and Vulnerability Assessment of Selected Coastlines	(12)	Kenya Mauritius, Nigeria	UNEP
• 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)

<sup>1)</sup> Updated information on *national* case studies can be found in the Climate Change Information Exchange Programme CC INFO

## CROPPING

*Elevated CO<sub>2</sub> concentrations*

Scientific studies and laboratory tests focusing on individual plant responses have shown that enhanced CO<sub>2</sub> concentrations lead to accelerated rate of photosynthesis, increased water use efficiency, increased above- and below-ground productivity, and decreased stomatal conductance and transpiration. C<sub>3</sub> crops (such as wheat, barley, rice and potatoes) seem to be more responsive than C<sub>4</sub> crops (maize, millet, sorghum and sugarcane) (Allen-Diaz 1994). However, the total effect of the CO<sub>2</sub> fertilization is 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<sub>2</sub> before and after heading at near-optimum temperature. The observed increase in yield was 28 percent and 11 percent, respectively, though the crop growth rate increased about 50 percent. An experiment on winter wheat crops indicates that the effect of CO<sub>2</sub> fertilization may be offset by increased temperature. The increase in yield caused by a doubling of CO<sub>2</sub> (between 14 percent and 36 percent) 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<sub>2</sub> concentrations (in laboratory) have been 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<sub>2</sub> 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 be great differences in the type, magnitude and direction of impacts on the regional and local level.

**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 1970s and 1980s (with emphasis on the 1982/83 drought)

- 1) Depletion of inland surface waters and water scarcity, resulting in the 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 feed production 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 about land ownership between farmers and grazers. The occupation of marginal lands was 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 an increase in the incidences of malaria in the highlands of Kabale, Uganda, has been observed, 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 Oti 1994)

Ecologist Michael Loevinsohn of the International Development Research Centre in New Delhi, India, has linked a one-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 Zaire, 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 diarrhea 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)

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 which 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 patterns. 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.

### *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 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 following figure.

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

As described in Chapter 2, the link between sea surface temperature (SST) anomalies and rainfall patterns is considered to be a major factor affecting 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<sub>2</sub> 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).



2050, under a "business as usual" scenario, 50 percent of the present tropical forests will be lost, with most loss occurring 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<sub>2</sub> 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 million 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 disproportionately 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).

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### *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 Zambezi River, 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<sub>2</sub>, 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 which 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<sub>2</sub>, 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 rangelands and result in land use conflicts. Rangeland ecosystems are 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<sub>2</sub> 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), suggest that, by

2050, under a "business as usual" scenario, 50 percent of the present tropical forests will be lost, with most loss occurring 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<sub>2</sub> emissions (see Chapter 4).

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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 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; thus one has to use general principles in order to assume possible impacts. The uncertainties involved in plant responses to elevated CO<sub>2</sub> 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 occurrence of

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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<sub>2</sub>, 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 occurred 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 which 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 accommodate 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 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 temperatures 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 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. Endemic species in lakes and rivers would be in particular 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 popula-

tion 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 percent 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<sub>2</sub> 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 percent 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<sup>1</sup> is very sensitive to precipitation. A study from Senegal, Niger and Shari River basins showed an increase in runoff of 30-50 percent due to an increase in precipitation of 20-30 percent and similarly 15-59 percent decrease in runoff due to 9-24 percent 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. De-

<sup>1</sup> Of the rain that reaches the soil, *runoff* (or overland flow) is the difference between that soaking in and that running off.

creased 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 percent, 94 percent and 77 percent, 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 and storms. The gain in water availability could have 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 from excessive withdrawals of aquifer water and hydrocarbons, will also drive 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 exceptional 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 rising sea levels will depend upon (1) the number of inhabitants in the 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 rises in sea-level 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 percent 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 caused by 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, 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 the 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.



## 4. *African priorities*

### **African policies to meet the threat of climate change**

**A**frican 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." In terms of the climate question African priorities will be concentrated on capacity building in the following areas: formulating national and regional inventories and programmes; developing effective negotiation skills; conducting research; formulating national policies, conducting cost-benefit analyses; building capacity in the area of technology assessment and transfer.

As expected, few if any African countries have national policies explicitly aimed at combatting the consequences of climate change. According to the convention they are 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 which are relevant to climate issues.

A useful review of African climate policies should include 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 "[t]he 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, contributes only about 7 percent of the world's total emissions—and given Africa's potential vulnerability—African policies should 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 improving educational facilities. It should, however, be pointed out, that most of these priorities are not now reflected in African budgets. None of these priorities 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. Thus, investment in human resources and capacity building on all levels will have beneficial effects on countries ability to handle global issues as well.

### **Future energy scenarios**

In an analysis of different energy scenarios, as well as mitigation and adaptation measures, an extraordinary long time perspective is necessary. A doubling of the carbon dioxide concentrations 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. Because development has shown limited progress in most of Africa during the last decade does not mean 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<sup>2</sup>, 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 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. Therefore, Africa is so far 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

<sup>2</sup> Liquid Petroleum Gas

and motorized transport. More than 40 percent of 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 important contribution to the greenhouse heating effect than emissions from the use of fossil fuels.<sup>3</sup>

On the basis of anticipated demographic and economic development, one may construct greenhouse gas emissions projections for Africa. The value of such projections are limited because of uncertainty about the political, technological, economic and demographic development in the region. 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 stress 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 long-term energy scenarios for the continent. The highest priority in African climate policy 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 mean 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 which 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. Africa is expected to continue with 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.

<sup>3</sup> 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.

Demographic development in Africa is the most uncertain element in the long-term population growth projections of the world (UN 1992). According to the medium-fertility assumption, the world's population will reach 11.5 billion in 2150.<sup>4</sup> 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 everywhere except Africa, where the total fertility rate is still above six births per woman. Although in some African countries the total fertility rate has declined since 1980, in several of the low income countries the fertility rate has actually increased after 1980. Improved living standards are necessary to reduce fertility rates and reduce population growth. Especially improved levels of education and better health among women are essential. As emphasized in the World Development Report 1992, there is no conflict between 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 to ensure 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 ensure that development with the characteristics of scenario 3 is favored over scenario 2.

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

<sup>4</sup> These projections do not fully take into account the increasing death rates from the AIDS epidemic. The social and economic impacts of the epidemic might, however, delay the demographic transition. In total, the AIDS epidemic will probably not represent a very significant force towards lower population growth.

**Table 4.1.** Three energy scenarios for Africa

	<b>Scenario 1 Stagnation</b>	<b>Scenario 2 Growth based on fossil fuels</b>	<b>Scenario 3 Sustainable growth</b>
<b>Basic scenario characteristics</b>	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).	
<b>Population</b>	High growth rate, 3.0 - 5.2 billion in 2100	Rapidly falling fertility rate, slow population growth. 1.6 - 3.0 billion in 2100.	
<b>Energy</b>	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
<b>Land management and deforestation</b>	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.	
<b>Vulnerability</b>	<b>High.</b> The traditional societies are highly vulnerable to climate changes.	<b>Lower.</b> 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".	
<b>GHG emissions</b>	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.
<b>Total contribution to the global warming</b>	<b>High</b> due to a large population and natural resources degradation.	<b>High</b> due to the use of fossil fuels, but not necessarily higher than in Scenario 1 because of lower population and good land management.	<b>Low</b> due to low population, the use of renewable sources of energy, and proper land management.

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

**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 since 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.

More specifically, 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. The *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 be an important 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 enhances the welfare of households.

## 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<sub>2</sub>. 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, regardless 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"). 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, for example, 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 1, 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, since 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 2, 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 people's health. Better health makes people more resistant to short-term fluctuations in weather. 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 3, a description of the African future is highly dependent on population growth. A high birth rate not only implies 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, for example, by extreme weather conditions can be reduced significantly by better material standards, such as better houses, etc. Better material standards may similarly 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-wide 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. First, the attention to adaptation suggests that measures should be directed towards 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. Second, 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 occurred. As was pointed out above, African countries will put great emphasis on their vulnerability rather than 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 Swart (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 possesses large amounts of natural gas. For example, exporting gas to 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 similar 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 because 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, 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 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

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Internet: <http://crux.csir.co.za/csir/csir.html>  
[gopher.mikom.csir.co.za](http://gopher.mikom.csir.co.za)

**ECA/WMO African Centre for Meteorological Application and Development (ACMAD)**

Niamey,  
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Established by:

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**Energy for Development Research Centre (EDRC)**

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Fax: 27 21 6502830

Contact person: Clive van Horen

Internet (University of Cape Town):

1. <http://www.uct.ac.za/>

2. Environment & Geographical Science (ENGEO) Department:

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**Environmental Development Action in the Third World/Energy Programme (ENDA)**

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Fax: 221 22 2695

E-mail: [energy@endadak.gn.apc.org](mailto:energy@endadak.gn.apc.org)

Telex: 51456 enda tm sg

Contact person: Mr. Youba SOKONA, Energy Department

## Building Blocks for Environmentally Sustainable Development in Africa

### **Group for Environmental Monitoring**

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Fax: 27 11 8387613

### **Intergovernmental Authority of Drought and Development (IGADD)**

Djibouti,  
Djibouti

### **Southern Centre for Energy and Environment**

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Fax: 263 4 739341  
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### **United Nations Environment Programme (UNEP)**

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Fax: (254-2)22-6886/22-6890  
Telex: 22068 unep ke  
Contact person: Ms. Renate CHRIST, Environmental Affairs Officer, Climate Unit,  
direct E-Mail: christ.unep@un.org

### **WMO African Regional Centre for Meteorological Research and Training**

Nairobi,  
Kenya

### **WMO Drought Monitoring Centres**

Nairobi, Kenya and  
Harare, Zimbabwe

### **Zambia Centre for Energy, Environment and Engineering (ZCEE)**

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**Zimbabwe Environmental Research Organization (ZERO)**

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44 Edmonds Avenue

Belvedere, Harare

Zimbabwe

Tel: 263 4 791333

Fax: 263 4 732858

Contact person: Dr. Yemi Katerere

**Updated list of African countries which ratified the Convention,  
in chronological order**

<b>Country</b>	<b>Signature</b>	<b>Ratification (Type)</b>	<b>Entry into Force</b>
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	
29. Central Afr. Republic	13 Jun 92	10 Mar 95	

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