The Economic Cost of Climate Change in Africa

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Contents

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Introduction

Climate change is already hitting Africa hard, not least economically. Any global deal on climate change must therefore reflect the region's interests.

The Pan African Climate Justice Alliance (PACJA), with support from Christian Aid, commissioned Practical Action Consulting to write this report in September 2009. It aims to document and analyse the economic costs of climate change in Africa. It also seeks to contribute to a more detailed understanding of the costs involved for Africa in mitigating and adapting to climate change.

Developed countries have so far committed to cutting emissions by, on average, 15 per cent by 2020. This could lead to global average temperature rises of 4˚C or higher above pre-industrial levels by 2060. Without strategies in place for adapting to a change of this magnitude, Africa will be seriously affected – particularly its agricultural sector. This will in turn have serious implications for the continent's food production and malnutrition levels. Economic growth and development could be disrupted, ultimately giving rise to severe social and environmental problems.

Given adequate support to effective adaptation strategies in the form of predictable finance, capacity building and appropriate technologies Africa can minimise the costs of future climate change, particularly on behalf of those who are most vulnerable to the impacts of climate change. This report provides a conceptual framework and preliminary economic analysis aimed at policy makers and planners seeking to manage the effects of climate change.

In particular, this report aims to support African countries in developing negotiating positions and structuring a fair, effective and development-oriented outcome at the Conference of the Parties 15 in Copenhagen, Denmark, in December 2009. It also provides evidence that could inform their requests for increased finance to support climate change adaptation and mitigation in Africa in the ongoing United Nations Framework Convention on Climate Change (UNFCCC) negotiations.

This report's key recommendations are as follows:

- Developed countries must immediately make significant cuts in emissions, and commit to cuts of at least 45 per cent by 2020 and 85-95 per cent by 2050 (relative to 1990 levels). Current commitments do not go far enough.
- The potential cost to Africa of adapting to climate change will reach at least US$10 billion – but will more likely be in the region of US$30 billion – every year by 2030. Adaptation funding is not a question of aid: it is an international obligation to compensate developing countries for causing damage to their environment, economies and societies. Developed countries therefore have a responsibility to provide the required adaptation funding immediately through structured financial mechanisms. This finance should be additional to Overseas Development Assistance (ODA).
- Current mitigation spending through the carbon market does not provide the capital Africa needs to develop in a low-carbon, sustainable way. Africa needs between US$510 and US$675 billion between 2010 and 2030 for low-carbon future growth. Fundamental reforms of the existing climate finance architecture are therefore required to provide the continent with the required funding.

Africa must ensure that its voice is heard at the negotiations in Copenhagen and push in a united front for immediate cuts in emissions, significant financing for adaptation and low-carbon development, and for improved financing mechanisms.

Glossary of Acronyms

AMCEN African Ministerial Conference on the Environment
CDM Clean Development Mechanism
CEPPA Centre for Environmental Economics and Policy in Africa
CER Carbon Emissions Reductions
ENSO El Niño-Southern Oscillation
EU European Union
FAO Food and Agriculture Organization
GDP Gross Domestic Product
GNI Gross National Income
IAM Integrated Assessment Model
IFF Investment and Financial Flows
IIED International Institute for Environment and Development
IPCC Intergovernmental Panel on Climate Change
ISDR International Strategy for Disaster Reduction
ISDR International Strategy for Disaster Reduction
LDC Least Developed Countries
MDG Millennium Development Goals
NAPA National Adaptation Programmes of Action
ODA Overseas Development Assistance
OECD Organisation for Economic Co-operation and Development
PACJA Pan African Climate Justice Alliance
ppm parts per million
REDD Reducing Emissions from Deforestation and Forest Degradation
UNEP United Nations Environment Programme
UNFCCC United Nations Framework Convention on Climate Change
UNWTO World Tourism Organization
VCM Voluntary Carbon Market
VER Voluntary Emissions Reductions
WHO World Health Organization

Executive summary

This report includes five chapters, which cover:

- The impacts of climate change in Africa;
- Options for adapting to climate changes;
- An assessment of the economic costs of climate change and adaptation;
- Mitigation scenarios; and
- Policy recommendations.

The first part of the analysis explores three scenarios for temperature increases above pre-industrial levels by the end of the century:

1 4°C – a 'business as usual' scenario
2 2°C – in line with current EU and G8 stated intentions
3 1.5°C – in line with current stated demands by Least Developed Countries and the Association of Small Island States.

The report starts with a review of available data on climate impacts in Africa. It goes on to survey the range of expected climate change impacts across a variety of sectors under each of the three scenarios. The report then identifies a diverse range of adaptation actions appropriate for Africa. This is followed by a review of existing research into the economic costs of climate change on the continent.

The second part of the report sets out three scenarios for a possible agreed outcome in Copenhagen under the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. These draw on proposals currently under consideration. Assumptions regarding financial flows to Africa are then explored, along with mitigation actions that would need to take place across the region.

The final section of the report makes preliminary recommendations on approaches African governments could adopt in the forthcoming climate negotiations. These include minimising impacts and adaptation costs, minimising mitigation costs and ensuring a fair deal in Copenhagen in December 2009.

Below is a short introduction to this report's main findings and recommendations.

The future of climate change in Africa

Accelerated climatic changes are expected to lead to potentially large impacts across Africa in the future. The scale of climate change in Africa is likely to increase with high anthropogenic emissions, greenhouse gas (GHG) concentrations, and average global temperature. While the temperature thresholds for large-scale disruptions to social and environmental systems – so called tipping-points – are not known, a global mean temperature rise of more than 2°C above pre-industrial levels will make such events more likely.

Evidence indicates that the world has already warmed by 0.8°C since the pre-industrial era. Historic emissions already commit the world to more than a 1°C mean temperature rise from pre-industrial levels. Under a business-as-usual scenario, global mean temperatures could therefore reach around 2°C by 2060.

Research commissioned for this report into the relationship between mean economic costs and mean temperature is shown below, as predicted in the PAGE model (see Chapter 3). The model predicts mean average global temperature of 1.5°C by just after 2040, with economic costs equivalent to 1.7 per cent of Africa's GDP. Then, as the mean temperature rises to 2.2°C by 2060, economic costs increase to the equivalent of 3.4 per cent of Africa's GDP. By the end of the century, with a mean temperature rise of 4.1°C, the economic costs are equivalent to just under 10 per cent of the continent's GDP.

Temperature rise	Year reached	Economic costs (per cent of GDP)
1.5°C	2040	1.7 per cent
2°C	2060	3.4 per cent
4.1°C	2100	10 per cent

In order to limit temperature rises by 2100 to as low as possible, and to reduce to very low levels the risk of extremely dangerous climate change, **developed countries will need to reduce emissions by at least 45 per cent by 2020 and at least 80-95 per cent by 2050** (both targets relative to 1990 levels).

The United Nations Environment Programme-sponsored AdaptCost project has recently investigated the economic costs of climate change adaptation in Africa, and will report on these in the run-up to the Conference of the Parties 15 in December 2009. Its researchers modeled the economic costs of a scenario where carbon dioxide or equivalent levels are at 450 parts per million (ppm). This reduces the economic costs of climate change in Africa from 1.5-3 per cent of GDP by 2030 to around 1 per cent of GDP by 2030. It also makes more likely average temperature rises will be limited instead of exceeding 4°C or more.

TThe benefits of limiting carbon dioxide and equivalent gases to atmospheric concentrations of 450ppm or lower is in reducing the greater costs of climate change after 2030. **The mean economic annual costs reported under the business-as-usual scenario of just under 10 per cent of GDP by 2100, would be likely to fall to an estimated 2.3 per cent of GDP under the 450 ppm scenario.** This dramatic reduction is due to less expected damage caused by climate changes, and to fewer expected large-scale climatic events.

Options for climate adaptation

There are no definitive ways to tackle climate change across a continent. Solutions must be context specific. Selecting which adaptation options to implement must be based on knowledge of local conditions.

Funding for adaptation is not a question of aid: it is an international obligation. While the figures remain uncertain, this report estimates the potential economic costs of climate change for Africa to be 1.5-3 per cent of its GDP by 2030. Africa's potential adaptation financing needs to address these costs are also highly uncertain, but they are likely to constitute **a minimum of US$10 billion a year by 2030, and could be £30billion a year, or more.**

Under the UNFCCC, developed countries are responsible for providing adaptation finance required by developing countries immediately through adequately structured financial mechanisms. African governments should be lobbying for this commitment at Copenhagen.

A fair global climate agreement in Copenhagen will require developed countries to support developing countries in the form of public finance, for both adaptation and mitigation. However, most developed countries actually intend to count providing climate finance towards the 0.7 per cent of Gross National Income (GNI) ODA targets. This would mean that climate finance from developed countries would come out of future aid budgets, leaving funds unavailable for tackling poverty and providing basic education or healthcare.

Any promise by developed countries to deliver public finances to support climate mitigation and adaptation in developing countries out of future ODA budgets is an empty promise, as it will merely shift priorities within future ODA budgets. However, this could happen – **unless the Copenhagen Agreement clearly excludes this possibility.**

Please see the table below for a summary of the key impacts, adaptation strategies and cost ranges with and without adaptation that are outlined in this report:

Mitigation scenarios

The authors of this report were asked to consider three scenarios for a possible agreed outcome in Copenhagen under the UNFCCC and its Kyoto Protocol, drawing on proposals currently under consideration. The three scenarios are:

Minimal commitment: Annex 1 countries commit to minimal mitigation of less than 25 per cent from 1990 levels. They agree to provide US$10 billion a year in additional public finance for climate action in developing countries by 2020, 80 per cent of which is for adaptation. Developing countries do not take on any further mitigation commitments, although the Clean Development Mechanism (CDM) will continue to deliver limited finance to projects with limited benefits.

Inadequate commitment: Annex I countries commit to greater, but still inadequate mitigation of 30 per cent from 1990 levels. They agree to provide US$100 billion a year in climate financing by 2020, half for adaptation, half for mitigation. In exchange, developing countries commit to an unquantified reduction in greenhouse gas emissions. This could involve some spending on mitigation by developing countries and countries implementing 'no-regrets' options, i.e. measures such as energy efficiency, to reduce mitigation costs. A scaled-up CDM would deliver increased finance to Africa, but again the spread and benefits of the projects will be limited and would not deliver additional mitigation over Annex 1 efforts.

Adequate commitment: Annex I countries agree to provide adequate mitigation of more than a 45 per cent cut by 2020. They decide to meet the full incremental costs of adaptation action in developing countries between now and 2020. Developing countries take significant mitigation actions but incremental costs are met. The CDM is not relevant to this scenario, given that developed countries will meet mitigation costs of developing countries, and will not rely on market mechanisms. The CDM would therefore have not function as a source of finance for mitigation, and will effectively be abolished.

This report concludes that between US$510 and US$675 billion between 2010 and 2030 are required for low-carbon development growth in Africa. In 2008, Africa received less than 2.5 per cent of financial flows from the Clean Development Mechanism (CDM). The CDM currently totals about US$22 billion, and Africa's small share is far from the capital needed for low carbon, sustainable development.

Summary of possible climate change impacts in Africa, adaptation strategies and cost ranges.

°C rise	1.5°C	2°C	4°C
Key Impacts	Potential yield increases in East Africa and the highlands; reductions in the Sahel. Potential increases in net revenue for small livestock farms; losses for large farms. Twelve million people could be at risk from hunger. Fisheries could be negatively affected by drought. Widespread coral bleaching could occur on Indian Ocean coasts. Possible increases in exposure to malaria of 0-17 per cent; diarrhoea by -0.1-16 per cent and increased inland flood deaths by 0-127 per cent. Increased flooding resulting in damage to infrastructure and property. Water stress increases, particularly in North Africa. Up to 15 per cent of sub-Saharan species could be at risk of extinction.	Potential crop yield increases in highland areas; significant reductions in Southern Africa. Potential increases in net revenue for small livestock farms, losses for large farms. Net revenue loss to agricultural sector could be as much as US$133 billion, about 4.7 per cent of Africa's total GDP. An additional 55 million people could be at risk from hunger. Water stress could affect between 350-600 million more people. Increases in malaria transmission and exposure are possible. Up to 40 per cent of species in sub-Saharan Africa could at risk from extinction. Flooding in coastal areas could cause around US$50 billion worth of damage.	Anticipated drops in wheat, maize and rice crops in some areas. Increased risk of hunger among up to 128 million more people. Higher risk of flooding in low-lying areas. Potential increases in net revenue for small livestock farms, losses for large farms. Malaria transmission area could double by 2100 in South Africa. Increased water stress, particularly in northern and southern Africa. Rainfall could increase in eastern Africa.
Adaptation strategies	Regional agreements to enforce environmental and animal protection laws. Promoting agro-ecological approaches to farming. Support to smallholders, including micro-credit finance, improved seed varieties, drought-tolerant stock and fertilisers, veterinary services, access to appropriate technologies for irrigation systems and training in improved soil and water management techniques via outreach extension services. Reforestation schemes. Regulations on fossil fuel intensive chemical inputs. Improving water storage and distribution technologies, establishing user associations and payment and compensation schemes for fair distribution of water and natural resources. Improved climate monitoring and forecasting. Disaster prevention and response plans. Coastal protection measures. Retrofitting or relocating infrastructure, development of building guidelines. Investments in health services, including education programmes, surveillance systems, staff training, and preventative measures. Introducing energy efficiency policy and decentralised off-grid renewable energy systems for rural areas.	Support to the agriculture sector, particularly smallholders, including improved crop varieties, drought-tolerant livestock, fertilisers and farming technology measures, such as irrigation. Additional water stress may require larger-scale interventions, such as water basin transfers and exploitation of groundwater supplies. Coastal protection measures. Explicit conflict mitigation efforts and peace-building where necessary. Energy efficiency and on-grid power extension to build human and industrial resilience in urban areas. Capacity building in the health sector. Biodiversity rehabilitation and conservation efforts scaled up with tighter regulations on natural resource use.	Building the resilience of the agricultural sector still crucial. Measures as before, potentially at larger scale. Reinforcement or relocation of industries, infrastructure and human settlements via coastal protection measures.
Cost Ranges With Adaptation	Minimum US$10 billion a year by 2030, and up to US$30 billion a year, directly in response to climate change.		
Cost Ranges Without Adaptation	1.7 per cent of Africa's total GDP	3.4 per cent of total GDP	10 per cent of total GDP

International negotiations must therefore agree alternative and innovative funding mechanisms to support low-carbon development in Africa. The CDM will require significant reform to ensure environmental integrity, strengthen social safeguards and improve community access to funds before it can play a useful role.

Preliminary indications in the AdaptCost study (see above and Chapter 4) show that adaptation could significantly reduce annual costs of climate change in Africa. Under the business-as-usual and 450ppm scenarios, adaptation is estimated to reduce the costs of climate change by around one third. The remaining economic costs are known as residual damages. Under the business-as-usual scenario, this still leaves very significant economic costs for Africa, for example, equivalent to around 6 per cent of Africa's GDP by 2100.

Under the 450ppm scenario, however, adaptation reduces the mean economic costs to the equivalent level of around 0.5 per cent of Africa's GDP in 2030 and 1.5 per cent of GDP by 2100. **This demonstrates the need for mitigation as well as adaptation to reduce the economic costs of climate change for Africa.**

Recommendations

The recommendations in this report set out:

- key commitments African governments should seek to secure from the UNFCCC negotiations in Copenhagen in December 2009, and
- proposed policy changes that African governments can make in light of the climate challenge, and
- further research priorities

Key commitments African governments should secure from the UNFCCC negotiations in December 2009

- A global deal on climate change must acknowledge the serious threat climate change poses to poverty reduction and sustainable development in Africa
- Developed countries must make immediate and significant emission reductions and commit to cuts of at least 40 per cent by 2020 and 85-95 per cent by 2050 (relative to 1990 levels)
- Immediate entitlement to a minimum of US$10bn a year, increasing to at least US$30bn a year by 2030 must be secured for adaptation in Africa
- Fundamental reform of existing mitigation financing mechanisms are required to provide sufficient capital for Africa to develop in a low-carbon sustainable way

Priority actions for African governments to implement nationally and regionally

- African national governments must establish common targets for demands on emission cuts and adaptation financing
- African governments must develop overarching climate change policies, plans and programmes targeted at poverty eradication and sustainable development
- National Adaptation Programmes of Action must prioritise poor people and be underpinned by equity and justice

Further research priorities

- Improving climate modeling and forecasting in Africa
- Identifying and supporting Africa's adaptive capacity
- Investigating potential changes in economic and social systems under climate change scenarios

1. The impact of climate change in Africa

Climate change is already having serious impacts across Africa. Africa is particularly susceptible to climate change because it includes some of the world's poorest nations. Its populations are also growing quickly, and natural resources are being lost through environmental degradation.

Millions of Africans are already feeling the impacts of climate change. This is resulting in significant economic and human losses and hindering efforts to meet the Millennium Development Goals (MDGs). Poverty and a low capacity to adapt to a changed climate are exacerbated by rises in the sea level and temperature. Increasingly variable seasons, rainfall, drought, and weather extremes are also problematic (IPCC, 2007).

The African continent has experienced general increases in warm spells since the industrial era (IPCC, 2007). Variable rainfall has also become more significant over the last century. In West Africa, mean annual rainfall has declined steadily since the end of the 1960s. Other regions, particularly southern and eastern Africa, have seen more intense and widespread droughts and a significant increase in heavy rainfall.

One third of Africans now live in drought-prone areas, mainly in the Sahel, around the Horn of Africa and in southern Africa. Climate change is putting a range of pressures on people living in these areas, not least because their crops are less productive and water in shorter supply.

1.1 Future impacts

There are currently very few regional and sub-regional climate change scenarios based on climate modelling for Africa. This is largely due to a lack of facilities and human resources to collect and process climate data. However, available information suggests that accelerated changes in the climate are expected to lead to potentially large impacts across the continent in the future.

The Sahara and central southern Africa are expected to experience hotter conditions (IPCC, 2007). Annual rainfall could decrease along the Mediterranean coast, the northern Sahara, along the western coast and in southern Africa during the winter months. Rainfall is expected to increase in tropical and eastern Africa, and in southern Africa during the summer months. Models for the Western Sahara are yet to show conclusive results regarding whether the region will experience generally drier or wetter conditions.

Limited information is available on extreme weather events, but some models show that the Sahel may experience increases in extremely wet and dry years over the next century. Some of the anticipated regional effects of climate change on Africa are shown in Figure 1 below.

These climate conditions will combine with social, economic and environmental factors to exacerbate Africa's vulnerabilities in the future, including lack of water, food insecurity, diseases, conflict and degradation of natural resources.

1.1.1 Agriculture

The agricultural sector is critically important to Africa, both in terms of social and economic development. Over 60 per cent of Africans depend directly on agriculture for their livelihoods (FAO, 2003). Production ranges from small-scale subsistence farming to large-scale export industries. Agriculture contributes to about 50 per cent of Africa's total export value and approximately 21 per cent of its total gross domestic product (GDP; Mendlesohn et al., 2000).

Agricultural activity is highly sensitive to climate change, largely because it depends on biodiversity and ecosystems. Sufficient freshwater supplies, fertile soil, the right balance of predators and pollinators, air temperature and average weather conditions all contribute to continuing agricultural productivity. Human interventions, such as excessive extraction of natural resources, forest clearance for pasture or cropland, large-scale monocropping and use of chemical fertilisers and pesticides, have resulted in biodiversity losses. These can ultimately damage an ecosystem's capacity to adapt naturally to changes in the climate. The resulting 'simplification of agroecosystems (...) brings losses in fertility and an increased risk of exposure to new pest and disease variants' (Ensor, 2009).

Drought is one of the most serious hazards for Africa's agricultural sector in certain areas. By 2100, regions of arid and semi-arid land are expected to expand by 5-8 per cent, or 60-90 million hectares, resulting in agricultural losses of between 0.4-7 per cent of GDP in northern, western central and southern Africa (IPCC, 2007).

A reduction in land suitable for rain-fed agriculture and crop production is also expected by the 2080s. In southern Africa, this could lead net crop revenues to drop by as much as 90 per cent. However, climate adaptation could reduce these effects (IPCC WGII, 2007). The importance of rain-fed agriculture varies regionally, and is most significant in Sub-Saharan Africa. Here, it accounts for about 96 per cent of total cropland (World Bank, 2008).

The impact on maize is of particular concern in western and southern Africa, while decreases in North Africa's wheat yields could increase famine (Warren et al., 2006). In contrast, increased temperatures and rainfall changes in certain areas – for example, parts of the Ethiopian highlands and Mozambique – could lead to longer growing seasons and increased agricultural production (IPCC, 2007).

The net balance in cereal production potential is expected to be negative, with up to 40 per cent of sub-Saharan countries set to lose substantial shares of their agricultural resources (Fischer et al., 2002). Sea level rises resulting in saltwater intrusion into inland freshwater supplies could lead to crop failure in coastal countries. These crops potentially include rice in Guinea; palm oil and coconuts in Benin and the Ivory Coast; mangoes cashew nuts and coconuts in Kenya; and shallots in Ghana (IPCC, 2007).

Figure 1: Examples of potential regional effects from Climate Change in Africa, (Watkiss et al., 2009)

Figure 2: Projected losses in food production due to climate change by 2080 (Cline, 2007)

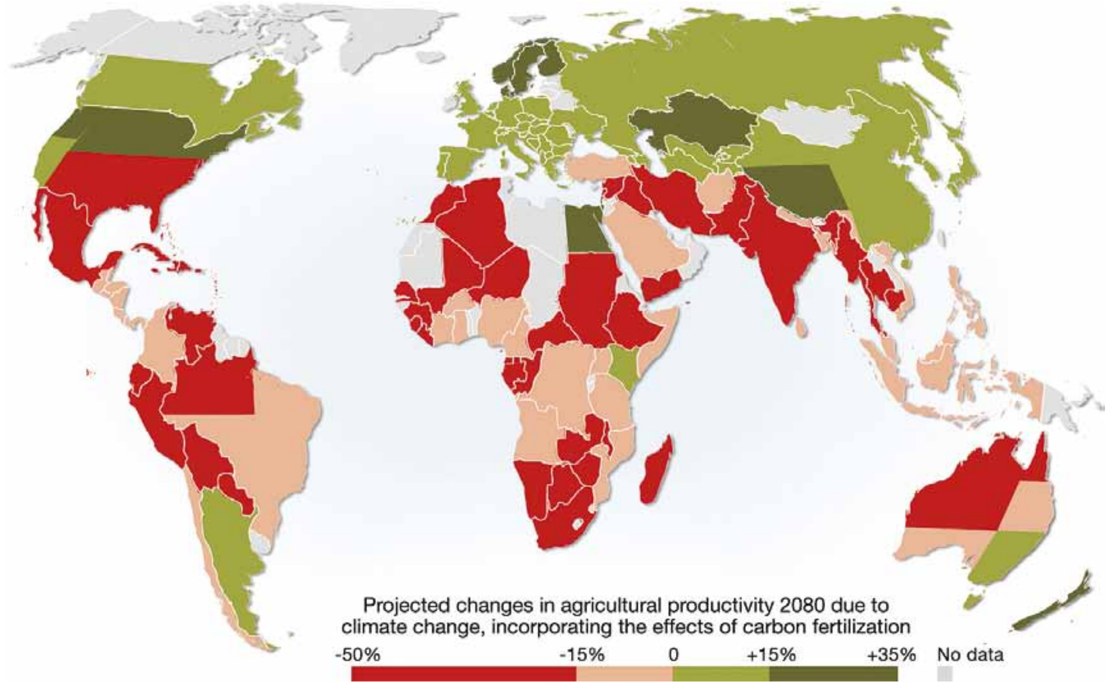
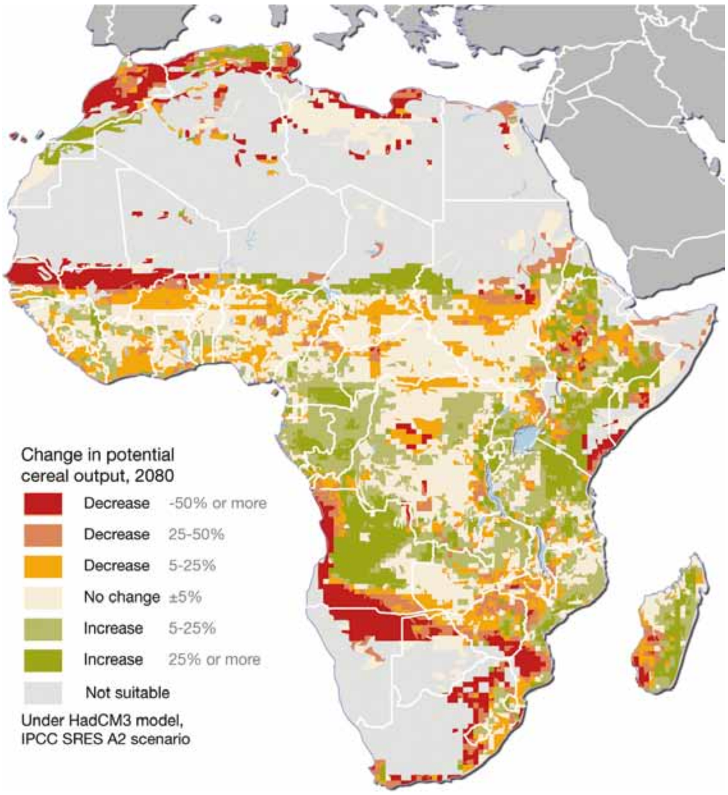


Figure 3: Impacts of climate change on cereal output in Africa (Fischer et al., 2005)



Africa's poorest people live in rural areas and depend mostly on agriculture for food and income. These people are the most vulnerable to hunger, as well as dependence on food imports and food aid caused by deteriorating farming conditions. Currently, around 40 per cent of sub-Saharan Africa's population is undernourished. By the 2080s, this number could increase by as much as 50 million to approximately 240 million (figure 4).

As for livestock, a warming of up to 5°C from 2006 average global temperatures could benefit some small-scale farmers in some areas who keep goats and sheep as they are more heat tolerant than other species.

By contrast, the same temperature rise could reduce the income of large-scale livestock farmers dependent on non-heat tolerant cattle by as much as 35 per cent, or US$20 billion a year compared to 2006. Increased rainfall would reduce livestock revenue for both large and small farms, due primarily to a reduction in the numbers of animals. (Seo & Mendelsohn, 2006b).

Given that large farms dominate Africa's agricultural sector, the overall effect on net livestock revenue equates to losses of billions of US dollars. Table 1 shows these findings converted to a pre-industrial temperature baseline, based on the general consensus that global mean temperature has risen by approximately 0.8°C since the pre-industrial era (Hansen, 2006).

As ecosystems shift from savannah to forest (and other areas where new disease vectors may emerge) small-scale livestock farmers will suffer losses. This will result from farmers lacking the information, skills and technology necessary to change animal stock to more suitable and adaptable species, or to shift from livestock to crop production (Seo and Mendelsohn, 2006b).

Table 1: Net farm revenue loss against pre-industrial temperature rises

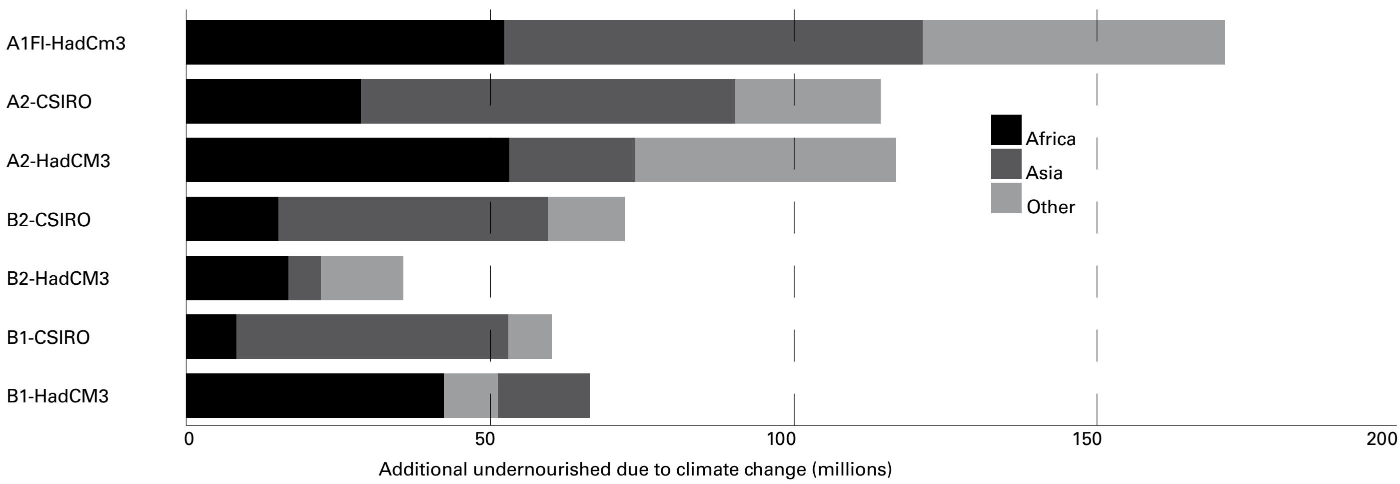
Temperature Increase	Net revenue	
	Small farms	Large farms
+ 2.8°	+25%	-22%
+ 5.8°	+58%	-35%

In coastal regions, coral bleaching, changes in water flows and salinisation of freshwater sources are expected to deplete fish species (IPCC WGII, 2007). Upwelling, an oceanic phenomenon whereby nutrient-rich colder water is driven towards the surface by the wind, will also be a contributing factor. Temperature rises in African lakes, combined with reductions in mean annual rainfall, are also expected to impact negatively on fish supplies. Wetlands and shallow rivers may become completely dried out (FAO, 2008).

Despite the projection that food production and livestock rearing may benefit from climate changes in some regions, cereal production in Africa is expected to halve by 2050 (Parry, 2007). By this point, global food production will need to have been increased by 70 per cent to meet increasing demand from a constantly expanding global population (FAO, 2009).

More than 60 per cent of the world's population growth between 2008 and 2100 will be in sub-Saharan Africa. Climate change therefore poses a serious challenge to the future food security of millions of Africans (World Water Assessment Programme, 2009). This in itself poses a severe threat to the region's ability to cope with and respond to other expected impacts of climate change.

Figure 4: Additional number of undernourished people due to climate change by region for an SRES A2[1] scenario in the 2080s (Fischer et al., 2001)



1 SRES are constructed by the IPCC to explore future global climate developments with reference to different GHG emissions. The SRES A2 storyline is summarised as 'a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines' (Nakicenovic et al., 2000).

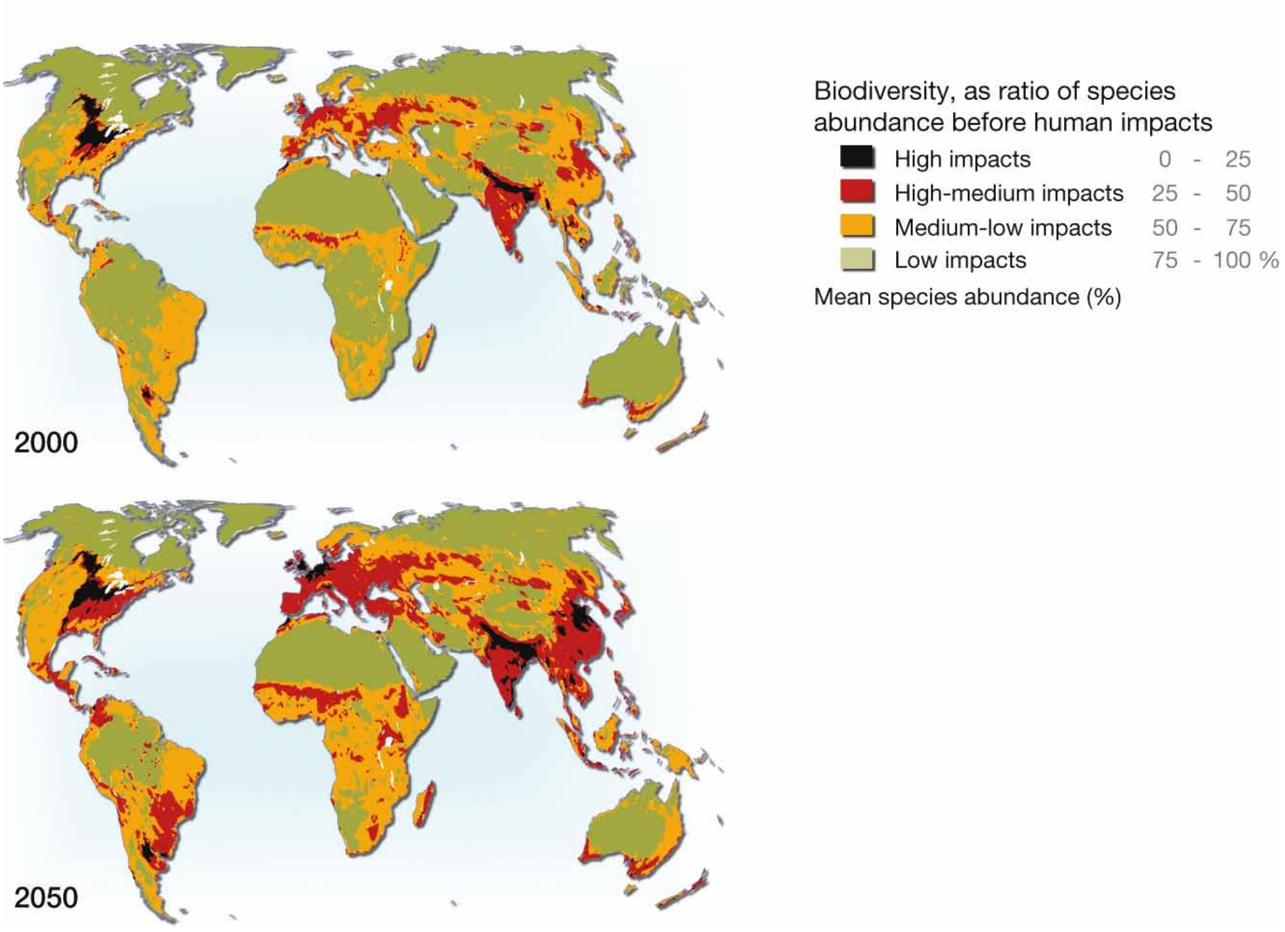
1.1.2 Biodiversity

Biodiversity sustains, and is fundamentally dependent on, ecosystems. Humans rely on biodiverse ecosystems to support our food, fuel and fibre production. We need them to regulate the climate, diseases and flooding, to recycle water and nutrients, and to provide us with cultural and educational experiences and opportunities (FAO, 1999).

As climate change impacts on the natural and human worlds, the biodiversity of Africa's ecosystems is being put at severe risk. Long-term declines in rainfall have increased the spread of deserts in southern and western Africa, resulting in shifting sand dunes and the loss of flora and fauna (IPCC, 2007). On the eastern coast, changes in sea water temperatures are causing coral bleaching. Mountainous ecosystems, mangroves and coral reefs are all expected to change further, resulting in species moving westward around the equatorial transition zone and eastward in southern Africa (IPCC, 2007). Some species will become extinct, primarily due to loss of habitat and vegetation, particularly in South Africa (Malcolm 2006), and biodiversity will be lost.

Based on a variety of scenarios, climate change is expected to cause losses of about 5,000 African plant species, over 50 per cent of some bird and mammal species, and decline the productivity of Africa's lakes by between 20 and 30 per cent by 2100 (IPCC, 2007).

Figure 5: Loss of biodiversity with continued agricultural expansion, pollution, climate change and infrastructure development (GLOBIO from Alkemade et al., 2009)



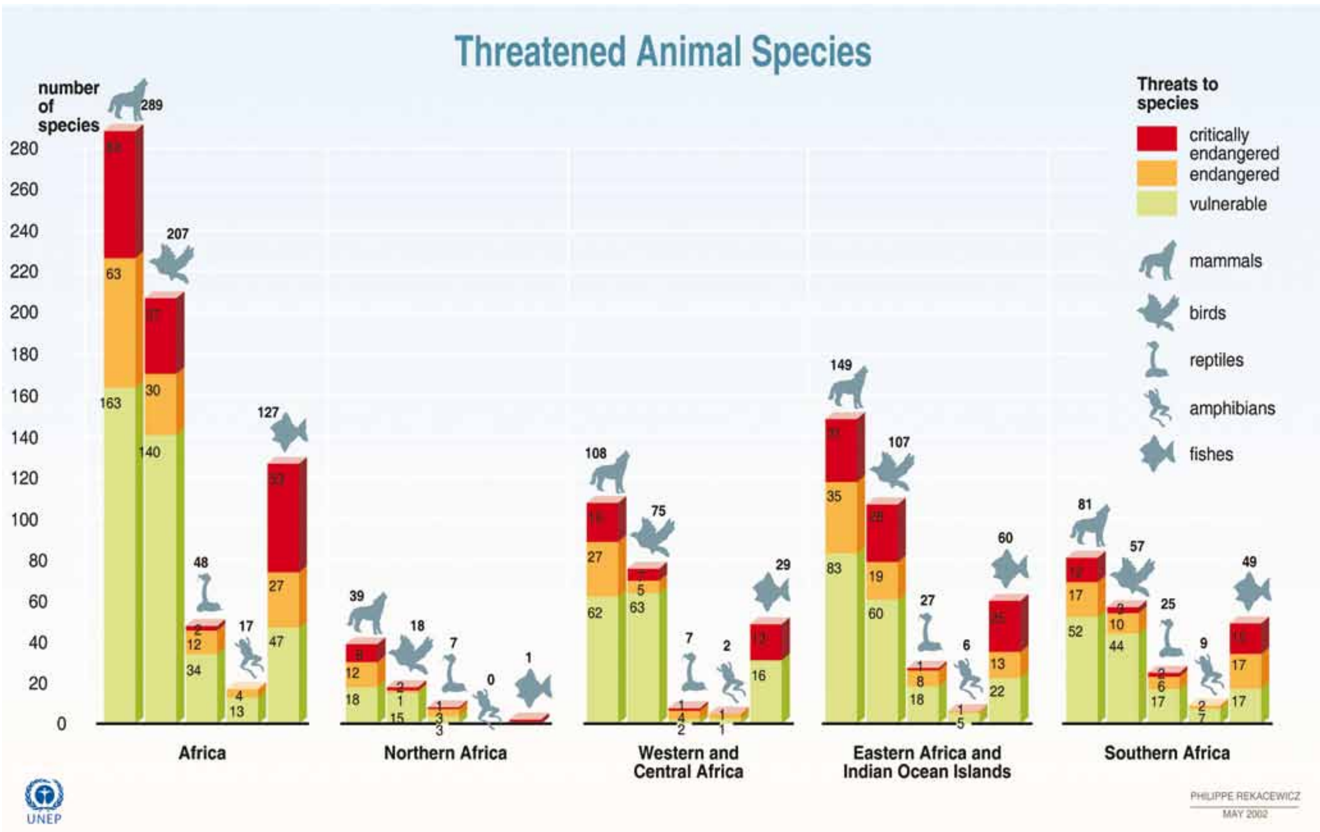
Given the integral nature of ecosystems, climate changes often produce a number of knock-on effects, or 'feedbacks'. These lead to further pressures that are not always possible to predict. Examples include human responses to environmental changes, such as accelerated deforestation and over-exploiting land for agriculture and livestock breeding.

The resulting loss of biodiversity can bring devastating consequences. Every ecosystem changes as time passes. However, self-regulating conditions (known as homeostasis) that depend on a large number of different species such as crops, animals, bacteria and fungi, are unable to respond quickly enough to the effects of climate change – be it new pests, warmer spells, more sporadic rainfall, or habitat loss due to deforestation. In an unstable ecosystem, 'deterioration sets in, (…) such as the loss of resilience and diversity and the erosion, salinisation or decline in fertility of soils' (Ensor, 2009).

As the climate warms, the impacts on ecosystems are expected to escalate quickly as species migrate or die out. This disturbance in the balance of ecosystems will be impossible to compensate for.

Under future changing climates, invasive alien species infestations will pose a significant threat to ecosystems and biodiversity (Sala et al., 2000; Gaston et al, 2003). Given that healthy, functioning ecosystems are vital to sustaining agricultural activity, increases in pests and diseases pose a major threat to future food production. For example, increases in winter rainfall in the Sahel could provide better breeding conditions for the desert locust, with catastrophic impacts on crop and livestock production in the Sahel region (FAO, 2008b).

Figure 6: African wildlife under threat from climate change, (Philippe Rekacewicz from UNEP/GRID-Arendal, 2002)



Sources: WCM/UICN-The World Conservation Union, 1998.

Agriculture is the backbone of Africa's rural economy. It provides food for rural and urban populations, as well as incomes, employment, and export earnings. The impacts of climate change on ecosystems are expected to produce negative knock-on effects for whole populations. Small-scale and subsistence farmers, the rural poor and traditional societies face the most serious and immediate risks because they rely most directly on ecosystems for food security and fuel, medicinal products, construction materials and protection from natural dangers.

1.1.3 Health

Africa's disease burden is at least two times higher than in any other region in the world. It is assessed using 'a time-based measure that combines years of life lost due to premature mortality, and years of life lost due to time lived in states of less than full health' (WHO). This fact is largely due to contagious diseases, and maternal, perinatal and nutritional conditions. Africa's injury rates are also higher than in other regions (WHO, 2008).

Climate change affects the key determinants of human health – air, food and water. It also influences how frequently people are exposed to physical and biological risks, such as extreme weather and new diseases. Uncertainties about projected rainfall impact on our overall knowledge of the potential spread of vector-borne diseases, such as malaria, dengue fever and diarrhoea. However, available data suggests some likely trends for how key climate changes will impact on people's health in Africa.

Shifts in malaria exposure and transmission zones are expected to expand and contract throughout the 21st century (IPCC, 2007). Higher rainfall in eastern Africa is expected to lead to increased malaria transmission, which is also expected to spread to some new areas on the continent, particularly southward into South Africa (IPCC, 2007). These increases in range will be altitudinal, to highlands and uplands, rather than longitudinal (Warren et al., 2006).

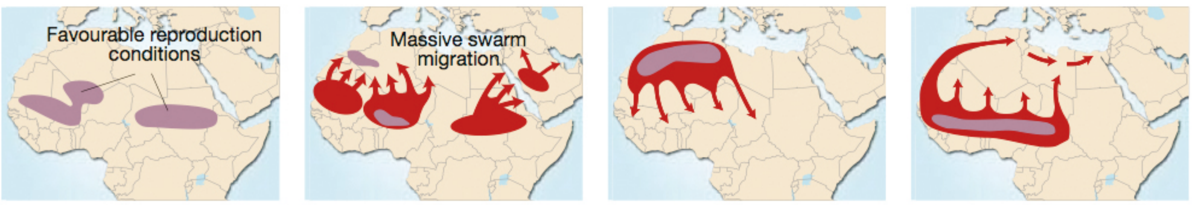
In contrast, malaria transmission may become rare in large parts of southern central Africa and the western Sahel by around 2050 (IPCC, 2007). Increased drought could cause decreases in vector-borne diseases in some areas, including reductions in malaria exposure around the Sahel and in semi-arid southern Africa (Thomas et al., 2004).

Nevertheless, the number of people exposed to malaria in Africa by 2070-2099 is estimated to be 13-18.9 per cent higher than at present, although these figures do not take population growth into account (Tanser et al., 2003). Dengue fever is also likely increase in western, central and eastern Africa (Warren et al., 2006).

Diarrhoea is a leading cause of Africa's disease burden. In 2008, it affected some 32.2 million people (WHO, 2008). Higher daily temperatures could cause rises in food poisoning, thereby leading to increased diarrhoea cases. However, this is difficult to predict accurately, given the many causes of diarrhoea (Warren et al., 2006).

Increased coastal and inland flooding caused by sea level rise and intense rainfall may also have health implications, including increased transmission of vector-borne diseases and more deaths from drowning (McMichael et al., 2006).

Figure 7: A shift in desert locust (Schistocerca gregaria) host range due to climate change might have catastrophic impacts on food and livestock production (CIRAD/UNEP/GRID, Arendal 2005)



July - September 2003
Exceptional rains favour locust reproduction. Lack of funding for preventive intervention in the Sahel.

October 2003 - February 2004
Situation aggravated and start massive migration of destructive swarms.

March - July 2004
Massive reproduction in the Maghreb, limited reproduction in the Red Sea region. Invasion into the Sahel. Gregarious populations eradicated on the coast of the Red Sea.

August - November 2004
Monsoon creates favourable conditions for reproduction in West Africa. Massive and early migration of swarms born in the Sahel towards the Maghreb and eastward towards Egypt, Lebanon and Cyprus.

In terms of animal health, increased average temperatures, floods and droughts are all predicted to impact on African livestock. The most significant effects of climate change are expected to be reduced access to water, particularly in northern and western Africa, and animal feed. There will also be shifting patterns and increased prevalence of vector-borne diseases (Van den Bossche & Coetzer, 2008).

Conflicts are likely to arise as pastoralists migrate across boundaries in search of food and water for their animals and come into conflict with settled communities (Magadza, 2000). Poor animal health also has an important knock-on effect on human nutrition.

If current socio-economic development trends in Africa continue, the impacts of climate change on people's health could be significant. More diseases will lead to higher rates of mortality, injury, malnutrition, and a decline in day-to-day economic activity. The latter is an important factor in African food production. All of this will put Africa's health services under additional pressure, and deplete the continent's overall work force.

Africa's most vulnerable people – the poor, young, malnourished, and particularly the elderly will be most at risk of new health problems caused by climate change, and will depend largely on accessible health services to cope.

1.1.4 Water

Africa's water resources are still too low in terms of the water its people require for drinking, farming and other basic needs (World Water Assessment Programme, 2006).

In 2002, 14 African countries were already experiencing water stress as the result of water scarcity, leading to increasing conflict over water use, a decline in water services, crop failure, and food insecurity. Another 11 countries are expected to join this statistic by 2025. By then, nearly half of Africa's population – almost one billion – will face water stress or scarcity (WWF, 2002). This is especially true for in arid and semi-arid areas, such as the Sahel region and North Africa, where water use and population growth are making it harder to sustain existing water resources (IPCC 2007 & Warren et al., 2006).

In the future, increased temperatures and variable rainfall could put additional pressure on water availability and demand in certain regions of Africa. By 2055, another 350-600 million more people in Africa will be at risk of increased water stress, especially in northern and southern Africa (IPCC WGII, 2007). Areas near Cape Town are predicted to hardest hit, with an expected 20 per cent drop in rainfall by 2070. This will reduce the perennial local water supply by nearly 60 per cent (de Wit y **Stankiewicz, 2006**).

Strong to moderate decreases in water supply are also forecast for upper reaches of the Orange River in south-eastern Africa. This will have a knock-on effect in south-western Africa, because the river is one of the area's key water sources. Today, this region is experiencing its biggest drought in over 100 years (de Wit y **Stankiewicz, 2006**).

Periods of intense drought or increased rainfall have been linked to fluctuations in lake-levels and freshwater supply, particularly in eastern Africa. Climate change is already reducing the reliability of water supplied by mountain ranges, which are of great importance to river basin supplies. Glaciers in Mount Kilimanjaro, Mount Kenya and Ruwenzori in Uganda all face the threat of disappearing completely within the next 15 years (Thompson et al., 2002 in Nkomo et al., 2006). In Africa's large basins of the Niger, Lake Chad and Senegal, the total water available has already decreased by 40-60 per cent (UNEP, 2001

In eastern Africa, rainfall could increase and water supplies may therefore improve. Somalia, for example, is expected to see a 20 per cent rise in rainfall, boosting the water it receives from rivers by ten times the current supply (de Wit y **Stankiewicz, 2006**). A negative impact of higher rainfall may be that it creates conditions for mosquitoes to breed, exacerbating the incidence of malaria.

Reduced water sources have a significant impact on ecosystems, farming and health. Less available water leads to a loss of life, flora and fauna, and causes humans and animals to migrate. All major African rivers crossing national boundaries pose the threat of potential conflicts over water resources erupting into wars (de Wit y **Stankiewicz, 2006**). Poor people in rural areas will suffer most from an increased lack of water, as they already travel considerable distances to access this basic human necessity

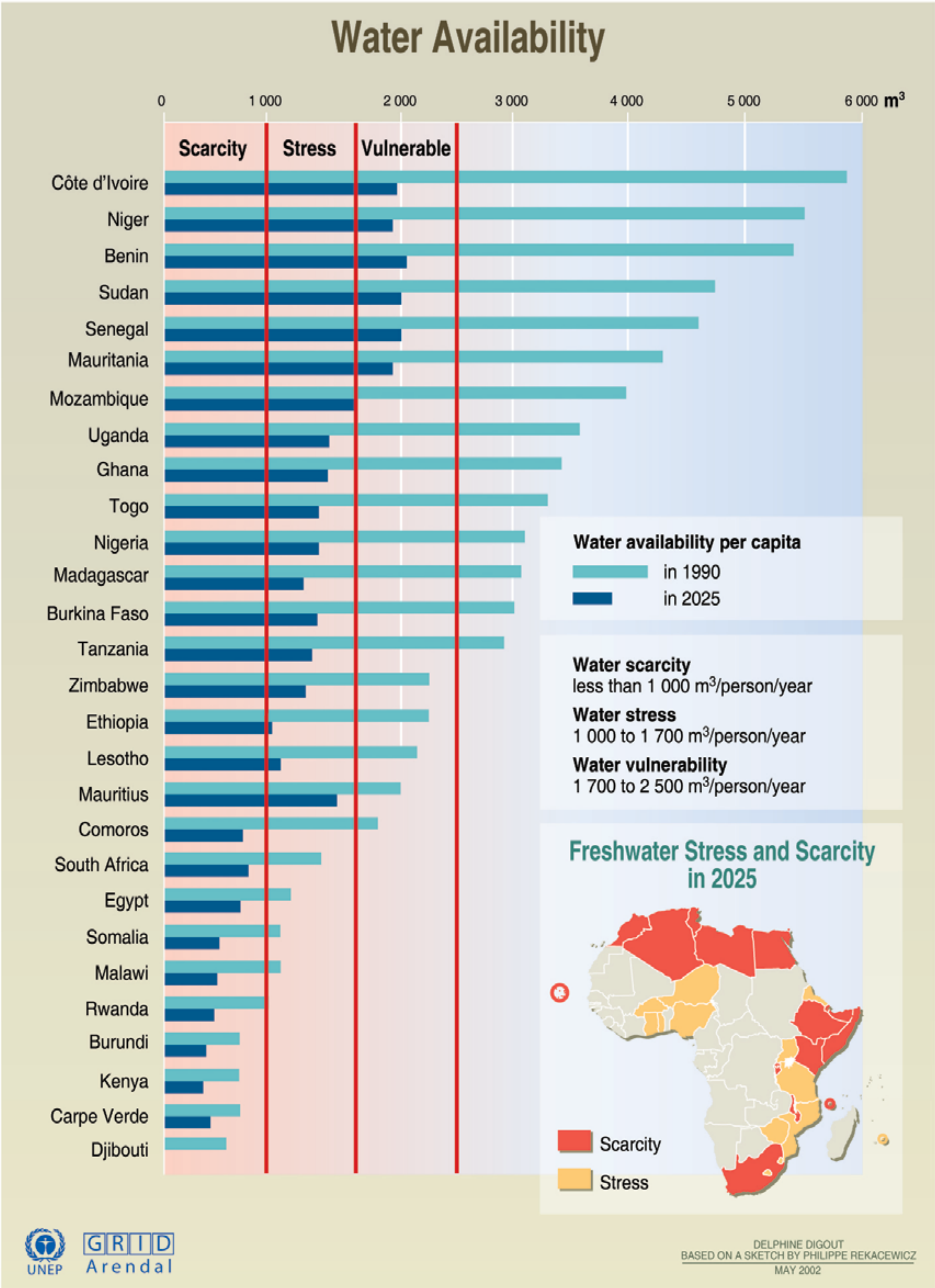
1.1.5 Settlements and Infrastructure

Africa's urban populations were estimated at 373 million people in 2007. This figure is set to double by 2030, when half the continent's population is expected to be living in cities (UN-HABITAT, 2008). A large percentage of these urban populations live in coastal cities. Here, flooding has become more frequent and intense, and now occurs in areas that were previously not at risk. This is caused by several factors, including climate changes and variability, weak infrastructure, and a lack of flood warning alerts and response mechanisms.

Floods in Mozambique during 1999 and 2000 displaced more than one million people and killed an unknown number (WWF, 2002). Rural people and those living in slums in and around Maputo and other towns were hardest hit. Water supplies were contaminated, and irrigation systems, roads and bridges were damaged. This incurred direct losses of US$273 million and reconstruction costs of US$428 million (UNHABITAT, 2008).

More than a quarter of Africa's population lives within 100km of the coast (Nkomo et al., 2002). By 2100, Africa's coastlines and river deltas with densely populated low-lying areas will be affected by a sea level rise of up to one metre. This will lead to increased flooding and coastal erosion, and unpredictable disasters may occur quickly and without warning (Nkomo et al., 2006). By 2080, North Africa, West Africa and southern Africa will be three of the world's five regions most at risk from flooding (IPCC, 2007).

Figure 8: Water availability in Africa (Digout, Delphine, based on a sketch by Philippe Rekacewicz; UNEP/GRID-Arenda, 2002)



Source: United Nations Economic Commission for Africa (UNECA), Addis Abeba ; Global Environment Outlook 2000 (GEO), UNEP, Earthscan, London, 1999.

Many countries in West Africa could be negatively affected by saltwater intrusion and damage to coastlines (IPCC, 2007). The eastern coast could be affected by increases in frequency and intensity of El Niño-Southern Oscillation (ENSO) events and coral bleaching (Klein et al., 2002) The Indian Ocean islands could be threatened by more frequent and intense cyclones (IPCC WGII, 2007). By 2080, approximately 70 million people could be at risk from coastal flooding in Africa (Nkomo, 2002). In Egypt, a 50cm rise in sea level is predicted to displace more than 1.5 million people and destroy 214,000 jobs in the coastal area between Alexandria and Port-Said, costing more than US$35 billion (UN-HABITAT, 2008).

Public services and infrastructure could be both positively and negatively affected by climate change in the future. Negative impacts in coastal areas will be heightened due to poor sea defenses and low disaster preparation levels. In some inland regions, repeated flooding could create water quality problems. Drought could restrict hydroelectric power generation in some areas, while increased rainfall could improve this resource in others (Magadza, 2000).

Poor people living in high concentration in and around cities are expected to suffer the most, given that they are more likely to live in areas at higher risk of flooding such as flood plains, and disease spread due to bad quality sanitation. Without formal land rights, poorer communities are rarely able to lobby for improved living conditions, such as flood resistant housing and adequate water and sanitation supplies, which could reduce their vulnerability to the impacts of climate change.

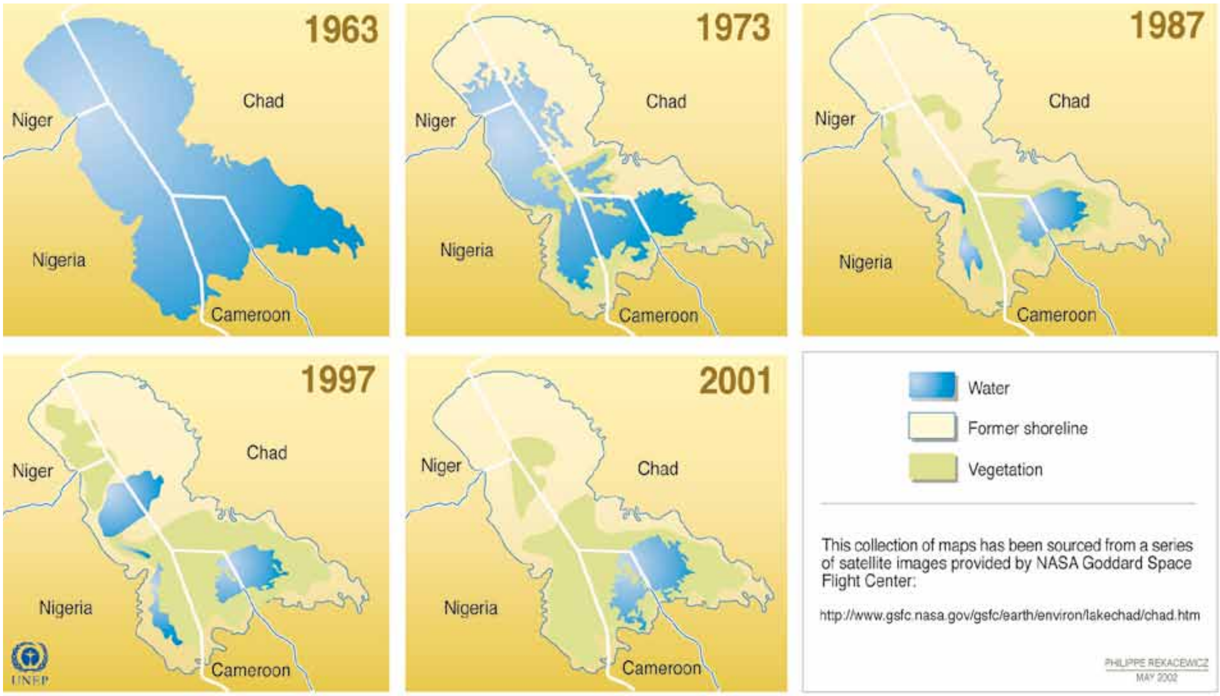
1.1.6 Security and conflict

The relationship between climate change and security is complex. It is difficult to predict where conflicts may occur and even harder to attribute conflicts directly to environmental changes. Yet studies suggest that climate change could contribute to conflicts caused by competition for food, water, energy and land. Current tension between farmers and herders in Darfur over disappearing pastures and declining water holes has in part been attributed to rainfall decreases. Such impacts of climate change have over the past 40 years led to the Sahara advancing by more than a mile ever year (UNDP, 2007).

Other potential sources of conflict related to climate change include unregulated migration, destabilised settlements and increased recruitment to armed groups as a result of reduced employment opportunities (Brown et al., 2007).

Poor people are the most vulnerable to conflict over resources. A temperature rise of up to 2.6°C might cause a decline in farmers' incomes and environmental degradation (Nkomo et al., 2002). Pastoral communities along the borders of Ethiopia, Somalia, Sudan, Kenya, and Uganda are notoriously insecure. These nation states have a long history of international and internal conflict, which could be aggravated by the impacts of climate change on livelihoods (UNEP, 2007). However, climate change impacts may also promote collaboration and co-existence if countries and their people decided to work together to find solutions.

Figure 9: Lake Chad – decrease in area 1963, 1973, 1987, 1997 and 2001. Climatic changes and high demands for agricultural water are responsible for the lake's shrinkage (Philippe Rekacewicz, UNEP/GRID-Arendal, 2002)



1.1.7. Tourism

It is extremely difficult to model future human behaviour and choice. Only limited information about how climate changes might impact on tourism is therefore available. In 2008, Africa accounted for five per cent of the world's inbound tourism, an increase of three per cent since 2004. It is the only region in the world where tourism is expected to continue growing over the coming years (UNWTO, 2009). It is uncertain whether these projections have taken climate change into consideration.

The World Tourism Organisation predicts a decline in peak summer visits and a stronger winter tourism market as two potential climate change implications for the tourism industry in northern Africa. In sub-Saharan Africa, there is little clear indication of climate change affecting tourism, although hotter and dryer, as well as wetter seasons could deter tourists slightly (UNWTO, 2003). Since many tourists travel to Africa to enjoy the continent's wildlife, any loss of biodiversity caused by climate change could cause a decline in tourist numbers and related economic losses.

1.2 Summary of likely impacts against proposed scenarios

Comprehensive attempts have been made since the 1990s to set out potential future impacts of climate change. Despite a wealth of available information, predictions about future impacts are unavoidably uncertain. The complexity of the Earth's systems means that a variety of plausible future scenarios can be developed. Temperature rises, sea level rises and glacial melting are the three most certain results of climate change. However, the degree and variability of change, and the impacts of these changes on society and the environment, still remain uncertain.

East Africa is often cited as an example of climate models' failure to provide a consensual outlook on a regional scale, with ongoing disagreements over future seasonal rainfall patterns (Ensor, 2009). However, efforts to assess future climate change impacts do constitute a meaningful approach to understanding how sectors and systems are likely to respond to these changes. It is only by taking uncertainty into account that we can reduce current vulnerabilities and build the adaptive capacity necessary to meet future climate change challenges.

Limited work has been so far been undertaken to understand the impacts of future climate change in Africa for different levels of warming. There are several reasons for this. Most assessments are based on global models, with very few studies carried out on a regional and local scale. Furthermore, climate observation systems in Africa are sparse and there is low regional capacity to carry out modelling assessments.

Although some new efforts are addressing such information gaps, high levels of uncertainly still exist. Many climate change impact estimates do not take into account the extent of adaptation, the rate of temperature changes or socio-economic development. The following section therefore presents a summary of available information against three (1.5°C, 2°C and 4°C) temperature rise scenarios above pre-industrial levels, according to the approach set out below.

1.2.1 Baselines

'Baseline' refers to the period from which temperature increases caused by climate change are measured. The choice of baseline often depends on the amount of available data and can vary from pre-industrial temperatures to those recorded as recently as 2000. The baseline period of this report is taken to be pre-industrial, defined by the IPCC (WG1, 2007) as the global average temperature recorded at around 1861.

Compiling information about scenarios for temperature increases of 1.5°C, 2°C and 4°C above pre-industrial levels requires bringing together information on potential impacts from a range of sources, all working from different baselines. For example, the IPCC Fourth Assessment generally refers to a base period of 1980-1999. The Stern Review includes a summary of impacts based on global temperature rise relative to 1990 levels, and research by the Centre for Environmental Economics and Policy in Africa (CEEPA) tends to work from 2006 temperatures.

In order to reconcile this information, adjustments have been made to the temperatures at which impacts are expected to occur. These are based on the understanding that since 1861, global temperatures had risen by a global average of 0.6°C by the 1990s (IPCC WGIII, 2007), and by approximately 0.8°C by today (Hansen, 2006). So, for example, McMichael et al., 2003 project a 0-17 per cent increase in exposure to and transmission of malaria at a 1-2°C temperature rise with a baseline date of 1990. When transferred to a pre-industrial baseline, this impact would then be expected to occur with a 1.6-2.6°C temperature rise.

Based on these calculations, Table 2 below (page 22) provides an overview of likely impacts against proposed scenarios, with narrative trend summaries underneath. This table draws heavily on a summary of impacts produced by Stern (2006), but also incorporates information from additional sources. Please note that distinguishing between impacts expected at 1.5°C and 2°C rises in global mean temperature is difficult, given that most information on predicted impacts tends to be presented in one degree rises (1-2, 2-3 and so on). Impacts shown under 1.5°C in Table 2 should therefore be assumed to be valid under a 2°C rise scenario. Security, conflict and tourism have not been included as separate sectors but instead incorporated into the summaries.

Integrated Assessment Models (see Section 3.4) commissioned by the AdaptCost study (2009) have generated figures that could indicate the economic costs of temperature changes. These have been used to provide an example of how economic costs rise with temperatures along a given scenario. They also provide a very approximate indication of how economic costs might change with 1.5°C, 2°C and 4°C rises in global mean temperature above pre-industrial levels (without adaptation). However, they do not provide information for scenarios that limit temperature to these levels under a stabilisation policy.

In each of the future scenarios described, climate change will have distinct impacts across society. Africa's most vulnerable people are already feeling the impacts and will be affected first and hardest in the future. Vulnerable populations typically have few resources and limited access to energy, health services, markets, skills, technology and information. Poorer people's livelihoods tend to depend heavily on ecosystems for rain-fed farming and vital water supplies.

Prevailing political and social systems tend not to favour the poor, who typically have little access to, and influence over, decision-making processes. Combined, these factors limit poor people's capacity to cope with, respond and adapt to climate changes.

1.2.2 A 1.5°C temperature rise

It is possible to estimate some of climate change impacts associated with a 1.5°C temperature rise from pre-industrial levels. However, evidence indicates that the world has already warmed by 0.8°C since the pre-industrial era (Hansen, 2006). Historic emissions therefore already commit the world to more than a 1°C mean temperature rise from pre-industrial levels.

Some parts of eastern Africa and the highlands are expected to gain growing days. However, the Sahel will probably experience shorter growing periods, yield reductions and drops in food production. According to Parry et al., 2004, 12 million people could be at risk from hunger as a result of falling crop yields. Overall, by 2060, a net agricultural revenue loss would be more likely than a gain (Mendlesohn, 1997). Whereas small-scale farmers can expect increased net revenues from livestock by up to around 25 per cent, large farms will suffer losses if they do not change their livestock to drought-tolerant species (Seo and Mendelsohn, 2006).

Fisheries in north-western and eastern Africa could be negatively affected by drought in lakes (ECF, 2004). In coastal areas, coral bleaching could affect up to 97 per cent of coral on the Indian Ocean coasts (Hoegh-Guldberg, 1999). Malaria exposure could increase in highland and upland areas, whereas reductions are expected around the Sahel and semi-arid southern Africa due to drying (Thomas et al., 2004). Overall, increases in malaria could vary between 0-17 per cent, diarrhoea by -0.1-16 per cent, and increased inland flood deaths by 0-127per cent (McMichael et al., 2003).

Depending on the future development of coastal areas, increased floods owing to sea level rise could damage to coastal infrastructure and property. The number of people suffering from water stress is generally expected to increase, with North Africa particularly affected by 2025. In areas where rises in annual rainfall is expected – such as eastern Africa – availability of land for rain-fed agriculture and growing seasons could increase. Losses in flora and fauna, including species range shifts, could occur in the Sahel and South Africa (ECF, 2004 and Rutherford et al., 1999). Up to 15 per cent of sub-Saharan species could be at risk of extinction (IPCC, 2007).

Based on the IPCC business-as-usual scenario,[2] the PAGE model predicts that the annual economic costs of climate change in Africa with a 1.5°C mean temperature rise could be equivalent to 1.7 per cent of the continent's GDP.

1.2.3 A 2°C temperature rise

A recent University of Copenhagen report (2009) asserts that 'temperature rises above 2°C will be difficult for contemporary societies to cope with, and are likely to cause major societal and environmental disruptions through the rest of the century and beyond'.

This judgment is based on three factors:

- a consideration of negative effects on humans and ecosystems
- the degree to which societies are willing to tolerate these negative impacts, and
- tipping-point levels, where a sudden, significant, irreversible shift in climate occurs.

The report also indicates that these tipping point changes could be triggered by a 1.5°C rise in global average temperature if ocean acidification is taken into account, but such observations must be understood according to the uncertainty on which they are based. Under a business-as-usual scenario, estimates suggest that global mean temperatures could reach around 2.2°C by 2060 (based on PAGE model runs commissioned by the 2009 UNEP-funded AdaptCost Study – see section 3.4).

2 The A2 scenario is one of the four scenarios used by the IPCC to estimate future GHG emissions. The A2 scenario describes a "very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines" (Nakicenovic et al., 2000):

Available data suggests that a 2°C rise may increase crop yields in highland areas (ECF, 2004). In contrast, productivity is expected to fall by as much as 80 per cent in southern Africa. Small-scale livestock farmers could experience net revenue rises of over 25 per cent, whereas large-scale farms could likely to suffer greater losses from drought-intolerant stock (Seo and Mendelsohn, 2006).

The net revenue loss to the agricultural sector for a 2°C warming by 2060 could reach US$133 billion, about 4.7per cent of Africa's total GDP (Seo and Mendelsohn, 2006). Around 50 million more people in sub-Saharan Africa could be at risk of hunger due to climate change (total approx. 240 million) (Fischer et al., 2001). Water stress could affect up between 350 and 600 million more people (IPCC, 2007), with South Africa most at risk (Stern, 2006).

Increases in malaria transmission areas and exposure could also occur (Warren et al., 2006 adapted from Tanser et al., 2003), although the regional distribution of these increases is uncertain due to rainfall variability. Up to 40 per cent of species in sub-Saharan Africa could be at risk from extinction (IPC, 2007), and tropical corals reefs could be eroded faster than they can grow back (University of Copenhagen, 2009). Flooding in coastal areas could cause around US$50 billion of damage, depending on which measures are undertaken to defend shorelines (Mendlesohn et al., 1997).

Based on a business-as-usual A2 scenario, the PAGE model predicts that the annual economic costs of climate change in Africa with a 2°C mean temperature rise could cost the equivalent of 3.4 per cent of Africa's GDP.

1.2.4 A 4°C temperature rise

Under a business-as-usual scenario, global mean temperatures could reach around 4.1°C by the end of the century (based on PAGE model runs commissioned by the 2009 UNEP-funded AdaptCost Study – see section 3.4.) Recent studies, such as work by the UK Hadley Centre, have indicated that temperature rises are likely to be quicker, and reach higher average temperatures than this.

Relatively little information exists on the likely impacts of a 4°C average temperature rise in Africa. However, it would be likely to have a significant effect across the region in addition to the impacts set out above, depending on the adaptation measures taken and socio-economic development trends.

Wheat, maize and rice crops are key to African diets and export markets. Anticipated drops in yields and losses of cropland due to flooding are expected to increase hunger levels for approximately 128 million more people than in the 2°C scenario by the 2080s (Parry et al., 1999). Northern, western and southern Africa would be particularly badly affected (Warren et al., 2006). As in previous scenarios, rising temperatures would tend to favour small-scale livestock farms and could improve their net revenues by as much as 58 per cent (Seo and Mendelsohn, 2006). Likewise, large livestock farms would continue to suffer – possibly by as much as 35 per cent in net revenue – if switches in stock were not made (Seo and Mendelsohn, 2006).

Additional pressures on the health sector could be expected in South Africa, where the malaria transmission area could double by 2100 (Republic of South Africa in Stern 2006). Water resources could be severely depleted throughout large parts of the continent, predominantly in northern and southern Africa (IPCC WGII, 2007). However, rainfall could increase water availability in other areas, such as in Kenya and Somalia (de Wit y Stankiewicz, 2006).

Based on business-as-usual A2 scenario, the PAGE model predicts that the annual economic costs of climate change in Africa with a 4°C mean temperature rise could be equivalent to 10 per cent of GDP. Recent studies, such as work by the UK Hadley Centre, have indicated that temperature rises are likely to be quicker, and reach higher average temperatures than this.

Table 2: Overview of likely climate change impacts in Africa against proposed scenarios of average temperature rise

Global mean temperature rise (from pre-industrial)	1.5°C
Agriculture	Reduced growing period of more than 20% in marginal areas of Sahel by 2020 and 2050 (DFID 2006, in Stern 2006). Some parts of East Africa and highlands gain growing days (Stern, 2006). Decreasing grain yields and diminishing food security in small food-importing countries (IPCC WGIII, 2001). In Guinea, 17-30% of existing rice fields will be lost to permanent flooding (Republique de Guinee in Stern 2006). Between US$85 billion agricultural loss and US$16 economic billion gain across Africa (FAO, 2000 in Stern 2006). Between US$11-132 Check!] billion net loss by 2060 (Mendlesohn, 1997). Fish production negatively affected by sea level rise and coral bleaching (Stern, 2006). Fisheries impacted NW Africa, E African lakes (ECF, 2004). Net revenue for small livestock farmers up by 25%, and down by 22% for large farms (Seo & Mendelsohn, 2006).
Health	Between 1.8-5.1% increase in malaria transmission area and 6-14% increase in exposure (Warren et al., 2006 adapted from Tanser et al., 2003). 0-17% increase in malaria cases (McMichael et al., 2003). -0.1-16% increase in diarrhoea cases (McMichael et al., 2003). Increased inland flood deaths of 0-127% more people than in 2003 (McMichael et al., 2003). 20 million more people at risk from coastal flooding, including eight million in cities like Lagos, Kinshasa and Cairo by 2015 (Stern, 2006). Increased coastal flood deaths of 9-20% (McMichael et al., 2003). In West Africa, risk of death from flooding could rise by 144% by 2050 (McMichael et al., 2004). Cardiovascular disease will increase by 0-1.1% due to extreme heat (McMichael et al., 2003)[3]. - 0.1-16% increase in risk of diarrhoea (McMichael et al., 2003)[4]. Twelve million people at risk from hunger because of falling crop yields (Parry et al., 2004).
Water	Between 75 and 250 million people will suffer from increased water stress (IPCC WGII, 2007). By 2025, north Africa will experience increased water stress (Nkomo et al., 2006). By 2050, between 224 and 310 million people in North Africa will be at risk of water stress (Arnel 2004). Africa will see a US$2-3 billion net loss from market impacts (Mendlesohn, 1997).
Infrastructure	Increased frequency of droughts disrupts hydro energy supplies (Stern, 2006). Between US$2-3 billion net loss in the energy sector from market impacts (Mendlesohn, 1997). Increase in global sea level of 1.8mm/year (Thompson et al., 2004, in Stern, 2006). Cost of sea level rise in Egypt equals US$2.5 billion and 14% of GDP (van Drunen et al., 2005). A sea level rise of 0.5m in Tanzania would inundate 2,000km² at a cost of approx US$51million (Stern, 2006) Shorelines behind bleached coral more vulnerable to storm damage and lost tourism by 2050, particularly in small islands (Stern, 2006).
Ecosystems	Widespread bleaching of up to 97% of coral reefs on Indian Ocean coasts of East Africa (Hoegh-Guldberg, 1999). Increased damage from floods and storms (IPCC WGII, 2007). Increasing species range shifts and wildlife risks (IPCC WGII, 2007). Flora and fauna disappear in the Sahel due to drought and shifting sands (ECF, 2004). Glaciers on Mount Kilamanjaro, Mount Kenya and Ruwenzori could be lost by 2015 (Thompson et al., 2002) Warmer temperatures lead to the expansion of dunes in the Kalahari (Thompson et al., 2005, in Stern 2006). Severe loss in the extent of the Karoo, a semi-desert region in South Africa, and one of the world's six 'floral kingdoms' threatening 2,800 plants with extinction (Rutherford et al.,1999). Between $4 and $6 billion losses in forest ecosystem services by 2060 (Mendlesohn, 1997). Range losses for animal species in south Africa begin. Five south African parks could lose more than 40% of their animals (Rutherford et al., 1999). 10-15% of sub-Saharan species will be at risk of extinction (IPCC WGII, 2007).

3 Figure for 1 to 2°C rise in average global temperature
4 Figure for 1 to 2°C rise in average global temperature

Global mean temperature rise (from pre-industrial)	2°C
Agriculture	Significant risk of 80 % crop failure for commercial and subsistence agriculture in southern Africa (ECF, 2004). 10% loss in maize production across continent (Jones & Thornton 2003)[5] Maize yields double in the Ethiopian highlands (Jones & Thornton 2003). Net revenue losses of US$49.2/hectare (Nkomo et al., 2006).
Health	Between 2.5-5.1% increase in malaria transmission area and 8.8-14% increase in exposure (Warren et al., 2006 adapted from Tanser et al., 2003)[6]. Damage to fisheries as a result of a decline in fish populations due to increases in mean temperature in Malawi removes primary protein source for 50% of the population (ECF, 2004). About 55 million people at increased risk of undernourishment by 2080 (Fischer et al., 2001).
Water	Between 350-600 million more people suffer from increased water stress (IPCC). South Africa most at risk from water stress (Stern, 2006).
Infrastructure	Coastal flooding causes $50 billion of damage (Mendlesohn et al., 1997)
Ecosystems	Spreads in ocean acidification and an acceleration in sea level rise (University of Copenhagen, 2009) Erosion is likely to outpace growth of tropical coral reefs (University of Copenhagen, 2009). At least 40% of sub-Saharan species at risk of extinction (IPCC WGII, 2007). Up to 66% of species lost from Kruger National Park in South Africa and four endangered species: the termite genus, canthonine dung beetle, golden mole and armoured lizard become totally extinct (Erasmus et al., 2002). About 22% of global coastal wetlands lost globally, including those in Africa (Nicholls et al., 1999).
Global mean temperature rise (from pre-industrial)	**4°C**
Agriculture	All cereals decrease in crop productivity (IPCC WGII, 2007). Wheat yield in northern, southern and western Africa and western Asia reduced by 30-40% (Warren et al., 2006)[7]. Maize yield losses of 30-40 % in North and southern Africa, 20-30 % in West Africa (Warren et al., 2006)[8]. In Egypt, more than 4,000km² of cropland could be lost to flooding with 1m. sea level rise (Stern, 2006). Rice yield losses of 30- 40 % in North and southern Africa, and 20- 25 % in West Africa (Warren et al., 2006)[9]. Losses for mangoes, cashews and coconuts in Kenya could reach US$472.8 million (Republic of Kenya 2002, in Stern 2006). Net revenue for small-scale livestock farms up by 58 % (Seo and Mendelsohn, 2006) Net revenue for large livestock farms down by 35% (Seo & Mendelsohn, 2006) Net revenue losses of US$95.7/ha (Nkomo et al., 2007) Entire regions of South Africa could be out of production due to warmer and dryer average weather conditions(Hare 2003 in Stern 2006).
Health	Up to 7.2% increase in malaria transmission area and 18.9% increase in exposure (Warren et al., 2006 adapted from Tanser et al., 2003)[10]. Transmission area for Malaria could double in South Africa by 2100 (Republic of south Africa in Stern 2006). Increasing burden from malnutrition, diarrhoea, cardio-respiratory and infectious diseases. Increased morbidity and mortality from heat waves, flooding and droughts. 108 million at risk from flooding by 2080s (Parry et al., 1999). 128 million more people at risk from hunger by 2080s (Parry et al., 1999). 1m. sea level rise could put six million people at risk of flooding in Egypt (Stern, 2006).
Water	Irrigation requirements increased by 2070 (Doll, 2002).
Infrastructure	Increased damage from floods and storms. In Nigeria, 75% of total agricultural area threatened with 1m sea level rise (Awosika et al., 1993). 259 producing oil fields in the Niger Delta at risk of a 1m. sea level rise, costing approx US$11 million (French et al., 1995). Gambian capital Banjul could be submerged at a cost of about US$217 million because of a 1m. sea level rise (Stern, 2009).
Ecosystems	

5 Assumes no adaptation
6 Figures for exposure to and transmission of *falciparium* malaria. Does not take into consideration growth in population
7 Should CO_2 fertilisation not occur. If CO_2 fertilisation does occur, the losses are considerably smaller, only 3 per cent globally at worst.
8 Should CO_2 fertilisation not occur. If CO_2 fertilisation does occur, 20 per cent losses will result in North Africa, 22 per cent in southern Africa, and 19 per cent in West Africa.
9 Should CO_2 fertilisation not occur. If CO_2 fertilisation does occur, losses would still occur (no figures given).
10 Figures for exposure to, and transmission of *falciparium* malaria. Does not take into consideration population growth

2. Adaptation options

The options for how to adapt to climate change are generally informed by two distinct approaches:

- responding to the impacts of climate change, and
- reducing vulnerability to climate change.

Approaches that focus almost exclusively on responding to climate change impacts involve interventions that can lead to clearly identifiable outcomes. For example, this can involve relocating a community in response to sea level rise, or constructing a sluice gate to protect against flood.

At the other end of the spectrum are approaches that aim to reduce the vulnerability of people, animals, soils and infrastructure to climate change. These involve adaptation processes specific to the social, economic and political context in question. Community-based approaches to reducing vulnerability try to identify and address the role climate change plays in impoverishing communities. Adaptation strategies can then be developed aimed at reducing poverty, diversifying livelihoods and empowering local people to manage their own communities.

Successful national adaptation efforts require careful analysis and selection of both types of responses. These should be integrated into wider development programmes and implemented with support from additional funding resources (Brooks, 2003). Financing will be required to implement these actions, as well as for the costs of impacts that cannot be avoided. A holistic approach to adaptation should ensure that the resources and other means are available as compensation so that African governments and societies can reduce vulnerability to and address the impacts of climate change.

2.1 Guiding principles

A wide range of adaptation measures exist, but they should generally be guided by the following principles:

Increasing awareness and knowledge

It is critical to give people access to information about expected climate changes. This should also clearly explain the uncertainty involved in predicting future impacts.

Strengthening institutions

Adaptation should focus on strengthening formal and informal institutions such as government ministries, civil society organisations, community-based structures, and decision-making processes through building skills, knowledge, and the ability of people to form social networks, participate in climate change planning processes that involve all citizens and improving the ability of governments to design and manage budgets, and develop and enforce laws that protect vulnerable people and infrastructure. Strong institutions underpin development in any society, and are vital to support adaptation measures.

Protecting natural resources

Climate change poses a threat to ecosystems, biodiversity and any related economic activity. It's therefore important to find the right balance between adapting to the social, environmental and economic impacts of climate change.

Providing financial assistance

It is impossible to adapt to climate changes without financial assistance. Funding should be filtered effectively to reach those groups, individuals and organisations most suitably placed to identify and carry out the different work involved. Establishing micro credit funds is a particularly useful way of supporting the most vulnerable people.

Developing context-specific strategies

Climate adaptation must be rooted in evaluations involving local people assessing their own situations and needs. People who understand the local culture are best placed to develop appropriate and sustainable adaptation measures.

Facilitating local participation

All stakeholders – households, civil associations, businesses, the public sector, and especially populations who are at risk – should be involved in selecting and implementing adaptation strategies. This is vital for these strategies to succeed. Participation makes people feel empowered and can help communities develop and prosper.

2.2 Working with uncertainty

A climate scenario approach to identifying adaptation options can be problematic. Different models produce a wide range of different scenarios and may not represent a full range of future possibilities. Implementing adaptation options that rely heavily on climate predictions could lead to maladaptation if climate changes turn out differently from those forecast.

If there is high certainty around a future climate scenario, impact-specific measures can be implemented, such as constructing flood-proof housing. If certainty is low, implementing a robust adaptation – or so-called 'no-regret' – measures will be more appropriate. These generate net social benefits under all future climate change scenarios, focusing on reducing vulnerability while strengthening communities' capacity to adapt through sustainable development (Ensor & Berger, 2009).

2.3 Creating conditions for successful adaptation

For successful climate adaptation to take place, it is crucial to create the right conditions (Bapna et al., 2009). To support this process in Africa, several key activities can be identified.

First, more accurate information about climate change is needed throughout the continent (Bapna et al., 2009). Climate monitoring stations and early warning systems therefore need to be established. Expanding networks of skilled professionals who can undertake local, regional and national research into climate change and its likely future impacts in Africa is essential. Information about climate change should also be spread in ways that will reach everyone affected in a format they can understand.

Adaptation can ultimately only succeed if governments commit to designing and implementing their own National Adaptation Programmes of Action. Climate change concerns need to be integrated into national policies, prioritising the needs of the most vulnerable people and sectors.

In order for communities to benefit from national interventions, local and national capacity needs to be built. Everyone involved – governments, community structures, civil society organisations – needs to be able to communicate adaptation priorities effectively, and identify, assess, select and implement appropriate options for adaptation, including managing finance Good governance practices, such as inclusiveness, accountability, responsiveness, fairness and accessibility should underpin these processes (Foti et al., 2008).

It is equally important for future decision-making to be informed by existing climate knowledge and traditional adaptation strategies (Ensor and Berger, 2009). Finally, potential adaptation measures should be piloted before full-scale adaptation takes place.

All of these activities are necessary in the immediate term, but they should also form part of long-term climate change adaptation processes. As such, they are 'no-regrets' actions – applicable and beneficial to a range of future scenarios.

2.4 Agriculture

Current evidence suggests that Africa's agricultural sector will be particularly sensitive to future climate changes and an increasingly variable climate. Farmers in some areas could benefit from longer growing seasons and increased yields. However, the general consequences for African agriculture are expected to be negative, unless appropriate adaptation measures are implemented (Mendlesohn et al., 2000).

Variable water supplies, soil degradation and recurring drought could exacerbate the effects of climate change and force large areas of marginal agriculture out of production (Mendlesohn et al., 2000). These pressures could lead to intensified agricultural land management and expansion of land areas used for farming.

Despite these concerns, there is little qualitative information available about how severe the impacts will be. Climate models do not always concur and cannot accurately project changes at regional and local level. Selecting appropriate adaptation options will depend on local conditions, and addressing impacts at the local level will be crucial (Ziervogel et al., 2008).

African farmers and fishing communities have developed their production systems to cope with a changing climate over thousands of years. These strategies will be increasingly challenged by the new dynamics of climate change. Increases in population and environmental degradation will put additional pressure on food production. Additional factors include population pressures and a degraded resources base.

Poor and marginalised farmers will struggle most to cope with, and respond to, these new conditions. Like everyone else, they will need financial and technical resources to adapt, including access to farming technology and improved infrastructure such as climate information, research, good roads and access to energy (Mendlesohn et al., 2000).

Where seasons are shifting, crop planting and harvesting can be realigned at very little cost to the farmer (Nhemachena et al., 2006). However, this approach is only likely to succeed where overall rainfall is either increasing or likely to remain constant. In areas where warmer temperatures and increased rainfall variability are expected, switches to more resilient crop varieties are needed, such as drought-tolerant and early maturing maize and high-yield seeds. Likewise, rainwater harvesting and improved soil management represent other near- and medium-term (20-30 years from today) adaptation measures (ISDR, 2008).

Participatory research into piloting and monitoring different crop varieties' performance will be crucial. This will ensure that farmers understand the limitations of different seeds and that future farming practices remain flexible to changing climatic conditions (Ensor and Berger, 2009).

Adaptations to cope with water stresses during droughts and high rainfall variability include irrigation water transfer, water harvesting and storage (Nkomo et al., 2005, and Osman et al., 2005). Reducing water consumption through more efficient irrigation will reduce dependence on rainfall and the water that runs off from fields when the soil is infiltrated to full capacity. (Smith et al.,2006). Therefore, irrigation can both reduce water consumption and reduce the dependence of farmers on erratic water supplies.

Crop diversification can help to insure against poor harvests and promote local biodiversity and food security (FAO, 2008c). In particular, agro-ecological practices can help people to diversify their livelihoods and make local ecosystems more resilient (Ensor, 2009). Agro-ecology both draws on and replenishes natural resources by integrating biological and ecological processes, such as nutrient recycling and soil regeneration, into food production. It uses a range of sustainable management practices, including biological pest control, crop rotations and organic fertilisers and other measures. Planting a variety of crops side-by-side can significantly reduce plant pests and increase productivity. This is because a higher variety of plants foster a diverse range of microbes and animals that between them are able to regulate – to a reasonable degree – the spread of pests and diseases. This means that plants and animals are more able to flourish or recover from pests and diseases, leading to higher productivity in turn.

Some studies claim that organic farming produces higher crop yields than chemical-intensive farming. It can also lead to environmental benefits such as improved soil fertility, better water retention and resistance to drought. (Lotter et al., 2003, and Fleissbach et al., 2006). Importantly, agro-ecology helps to support a broad variety of species, habitats and soils, and a full range of microenvironments, which differ in factors such as soil, temperature, water, and fertility. Biodiverse ecosystems' inherent ability to withstand shocks and stresses – such as extreme weather events and drought – makes crop and livestock diversification easier. It ultimately enhances climate adaptation in food, fuel and fibre production (Ensor, 2009).

Ensor (2009) claims that highly intensive, chemical-based farming practices could increase yields in the short term. However, by fostering artificial environments, biodiversity is lost and the whole ecosystem becomes less resilient to climate impacts. Ensor therefore argues in favour of agro-ecological farming as an adaptive strategy for African nations. This approach could be promoted through government support in the form of credit for organic fertiliser and new seed varieties provided for smallholders at relatively low cost (Nhemachena et al., 2006). Investing ecosystem-based adaptation approaches represents a relatively low-cost option for African governments, given that it would enable around 70 per cent of the continent's population to adapt. This would also strengthen the resilience of a sector that currently contributes to 30 per cent of the region's GDP.

Just as improvements to seed varieties can enhance crop yields, similar selection methods can be used in animal husbandry. Options at the local level include creating nucleus herds for improved livestock breeding. This technique involves identifying the most healthy and resilient females and males, which are then selected for breeding stock and given special attention in terms of veterinary care, food and water. These animals are then used to build more resilient herds and flocks, and to rebuild stocks in times of drought.

Appropriate policy measures and institutional support could also strengthen African livestock farmers' capacity to adapt. This includes developing effective animal health services, disease control and prevention programmes, and monitoring and emergency preparedness systems (Van den Bossche & Coetzer, 2008). Livestock could provide an important option for smallholders if rainfall is reduced. In particular, farmers should be supported to invest in drought-tolerant goats and sheep, as opposed to climate-sensitive cattle and chickens (Van den Bossche & Coetzer, 2008).

Investment in agricultural extension services creates employment. It can also help farmers struggling against physical isolation and a lack of resources to access relevant information about climate change and adaptation options (Ensor and Berger, 2009). Farmer-to-farmer extension agents provide practical outreach support services, such as veterinary care and advice on agricultural practices, optimal sowing dates, pest identification and treatment, irrigation, etc. Women who are trained to fulfil these roles can achieve financial independence and gain more autonomy and decision-making powers (de la Torre Postigo, 2004).

In fisheries, ecosystem-approaches to aquaculture incorporate methods for harvesting fish stocks that promote conservation and sustainable farming of diverse domestic breeds in specially designed pools. These techniques are expected to be particularly effective for adaptation in Africa, given that they allow for selective breeding for higher temperature tolerance (FAO, 2008).

Aquaculture could also provide a suitable alternative livelihood option where agricultural productivity suffers due to salination resulting from sea level rises and seawater intrusion. If saltwater intrusion occurs, fishing communities will need support to move nurseries upstream or start cultivating plants and animals in saltwater. (FAO, 2008). Relocating breeding sites may also help to minimise damage and stock losses caused by extreme weather events.

In water stress situations, credit provision can help fishing communities to invest in faster-growing species, buy formulated and environmentally sound feed and move production to shared areas, such as rice paddies. Governments can also offer support by protecting habitats and setting up improved forecasting and weather warning systems. Other adaptation options include government assistance to diversify stocks and markets, or to develop alternative livelihoods to insure against future stock variability. Longer-term adaptation measures, such as stock management regulations, will also be needed to minimise the risks of over-exploitation (FAO, 2008).

African government policies need to support research and development of technologies to help farmers adapt to climate changes (Nhemachena et al., 2006). Government policy needs to create incentives for farmers to switch crops (Lewandrowski & Brazee 1993) and establish new, especially local markets for new crops to facilitate adaptation strategies (FAO, 2008c).

2.5 Ecosystems

Ecosystems are important to the human race because they provide services such as decomposing waste or producing clean drinking water, simply by virtue of their existence. Adaptation options aimed at making ecosystems more resilient to future climate changes must focus on conservation and sustainable use of natural resources. They should preserve a viable diversity of genes, species, and ecosystems within terrestrial, freshwater, or coastal ecosystems. This is especially important for ecosystems that are inhabited and used by people.

Adaptive strategies must be based on a comprehensive understanding of the drivers and stresses that shape land use and the links between biodiversity, ecosystem function and services, and human well-being.

Rehabilitating and protecting natural resources are a priority in climate adaptation. This requires approaches that cut across different sectors and boundaries. These include:

- new conservation and land use agreements
- legislation and regulations, and
- stricter enforcement of laws to protect forests and animals.

Widespread reforestation – including of mangroves along coastlines – is also key to replenishing topsoil and protecting water resources, rehabilitating coastal dunes, and restoring degraded vegetation. However, stricter enforcement of environmental protection laws must be carefully balanced with the local people's needs to maintain their livelihoods (Leary et al., 2007).

In areas where pressures on existing biodiversity have been identified, industries must be regulated and required to invest in rehabilitating natural resources. Due to the urgency and scale of action required, considerable financial investment, political commitment and regional cooperation will be key to implementing and sustaining these measures.

Promoting sustainable, alternative livelihood options in rural communities is a relatively low-cost and complementary approach to adaptation. This should include building communities' capacity to manage sustainable natural resources and promoting agro-forestry and agro-ecology.

2.6 Health

Rebuilding public health infrastructure has been identified as 'the most important, cost-effective and urgently needed' adaptation strategy (IPCC, 2001). Organising prevention and control measures for disease exposure and transmission are also key adaptation strategies for the health sector in future climate scenarios (McMichael et al., 2003).

Health sector adaptation strategies should not be considered in isolation from broader public health concerns, such as poverty, population growth, nutrition, sanitation and environmental degradation. Government ministries responsible for health, infrastructure, agriculture and the environment need to collaborate in order to meet future challenges posed by a variable climate and extreme weather events (McMichael et al., 2003).

Disease surveillance and vector-control should be carried out at the local, national and regional levels, alongside staff training, deployment and expertise. Treatments and preventative efforts, such as distributing medical supplies and mosquito nets, are also important. Lower-cost adaptation actions include community education and awareness-raising of exposure to and transmission of diseases and prevention measures.

Health education campaigns and investments in infrastructure and technology such as warning systems, improved water supply and sanitation and storm shelters can also help reduce disease transmission (IPCC, 2007). Any new chemicals or treatments for vector controls must be non-toxic and should not break down quickly in the environment.

Governments and local authorities should also establish disaster prevention and post-disaster management plans to ensure minimal loss of human life if disaster strikes (McMichael et al., 2003).

Issues of fairness need to be addressed nationally and internationally to help Africa adapt to climate change (Grambsh & Menne, 2003). This means securing access to cheap generic drugs and new vaccines to treat diseases. It also involves concerted efforts to retain health professionals and increase poor people's access to health care. Overall, Africa will need considerable external funding in order to ensure that its health sector can cope with current and future pressures.

2.7 Water

As Africa's population is set to increase rapidly throughout the 21st century, coping with variable water supplies, increased water stress, risk of flooding and a need for increased food production poses a particular challenge for the continent.

Integrated Water Resource Management could be a particularly suitable approach for Africa, given that its water supplies transcend boundaries and are host to a range of competing uses and demands. This approach recognises that different uses of water are interdependent and must be considered together. To meet the challenges of managing water supplies that cross national boundaries, African countries that share river basins must find mutually acceptable ways of managing cross-border water basins. To ensure fairness, countries will need to draw up legal arrangements between them (Magadza, 2000).

A variety of low-cost techniques, such as harvesting rainwater, establishing shallow wells for the extraction of groundwater for irrigation and water impounding basins to store water all offer potential local adaptation options. Local associations of water users can promote community participation and empowerment, and help reduce potential future conflict (Leary et al., 2007). Such measures will be most needed on savannahs and in arid areas where rural populations are expected to become more vulnerable to water stress. In many parts of rural Africa, exploiting groundwater sources could provide rural communities with reliable, good quality water supplies (Goulden et al., 2008).

Impact-focused adaptation strategies include improving infrastructure for storing and distributing water, such as:

- constructing new dams, reservoirs and pipelines
- flood control
- drainage
- irrigation schemes
- repairs to minimise leaking and evaporation.

Additionally, transfers between different water basins, improved water-management, removing levees to maintain flood plains, rehabilitating watersheds through reforestation, and protecting waterside vegetation can also contribute to managing sustainable water resources in a range of possible future climate scenarios.

Regulations and technologies for controlling land and water use, as well as incentives and taxes that could include charging for water use or waste or tax breaks for water efficiency and planning for drought, will also play an important part in future adaptation efforts (Magdza, 2000).

Before implementing any one strategy, all adaptation planning processes must consider the range of livelihoods and ecosystems that depend on the water sources in question. For example, reducing downstream water flows can have extremely damaging impacts on fisheries and farms that are miles away.

Some western countries have implemented water pricing and marketing schemes such as charging for water use as an adaptation strategy for reallocating water resources efficiently (Warren et al., 2006). However, these approaches could result in water being diverted away from communal use if water from communal resources is bought up by private companies. Economic reforms that constrain sectors that are large water consumers such as certain manufacturing industries and mining could be more appropriate, and go hand-in-hand with legislation to improve access for the poorest people (Leary et al., (2007).

2.8 Settlements and infrastructure

Sea level rises, temperature increases and more frequent and intense extreme weather are expected to negatively affect infrastructure and settlements across Africa, particularly in coastal and low-lying areas.

Previous sections of this report have already touched on some adaptation requirements and options for improving infrastructure in specific sectors. More generally, long-term interventions that incorporate available climate change information into their design and planning processes will be vital to ensure future sustainability.

Existing infrastructure will need to be adequately reinforced and new investments made into building and improving bridges, roads, transport, energy, health, agriculture, water and sanitation facilities (Smith et al., 1996). To guide these processes, climate risk screening guidelines and better standards for building, planning, land and water use will need to be developed (World Bank, 2006b).

A key investment area should be upgrading climate change monitoring systems and expertise and extending them into underserved areas (UN-HABITAT, 2008). Shoreline defence structures and flow regulators in coastal embankments could help protect vulnerable coastlines. However, these should if possible not be built to the detriment of coastal ecosystems and local livelihoods (IPCC, 2007).

For human settlements, improved planning and building regulations, flood-resistant housing design, water, sanitation and drainage will be key. Disaster warning systems and robust management plans could also help minimise the impacts of extreme weather in the future (Magdza, 2000). Addressing land and settlement problems that lead to the poorest urban residents inhabiting high-risk land, such as flood plains, must also be resolved (McGranahan et al., 2007).

In order to help the energy sector adapt to future climate conditions, the following are needed:

- A critical review of current and future energy supply and demand;
- Energy sector reforms;
- Developing on- and off-grid solutions for scaling up electricity production to include new renewable energy sources;
- Increased technology transfer to developing countries;
- Innovative financing mechanisms that will increase access to funding to match the scale of investments (UN, 2008).

Offshore wind, wave and tidal energy technology could provide new sources of energy, taking care to avoid damage to aquatic resources. Watershed management practices such as agro-forestry, erosion control and livestock management can protect and enhance hydro potential (Harrison and Lindquist, 1995).

Adaptation to climate change is not technologically neutral. Decentralised off-grid renewable energy technologies have considerable potential for giving Africa's rural populations fair access to energy. These include:

- solar photovoltaic
- small and micro hydropower
- biogas digesters and gasifiers
- small wind turbines, and
- biofuels from non-food crop sources.

These technologies could also improve an area's adaptive capacity and reduce the risk of natural disasters (The South Centre, 2008).

Access to energy provides many development benefits, such as poverty reduction, better health and more economic opportunities (Practical Action, Briefing Paper) Renewable energies can also promote gender equality by reducing the burden on women to collect firewood and other types of biomass to carry out household chores and generate income (Muchiri, 2008).

Reducing the need for using biomass for cooking, heating, and so on significantly reduces deforestation. This improves soil fertility and water drainage, and reduces the risk of flooding. Electricity can be used for pumping deep groundwater through wells, thereby improving access to clean water. It can also power sterilisation and refrigeration for vital medical supplies in rural health centres (The South Centre, 2008).

Adaptations such as improving existing infrastructure, new designs and construction are expensive, and will require external financial support. However, developing off-grid decentralised renewable energy supplies is a cost-effective way of increasing access to energy in rural areas. It also provides an appropriate solution for a continent where a centralised system would struggle to reach everyone.

Off-grid options such as micro-hydro, solar panels and wind turbines can also help progress towards the MDG on energy access (Practical Action, Briefing Paper). In terms of large-scale energy provision, the African Development Bank (2008) proposes interconnecting integrated national power grids and fuel bulk supplies regionally and between countries, as a way of meeting future energy demands in urban areas. Government policy can support improved energy efficiency through regulation and financial incentives (UN, 2008).

2.9 Security and conflict

Scarce resources, vulnerable livelihoods, poverty, migration and weak states are all factors that affect conflict and security in Africa within the climate change context (Barnett and Adger, 2005).

Peace building, crisis response and recovery programs all need to make climate change part of their design and policies. They also need to minimise their work's environmental impact. Adaptation activities that emphasise spreading information about climate risks and early warning systems could help to prevent conflict. Likewise, adaptation could contribute to longer-term peace building in conflict-prone areas by building up local communities' capacity to adapt, for example, by managing water resources together and improving general resource management (Brown et al., 2007). All of these options represent either no- or low-cost adaptation strategies.

Any process of planning, selecting and implementing adaptation measures should include maximum participation from all stakeholders. Particular efforts should be made to include vulnerable and excluded groups in decision-making processes to minimise social and political tensions. Explicitly addressing power relations – such as gender equality, social justice and human rights – and promoting equal and fair access to resources and services, should underpin all adaptation strategies (Wijeyaratne, 2009).

2.10 Tourism

Adaptation options for the tourism sector largely reflect those outlined in previous sections regarding water, ecosystems, settlements and infrastructure. Other measures to be considered include:

- efficient water and energy use, such as rainwater storage tanks and renewable energy supplies in hotels
- conservation measures
- land use, such as landscaping design in resorts, which can help reduce run-off and water use in areas where water supply will be uncertain
- new regulations for the number of tourists allowed to visit particularly vulnerable areas
- the types of tourist activity allowed.

Tour operators may be required by government regulation to redirect holidaymakers away from areas that are vulnerable and suffering from climate change impacts. Introducing tourism 'eco-taxes' would provide additional funding for adaptation measures, but may prove controversial with customers and the industry itself as prices could increase considerably for the use of natural resources and waste disposal. Governments can build the tourism sector's adaptive capacity by strengthening communities' and authorities' knowledge, resources and skills in developing and managing ecotourism. This can help diversify local livelihoods and raise finance for conservation (International Ecotourism Society, 2007).

2.11 Summary of adaptation options against proposed scenarios

The following section sets out different adaptation actions against the 1.5°C, 2°C and 4°C global mean temperature rise scenarios. However, adaptation is a process and the individual measures should be seen as part of an entire range of options that will need to be implemented according to local conditions, and not depending on magnitude of temperature rise. This report simply attempts to highlight which options are likely to be required in greater force at which stages.

Information about adaptation strategies does not attempt to link adaptation actions to specific temperature scenarios. This is because any adaptation must be highly context-specific. The recommendations set out below cannot account for local conditions. The adaptation options presented can therefore only be as general as the possible impacts set out in the previous chapter.

Given the degree of uncertainty regarding future impacts of climate change in Africa, approaches that build adaptive capacity and resilience are recommended above all else. This is because these are 'no- regrets' activities that will be beneficial across a varied range of potential future climate scenarios (Ensor and Berger, 2009).

2.11.1 A temperature rise of 1.5°C

The estimated impacts of a 1.5°C rise in global mean temperatures above pre-industrial levels are described in section 1.2.2 above.

Biodiversity is key to food production in Africa and ecosystems are highly sensitive to temperature rises. Any immediate adaptation actions must therefore prioritise rehabilitating and protecting biodiversity.

Stricter enforcement of environmental and animal protection laws, and issuing penalties to polluting and high resource-consuming industries is strongly recommended. Regional agreements will also be crucial for ensuring cross-continent commitment to preserving ecosystems.

Promoting agro-ecological food production will minimise environmental degradation and maximise crop productivity in order to meet the continent's future food requirements. It can also reduce malnutrition rates and limit climate change and human impacts on ecosystems.

It is possible to support smallholders through micro-credit schemes, improved seed varieties and organic fertilisers that are drought-tolerant and high-yield. Access to appropriate technologies for developing irrigation systems and training in soil and water management techniques will also make a difference.

Supporting livestock farmers to move towards drought-tolerant livestock, such as goats and sheep, will make their livelihoods more resilient. Animal health and technology support could be provided by extension services such as mobile health units.

Export industries should be encouraged to shift to more sustainable food production practices. Fossil fuel-intensive chemical inputs should be regulated, and payment and compensation schemes established to ensure that water and natural resources are distributed fairly among commercial and subsistence farmers. Reforestation schemes would complement these measures, and help improve water supplies during droughts and periods of variable rainfall.

It will also be necessary to improve infrastructure for storing and distributing water, particularly in areas likely to suffer most from water stress, such as northern Africa. Measures could also be taken across the continent in anticipation of future water shortages. A range of possible options exist for this, including repairs to reduce leakage and evaporation in water supply systems, extending rainwater harvesting technologies and rehabilitating degraded watersheds through tree planting.

Given the estimated magnitude of future water stress, larger-scale measures such as constructing new dams, reservoirs and pipelines may also be necessary. Some of these will need to be developed across national boundaries. Establishing local user associations to manage water supply and demand could mitigate potential future conflicts. These organisations would be particularly useful in rural areas already suffering from drought and variable rainfall.

Improved climate monitoring and early warning systems will be needed to help build resilience to extreme weather events. Governments should develop comprehensive disaster prevention and response plans. Building improvements into existing infrastructure or relocating existing coastal infrastructure and developing guidelines for future constructions are also recommended to minimise climate risks.

Health services should be strengthened to cope with anticipated increases in vector-borne disease transmission in certain areas. This includes investing in educational programmes and disease surveillance systems, training and retaining medical staff, and developing drug supplies and preventative measures. These all represent 'no-regret' adaptation options that will strengthen the sector's resilience in a 1.5°C mean temperature increase and above. Highland and upland areas should prepare for future disease transmission through local capacity-building and investment. Health outreach work in rural areas should receive particular attention.

Investment in decentralised off-grid renewable energy for rural areas is highly recommended, given its multiple social, economic and environmental benefits – ranging from reduced deforestation to improved health. Policy frameworks for energy efficiency and expansions to on-grid electricity provision would extend these benefits.

2.11.2 A temperature rise of 2°C

The estimated impacts of a 2°C rise in global mean temperatures above pre-industrial levels are described in section 1.2.3 above.

In addition to the actions set out under the 1.5°C rise scenario, a warming of 2°C could further reduce agricultural productivity in some regions. Supporting the agricultural sector through drought resilient crop varieties, fertilisers and farming technology measures, such as irrigation, could help increase crop productivity in some areas (Eid et al., 2006).

Farmers should also receive support to diversify their livelihoods toward drought-resilient livestock and aquaculture. Additional water stress may need to be addressed by large-scale adaptation measures such as transferring water sources and exploiting groundwater supplies.

Unless coastal protection measures can be successfully applied, intense and frequent flooding in coastal areas could force some populations to move away from coastal and low-lying areas.

Conflicts could occur because of food, water and natural resource shortages. Any planning and implementing of adaptation strategies should therefore include particular efforts to identify and mitigate potential future conflicts. Conflict should also be met with appropriate peace-building and resolution measures.

Renewable energy options could continue to improve poor people's lives, where wind and water supplies would not be detrimentally affected. Investments in energy efficiency and on-grid extension could support industry and urban populations.

A full range of adaptation options would continue to build important capacity in the health sector. Biodiversity rehabilitation and conservation efforts would need to be scaled up and tighter regulations brought into force for the use of natural resources.

2.11.3 A temperature rise of 4°C

The estimated impacts of a 4°C rise in global mean temperatures above pre-industrial levels are described in section 1.2.4 above.

As limited data is available for the expected impacts of climate change, setting out suitable adaptation options under a 4°C scenario becomes problematic.

In addition to the options set out under the 1.5°C and 2°C scenarios, strengthening the agricultural sector's resilience will be crucial in a higher temperature scenario. Without adaptation measures, the productivity of staple crops could be significantly reduced. As with a 2°C rise, crop productivity in higher temperature scenarios of up to 4.3°C could be increased with appropriate irrigation measures (Eid et al., 2006).

Agro-ecological food production could be feasible and appropriate, depending on local conditions, with production methods being refined as conditions change. In some regions, sea level rises associated with a 4°C temperature rise would flood vast areas of some African countries (see Table 2). Unless coastal protection measures can be applied successfully, industries, infrastructure and human settlements will need to be relocated.

It is clear that as temperatures rise, Africa's ability to adapt to climate change will be severally challenged. For lower temperature rises, adaptation options include low cost 'no-regrets' approaches. But as the temperature rises towards a 4°C increase, large-scale, high cost measures will probably also be necessary.

Implementing low-cost adaptation measures provides many groups with important benefits, including better access to basic services, more secure land and asset ownership rights, promotion of indigenous knowledge and practices and poverty reduction. Such measures should be prioritised accordingly.

For a temperature rise over 4°C, low-cost adaptation methods may be less effective (Parry et al., 2005). It is therefore vital for African governments to design and implement National Adaptation Programmes of Action (NAPA), and for developed countries to commit to providing the funding required.

3. Economic cost assessments

3.1 Background

Since the developed world has contributed the vast majority of atmospheric global GHG concentrations, it should be responsible for providing a significant proportion of the financial support needed for climate change adaptation.

The costs to African countries and societies of climate change include:

- The costs associated with actions taken to avoid or minimize the negative effects of climate change
- The direct costs associated with actual effects of climate change (e.g. direct costs of increased natural disasters, changes in production and so on; and
- The indirect costs associated with actual effects of climate change (e.g. broader social and economic costs, lost opportunities for development

The relative costs of climate adaptation under the different scenarios set out in this report are discussed in Chapter 4. However, they do not necessarily correspond with the actions set out in Chapter 3. As will be shown, current estimates of the economic costs of climate change are largely focussed on top-down approaches and do not account for the breadth of potential strategies set out in Chapter 2.

The economic costs of climate change for Africa and the additional costs and benefits of adaptation are uncertain. However, assessments are in progress and these indicate that climate change is likely to lead to potentially very large economic costs for the continent. **The cost figures set out in the report are therefore only partial estimates.**

Africa therefore needs high levels of adaptation finance. Developed countries should commit to providing substantial funds for its climate adaptation efforts, in addition to existing development aid. Given the large potential climate impacts and finance flows involved, it is crucial for African nations to put pressure on developed countries to make such significant mitigation and funding commitments at the Copenhagen meeting. Furthermore, any future international deal – including financing mechanisms – must suit Africa's specific needs and promote equity and efficiency.

There is evidence to provide indicative estimates of potential economic climate change costs for Africa, and its potential adaptation funding needs. These include:

- outputs from highly aggregated economic models
- estimates of investment and financial flows (IFF) based on enhancing the climate resilience of projected investment, and
- estimates based on regional, national or local assessments.

The 2009 AdaptCost Africa project funded by the United Nations Environment Programme (UNEP) provides a critical review of these methodologies and includes new analyses that have also produced a range of estimated potential costs. The following chapter provides a short summary of the AdaptCost study findings, as well as research into national and local case studies. The AdaptCost Briefing Papers are aimed at the African Ministerial Conference on the Environment (AMCEN) meeting in October 2009.

It is highly probable that the figures produced by all the assessments outlined in this study underestimate the actual economic costs incurred by Africa as a result of climate change.

Much of the data used are based on simplistic assumptions and do not incorporate the complete extent of likely damage and adaptation needs, such as widespread loss of life and livelihoods. Not all sectors are included in the analyses – extreme events are left out, future climate mark-up values are approximate, and some figures are based on assumed economic growth and development. Economic losses due to depleted natural resources are not included either, as they would not be straightforward to calculate in monetary terms.

With regards to adaptation analysis, to date no study has incorporated the costs and benefits resulting from adaptation actions. The focus tends to be on hard adaptation measures such as infrastructure construction and investment protection, with little allowance made for costs generated by community-based and driven approaches to adaptation.

Nonetheless, these studies do provide estimates for Africa's additional adaptation financing needs that can help policymakers and civil society focus on a collective target during the Copenhagen negotiations in December 2009.

As further studies with more depth and scope are carried out, the figures for economic costs estimations are highly likely to rise. Any lobbying of developed countries at the meeting in Copenhagen should reflect this likelihood.

3.2 National and local case studies

One study into the economic costs of climate change in Namibia estimates that the expected climate impacts on the country's natural resources will cause annual losses of between one and six per cent of GDP (IIED, 2007). Livestock production, traditional agriculture and fishing are expected to be hardest hit, with a combined loss of US$461-2,045 million per year.

Researchers involved in this study brought together a panel of experts on climate change and its impacts on the country's different sectors. The panel reached a consensus on the parameters of climate change impact, which was then quantified by IIED's economists.

This study does have a number of significant limitations. It does not include any suggested responses to climate change, even autonomous adaptation, and therefore represents a partial and static view of change. This is compounded by the fact that the model does not factor growth productivity – the value of goods and services produced – into the sectors, or the wider economy. The study does not take account of future improvements in agriculture such as irrigation, improved crop varieties, and improved agricultural practices, or reduced vulnerability due to development, and so on.

The socio-economic losses caused by a sea level rise of 0.5m in Egypt's Port Said Governorate is estimated at US$2,250 million by another study into climate impacts in the Nile Delta (OECD, 2004). In Alexandria, which is home to about four million people and the base of 40 per cent of Egypt's industrial activities, a sea level rise of 0.5m would inundate about 30 per cent of the city's entire area. The economic costs of such an impact are estimated to be in the range of US$30 billion. Coastal adaptation would cost upward of US$1,687 million in Port Said and US$2,000 million in Alexandria.

Another report commissioned by the Organisation for Economic Co-operation and Development (OECD) estimates the economic costs of damage to port cities from flooding, storm surge and high winds caused by climate change. It indicates that in Alexandria alone, US$563.28 billion of assets could suffer damage or be lost because of coastal flooding alone by 2070 (Nicholls et al., 2007).

The Centre for Environmental Economics and Policy in Africa (CEEPA) has undertaken a number of studies into the economic costs of climate change for agriculture in Africa. These studies assess losses and gains under a variety of scenarios across the region, using temperatures from 2006 as a baseline. Under projected 1.5°C and 3.6°C mean temp rises, the climate change effects on per hectare net farm revenue in Egypt are reduced when heavy machinery is introduced into farming methods. When irrigation is improved, net revenue per hectare increases significantly (Eid et al., 2006). Table 2 shows these impacts under figures converted to a pre-industrial baseline.

Table 3: Net revenue per hectare under 2.3°C and 4.4°C global mean temperature increase scenarios (Adapted from Eid et al., 2006)

Adaptation scenario	Net revenue/ha	
	+2.3°C	+4.4°C
Total (without) adaptation	-US$1,453.41	-US$3,488.18
With heavy machinery	-US$1,116.67	-US$280.01
With irrigation	+US$39.26-226.44	+US$94.21-543.46

Cameroon's economy is highly dependent on rain-fed agriculture. Here, a 14 per cent reduction in rainfall is predicted to cause the biggest losses, up to around US$4.65 billion. A seven per cent reduction in rainfall will reduce the country's net revenue by six and a half per cent per hectare (Molua & Lambi, 2006).

In Ethiopia, marginal temperature increases in winter and summer will reduce net farm revenue by US$997.7 and US$177.6 per hectare respectively. Increased rainfall will also negatively affect net revenues (Deressa, 2006). Similar results were found for Zimbabwe, where a 2.5°C increase in mean temperature (equivalent to 3.3°C with a pre-industrial baseline) would decrease all net farm revenues by US$0.4 billion. Importantly however, farms with irrigation would experience an increase in net revenue of US$0.3 billion (Mano & Nhemachena, 2006).

An important policy message from these findings is that climate change is damaging to African farmers and that investment in improved water management will be a successful adaptation option.

In Africa, National Adaptation Programmes of Action (NAPA) provide country-level estimates of adaptation costs. These have been developed through consultations with all stakeholders and on the basis of local assessments. On average, NAPA estimate adaptation costs to total around US$5-20 million per country, per year.

The main advantage of NAPA assessments is that they reflect local adaptation needs that have not been captured by top-down studies. They can therefore help guide prioritisation of future adaptation interventions. Their main disadvantages are that their estimates only represent immediate needs, and that their methods for arriving at final figures are unclear (AdaptCost, Briefing Paper 2 and Briefing Note 3, 2009).

A number of other studies into the economic cost of climate adaptation will report later in 2009, too late for inclusion in this report. These focus on Kenya, Tanzania, Rwanda, Burundi, Ethiopia, Mozambique and Mali.

National and local case studies provide some useful material that can be added to the context studies of different sectors covered below. However, these analyses tend to cover limited scenarios and are usually associated with a business-as-usual scenario. Yet they do provide information about which sectors and areas are most vulnerable to climate changes, and thus about the distribution of climate change-related economic costs in Africa.

3.3 Investment flow analysis

Investment and financial flow analysis is a top-down approach used for calculating approximate global or continental costs for safeguarding future investments against climate impacts for up until 2030. This is known as climate proofing or climate resilience.

These studies provide only a partial analysis of the likely costs facing Africa from climate change. They focus principally on the costs associated with avoiding adverse impacts in certain sectors while ignoring or understating costs associated with climate related damages as well as broader economic and social costs and impacts.

The first of these analyses was a 2006 World Bank study, which focused on the global scale. Adaptation costs were calculated by first identifying infrastructure investments vulnerable to climate risk. A mark-up percentage was then added to represent the additional costs involved in reducing that risk. This study produced a total estimate of US$9-41 billion per year for adaptation to take place in all developing countries.

This study was then taken up by the United Nations Framework Convention on Climate Change (UNFCCC). It went on to split costs by sector, using a more detailed approach. Total investment flows to developing countries were estimated to be between US$28-67 billion per year by 2030, representing 39-57 per cent of projected total global financial flows to Africa.

The African Development Bank used the World Bank figures to estimate climate proofing new investments in Africa to a cost of US$2-7 billion per year (van Aalst et al., 2007). Using the information presented by the UNFCCC, the 2009 AdaptCost study has derived cost estimates for Africa of $7-10 billion per year.

Key criticisms of these figures focus on the emphasis placed on vulnerabilities in the infrastructure sector. They also argue that a lack of consideration is given to supplementary adaptation funding, or to the additional adaptation activities needed to support interventions in agriculture and other sectors.

A more recent study by the International Institute for Environment and Development (IIED) and the Grantham Institute for Climate Change highlights several problems with the UNFCCC's methodology (Parry et al., 2009). As a consequence, the results underestimate the final figures produced by a factor of between two and three. Other problems include the omission of some sectors, including ecosystems, energy, mining, manufacturing, retail, and tourism. There is also a lack of consideration for 'adaptation deficit' – Africa's low resilience to current climate extremes – which would need to be addressed at a cost of US$61 billion per year (IIED, 2009).

The potential costs of adaptation finance needed for Africa increases from US$12 billion to US$28 billion, based on the implications of the IIED/Grantham findings on the UNFCCC (2007) figures, including climate proofing any adaptation deficit. The AdaptCost study suggests that these figures need further reviewing (AdaptCost, Briefing Paper 2 and Briefing Note 3, 2009).

Figures from the UNFCCC study were supplemented with adaptation cost estimates in the Stockholm Environment Institute's briefing for AMCEN in 2008. It was split into four categories:

1 Assessing vulnerability (building on assessments contained in NAPA);
2 Building institutional capacity (climate information, skilled professionals, and so on);
3 Piloting adaptation strategies;
4 Operational adaptation (needed to cope with new hazards and conditions).

These estimates produce a total annual adaptation cost of US$1-2 billion by 2012, rising to US$3 billion by 2030 for Africa.

Additional costs to be considered include those obtained from the 2009 International Strategy for Disaster Reduction report (ISDR, 2009), which estimates costs for disaster response and humanitarian aid at US$10-15 billion per year for Africa.

These figures are highly uncertain. As noted above, one study commissioned by OECD has estimated that assets valued at over half a trillion dollars in one city (Alexandria in Egypt) alone could suffer damage or be lost because of coastal flooding. **Nevertheless, Africa's adaptation financing needs relating to the cost components identified above are likely to reach a minimum of US$10 billion a year by 2030, up to as much as US$30 billion a year. The expected cost of other components – including actual damages associated with loss of lives and livelihoods, extreme events, and economic losses requires further analysis**

3.4 Integrated Assessment Models (IAM)

In the context of climate change, 'integrated assessment' is used to describe the integration of a number of climate change impact sectors, and often economics too, within a single analytical model.

These integrated approaches include global integrated economic assessment models, such as the PAGE and FUND models. The former is also used in the Stern Review. These combine the scientific and economic aspects of climate change in a single analytical framework. The advantage of these models is an additional element in which climate impacts feed back into the socio-economic module, thereby linking emissions, climate modelling, climate change impacts and the economy.

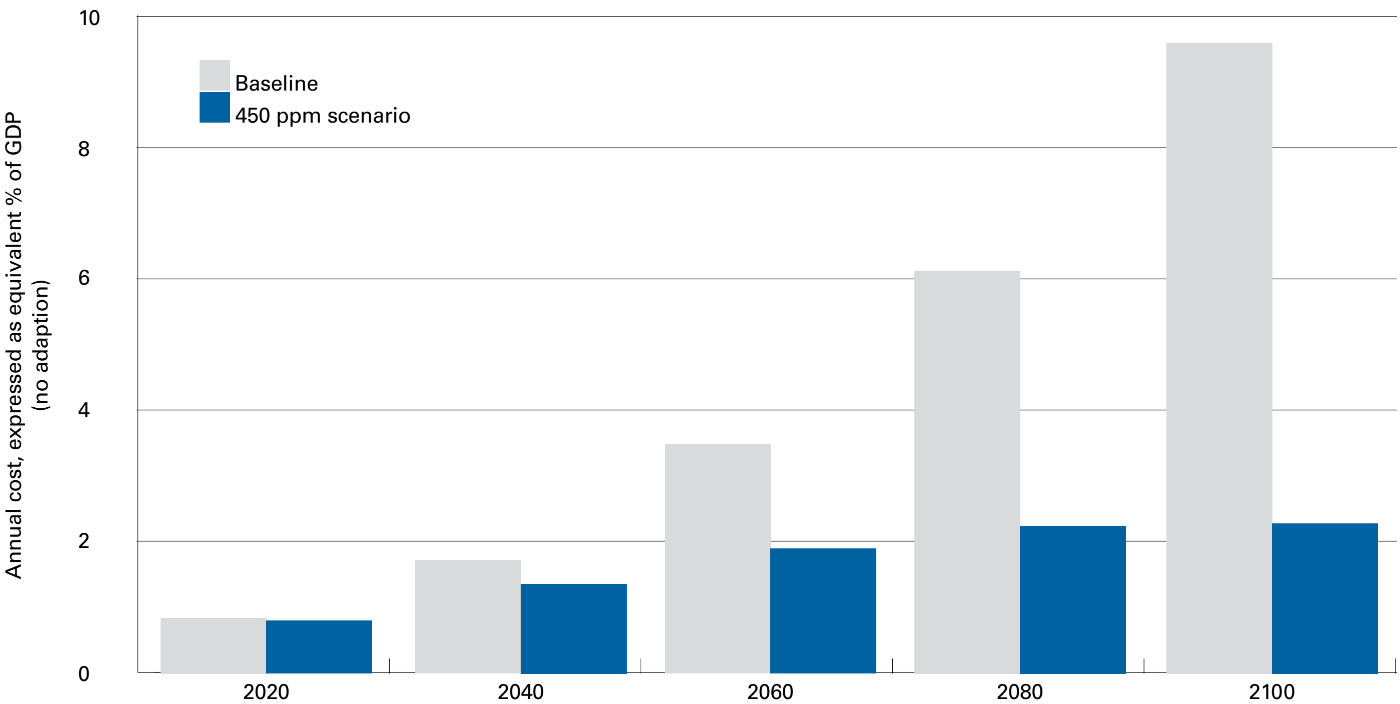
These models also provide headline numbers that can immediately convey the impacts of climate change in economic terms, such as the percentage of GDP-equivalent loss. The models' main disadvantages are that they are technically complex to construct, often cover a limited number of impacts and linkages, and that the method used to achieve the result is not always transparent (AdaptCost, 2009).

Recent work undertaken as part of the AdaptCost study funded by UNEP[11], has commissioned integrated assessment modelling runs for Africa. While the results from these models are uncertain, they indicate that the economic costs of climate change in Africa could equal an annual GDP loss of 1.5 – 3 per cent by 2030 under a business-as-usual scenario. The costs could rise rapidly beyond this time, though results vary with the model. As an indication, one model (the PAGE model, used in the Stern review) indicates that these costs could rise to almost 10 per cent of GDP lost by 2100.

The AdaptCost study has also modelled the economic costs of a scenario in which carbon dioxide or equivalent levels are at 450 ppm (parts per million). It is likely that this would lead to an average temperature rise of around 2°C greater by 2100. The Intergovernmental Panel on Climate Change (IPCC) estimates that a 450ppm scenario is consistent with a 50% chance of keeping below two degrees, although recent science, such as work by NASA scientist Jim Hansen, indicates that the atmosphere may be more sensitive to carbon dioxide or equivalents than previously believed. Assuming only a 2°C rise, the PAGE model estimates that the economic costs of climate change in Africa would fall from the 1.5 – 3% of GDP by 2030 down to around 1% of GDP by 2030.

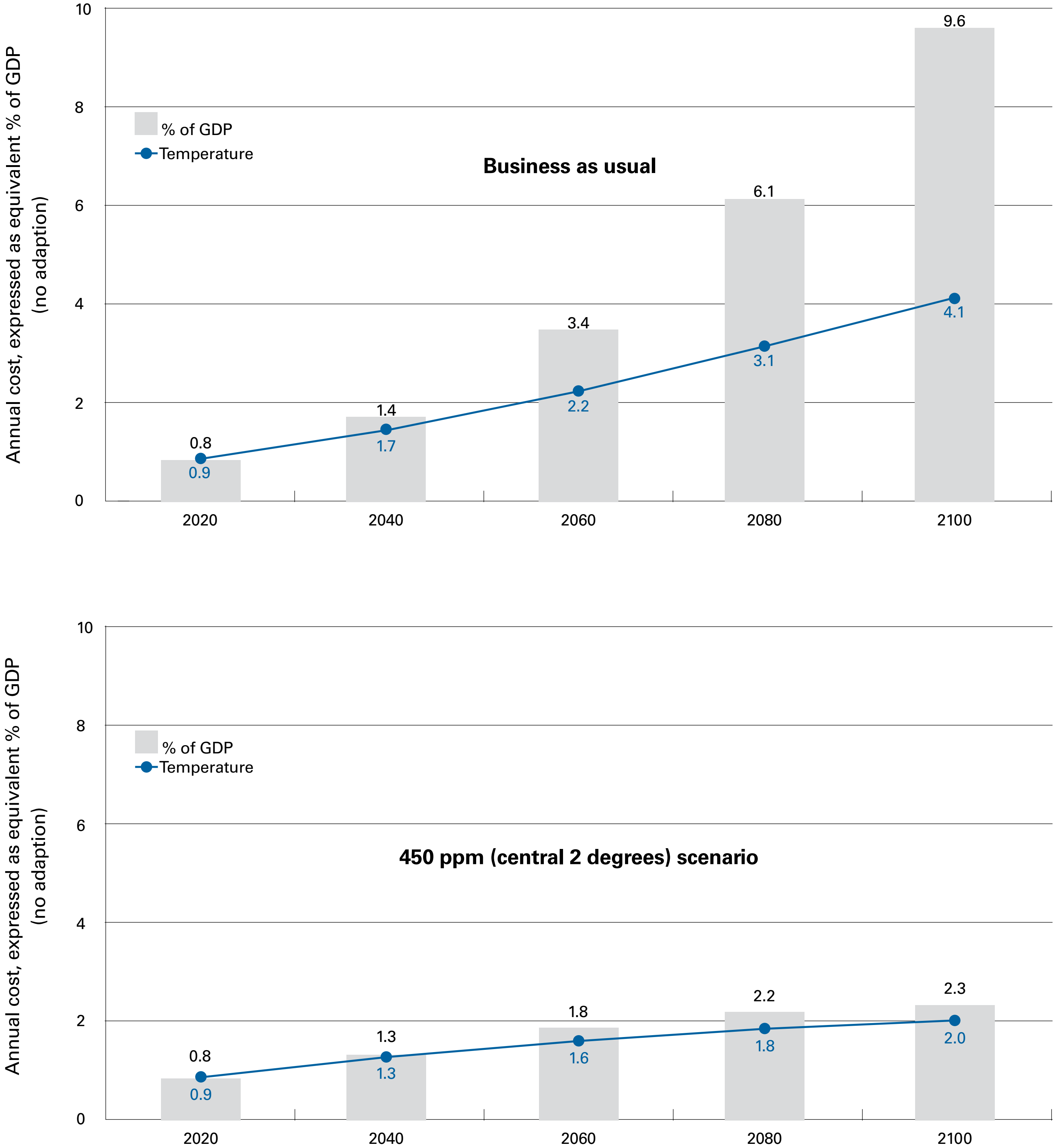
However, the real benefit of the 450 ppm scenario is in limiting the potentially much higher costs in the longer term through to 2100. The mean economic annual costs reported under the business-as-usual scenario from the PAGE model (annual costs equivalent to just under 10% of GDP by 2100), fall to an estimated 2.3% of GDP under the 450 ppm scenario. This dramatic reduction is due not just to reduced damages in the economic and non-economic sectors, but also owing to the reduced probability of large-scale major climatic events. Note that these results are produced by one IAM only and other models give different results.

Figure 10: Mean annual economic costs in Africa, expressed as equivalent % of GDP, no adaptation (PAGE Model. Source: AdaptCost Briefing Paper 2: Integrated Assessment Models – Africa results, 2009)



11 Note that the results do not necessarily represent the official views of the sponsors.

Figure 11. Mean economic costs per mean temperature, expressed as equivalent % of GDP (no adaptation) for baseline (top) and 450 ppm (bottom) (PAGE Model, AdaptCost Briefing Paper 2: Integrated Assessment Models – Africa results, 2009)



The mean economic costs from climate change in Africa from the PAGE model for the baseline and 450 ppm scenarios are shown below in Figure 10. Note that these costs do not include adaptation.

The relationship between mean economic costs and mean temperature is shown below from the PAGE model in Figure 11.

- Under the business-as-usual scenario, the PAGE model predicts mean average global temperature of 1.5°C by just after 2040 (with economic costs equivalent to 1.7% of GDP for Africa) and then, as mean temperature rises to 2.2°C by 2060, economic costs rise to the equivalent of 3.4% of GDP for Africa. By the end of the century, with a mean temperature rise of 4.1 degrees, the economic costs are equivalent to just under 10% of GDP for Africa.
- Under the 450 ppm scenario, temperature levels are similar in 2020 and early periods but rapidly diverge after 2050. The PAGE model estimates mean average global temperatures of 1.6°C by 2060 (with economic costs equivalent to 1.8% of GDP for Africa). Temperature levels only rise slowly over the rest of century. As mean temperature rises to 2°C by 2100, mean economic costs rise to the equivalent of 2.3% of GDP for Africa.

In the short-term (2030), the difference between the scenarios is not very large – it is only in the longer term (post 2050) when significant differences emerge.

There are currently no models focusing on temperature rises being limited to 1.5°C above pre-industrial levels. This is because to date, studies have been conducted on the premise that such a limit cannot be met. Global average temperatures have already increased by 0.8°C since pre-industrial levels (Hansen, 2006), and historic emissions therefore commit the world to more than a 1°C increase from pre-industrial levels.

Some insights can be achieved into the possible economic costs of lower temperature changes by looking at information in the runs above in Figure 11. Technically it is not possible to read directly off the curves for an alternative scenario, because economic costs are a function of the population and economy which change over time. Nonetheless, both figures indicate that, based on the PAGE model outputs, limiting temperature change to 1.5°C could limit annual economic costs to the equivalent of around 1.7% of Africa's GDP. This is not a very large reduction from the 450 ppm scenario. However, the real benefit of a lower temperature limit is the reduction in the risk of major events or tipping points.

The AdaptCost study has run some adaptation scenarios through the PAGE model. These give preliminary indications that adaptation could reduce annual costs of climate change in Africa significantly below the figures above[12]. Under both scenarios (business-as-usual scenario and the 450 ppm scenario), adaptation is estimated to reduce the costs of climate change by around one third: the remaining economic costs are known as residual damages. Under the business-as-usual scenario, this still leaves very significant economic costs for Africa. For example, this is equivalent to around 6% of Africa's GDP by 2100 under the business-as-usual scenario. Under the 450 ppm scenario, adaptation reduces down the mean economic costs to the equivalent level of around 0.5% of Africa's GDP in 2030 and 1.5% of GDP by 2100, thereby further reducing down the (relatively) low economic costs. This demonstrates the need for mitigation as well as adaptation to reduce down the economic costs of climate change for Africa.

3.5 Main findings

A number of estimates have been made for the costs of climate change adaptation for Africa. These are based on investment and financial flow analysis and integrated assessment models (IAM). Based on a critical analysis of these assessments and new analyses using IAMs by the AdaptCost study, and highlighting the very high uncertainty in these figures, an indicative estimate of the potential economic costs of climate change for Africa is 1.5-3 per cent of GDP by 2030. The potential adaptation financing needs to address this are also highly uncertain, **though they are likely to be a minimum of US$10 billion a year by 2030 for Africa, and could reach as much as US$30 billion a year.**

Only the IAMs commissioned by the AdaptCost study have generated figures that can provide indicative estimates of the different levels of economic costs in relation to temperature changes. These show how economic costs increase with temperature rises along a given scenario, and provide a very approximate indication of how economic costs might change with 1.5°C, 2°C and 4°C rises in global mean temperature above pre-industrial levels (without adaptation). However, they do not provide information for scenarios that limit temperature to these levels under a stabilisation policy.

Table 4: Annual costs of climate change in Africa, as an equivalent percentage of GDP (AdaptCost, 2009)

Temperature rise	Year reached	Economic costs (per cent of GDP)
1.5°C	2040	1.7 per cent
2°C	2060	3.4 per cent
4.1°C	2100	10 per cent

This is only one model, however, and other models project different increases over time, with lower economic costs against a similar temperature profile.

12 The analysis assumes adaptation investment of around $4.5 billion a year to Africa. The model shows high benefits compared to costs from adaptation.

4 Mitigation scenarios

As United Nations (UN) negotiations in Copenhagen approach, the urgency of achieving a robust outcome for tackling climate change is becoming more pressing.

Current discussions about climate change science within the European Commission and G8 show support for cutting global GHG emissions by at least 50 per cent below 1990 levels by 2050. They also aim to limit global average temperature changes to a 2°C rise above pre-industrial levels.

The temperature thresholds for large-scale disruptions to social and environmental systems – so called tipping-points – are not known for certain. However, a global mean temperature change of more than a 2°C rise above pre-industrial levels is associated with a higher probability of such events occurring. The best chance of avoiding such tipping points would be in keeping temperature rises as low as possible, and below 1.5˚C

The 2007 Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report indicates that to avoid a 2°C rise, global emissions must peak and begin to decline by 2015 at the latest. These must also be reduced by at least 50 per cent by 2050. However, a 50 per cent reduction in GHG emissions by 2050 would only give around a 50:50 chance of stabilising the global average temperature rise at 2°C.

Another briefing paper makes clear that the IPCC Fourth Assessment figures are now seen as very conservative in terms of the emissions reductions needed to limit average global warming to 2°C (Bill Hare for the Potsdam Institute for Climate Impact Research, 2008). The paper proposes that to limit the global temperature rise to below 2°C, the 36 industrialised countries and economies in transition listed in Annex 1 of the UNFCCC that signed up to emissions cuts under the Kyoto protocol (Annex 1 countries) will need to reduce emissions by at least 20-45 per cent by 2020 (relative to 1990 levels) and by at least 80-95 per cent by 2050.

In Africa, significant social and economic impacts have already been observed with the current level of warming (0.8°C since pre-industrial times) and the scientific evidence indicates will this further increase due to the current atmospheric GHGs concentrations. Due to this ambitious, quantified, legally binding GHGs emissions reduction commitments must be made by developed country parties of at least 45% below 1990 levels. This must be part of package, together with finance and technology transfer to support actions in developing countries, consistent with keeping global warming well below 1.5°C

The potential impacts and economic costs of climate change up to 2030 cannot be avoided by reducing emissions. These result from past emissions and are already locked into the climate system. They are likely to occur irrespective of any commitments made at Copenhagen to reduce emissions. To address the likely short-term impacts and costs of climate change in Africa, adaptation strategies and immediate financing are needed, with significant support from developed countries.

However, developed countries still need to commit to stringent emissions reductions in Copenhagen to meet the global targets above. Any delay will increase the challenges ahead, and the economic costs are likely to increase due to accumulating climate change damage. As the IPCC's 4th Assessment Report (2007) puts it:

"Mitigation efforts over the next two to three decades will have a large impact on opportunities to achieve lower stabilization levels in the long term (beyond 2030). (…) Delayed emission reductions lead to investments that lock in more emission-intensive infrastructure and development pathways. This significantly constrains the opportunities to achieve lower stabilization levels and increases the risk of more severe climate change impacts."

An alternative viewpoint is that technological advances will allow us to achieve the necessary emissions reductions more effectively in the future, and that there may be value in advancing research and development first before acting to reduce GHG emissions.

One study reviews ways of identifying GHG emissions trajectories, leading to recommendations about near-term reductions in emissions, such as by 2020, and long-term reductions, such as by 2050 (Goulder and Mathai, 2000). It considers the main factors affecting decisions about the timing of emissions reductions, and concludes that the total set of emissions trajectories that could be considered is very large (for more details, see Appendix 1).

4.1 Assessing proposed scenarios against likely costs and benefits

The authors of this report were asked to consider three scenarios for a possible agreed outcome in Copenhagen under the UNFCCC and its Kyoto Protocol, drawing on proposals currently under consideration. The three 'burden-sharing' scenarios, requiring different countries to take on different mitigation responsibilities are:

1 **Minimal commitment**: Annex 1 countries commit to minimal mitigation of less than 25 per cent from 1990 levels. They agree to provide US$10 billion a year in additional public finance for climate action in developing countries by 2020, 80 per cent of which is for adaptation. Developing countries do not take on any further mitigation commitments, although the Clean Development Mechanism (CDM) will continue to deliver limited finance to projects with limited benefits.

2 Inadequate commitment: Annex I countries commit to greater, but still inadequate mitigation of 30 per cent from 1990 levels. They agree to provide US$100 billion a year in climate financing by 2020, half for adaptation, half for mitigation, in line with current EU and G8 stated intentions. In exchange, developing countries commit to an unquantified reduction in greenhouse gas emissions. This could involve some spending on mitigation or implementation of adaptation strategies by developing countries or countries implementing 'no-regrets' options, i.e. measures such as energy efficiency, to reduce mitigation costs. A scaled-up CDM would deliver significantly increased finance to Africa, but again the spread and benefits of the projects will be limited.

3 Adequate commitment: Annex I countries agree to provide adequate mitigation of more than a 45 per cent cut by 2020. They decide to meet the full incremental costs of adaptation action in developing countries between now and 2020. Developing countries take significant mitigation actions but incremental costs are met. The CDM is not relevant to this scenario, given that developed countries will meet all the mitigation costs of developing countries, and will not rely on market mechanism. The CDM would therefore have no function as a source of finance for mitigation, and will effectively be abolished.

4.2 Scenario 1 – Minimal ambition

It is impossible to project the exact temperature change associated with any specific target reduction in 2020. The actual temperature outcomes are a function of the stock of gases released from today to 2050 and beyond, including by developing countries.

However, in order to provide very broad indications of what short-term emission reductions might mean in the context of similar longer-term emission reduction paths, this study has drawn on available information about broad classifications of different ambition levels, based on emissions reductions in 2050 relative to 2000 (Table 5).

Under this scenario only limited mitigation will take place and global emissions will not peak until after 2020. Global emissions are likely to rise to 10-60% over 2000 levels or higher, leading to temperature global mean temperature rises of 3.2-4.0 ˚C above pre-industrial levels.

4.2.1 Likely costs of significant climate actions taken by African governments

Under this scenario, significant climate actions taken by African governments will need to represent a complete range of adaptation strategies, as set out in Chapter 2. This will most likely include 'no-regrets' adaptation strategies and impact-focused measures.

The headline costs of these actions are uncertain, although recent estimates of adaptation financing needs have been prepared as part of the UNEP AdaptCost study (see Box 1 overleaf). These do not look beyond 2030, but it is likely that Africa's adaptation financing needs would increase.

Table 5: Classification of stabilisation scenarios and global mean temperature increases above pre-industrial levels by 2100, according to different concentration targets (Committee on Climate Change, 2008)

CO_2 concentration (ppm)	CO_2e concentration (ppm)	Global mean temperature increase above pre-industrial at equilibrium (°C), using "best estimate climate sensitivity"	Peaking year for CO_2 emissions	Change in global CO_2 emissions in 2050 (% of 2000 emissions)	No. of assessed scenarios
350-400	445-490	2.0-2.4	2000-2015	-85 to -50	6
400-440	490-535	2.4-2.8	2000-2020	-60 to -30	18
440-485	535-590	2.8-3.2	2010-2030	-30 to +5	21
485-570	590-710	3.2-4.0	2020-2060	+10 to +60	118
570-660	710-855	4.0-4.9	2050-2080	+25 to +85	9
660-790	855-1130	4.9-6.1	2060-2090	+90 to +140	5

Source: Adapted from IPPC Working Group III Fourth Assessment Table 3.5

Note: Equilibrium temperatures assume a climate sensitivity of 3°C and are different from expected global mean temperatures in 2100 due to the inertia in the climate system.

Box 1: Headline costs of adaptation in Africa (AdaptCost, 2009)

The UNEP sponsored AdaptCost project is investigating the economic costs of climate change adaptation in Africa, and reporting on these in the run-up to the Conference of the Parties 15 in December 2009. It reported on the existing evidence and presented draft estimates at the AMCEN meeting in October 2009. Draft estimates are presented below.

The study reviews the available evidence on the potential economic costs of climate change in Africa. While these estimates are highly uncertain, the available information indicates that the costs could be equivalent to 1.5-3 per cent of the continent's GDP per year by 2030. It notes that these costs are much higher than those projected for other world regions. This implies significant adaptation financing needs for the continent.

The estimates of immediate adaptation financing needs for Africa in the short-term, up to 2012, are reported in the study as a minimum of US$1-2 billion a year. This includes undertaking vulnerability assessments, building capacity, piloting adaptation, and tackling immediate hazards (based on SEI, 2008). These costs will rise in the future, possibly to US$3 billion per year by 2030.

In addition, the costs of 'climate proofing' investment in Africa has been estimated to be US$7-10 billion per year in 2030 (based on various estimates, including UNFCCC, 2007). However, this could be a significant underestimate for several reasons. Firstly, Africa currently has low resilience to climate extremes. To remedy this, an estimated US$3.1 billion will be needed per year (IIED, 2009). The additional cost of climate proofing new infrastructure is estimated at US$3-12 billion per year by 2030. Secondly, the potential additional costs for increasing disaster protection and humanitarian aid in Africa are estimated at an additional US$10-15 billion per year (Grantham, 2009).

Overall, the AdaptCost study reports that minimal financing needs of US$10 billion per year in 2030 are likely. Africa could need several times this amount if social protection and addressing the current adaptation deficit – the costs that Africa is currently bearing but for which it should be compensated – are also included. Upper estimates that include these categories are very uncertain, but could be in excess of US$30 billion, and potentially reaching $60 billion per year by 2030.

The AdaptCost study will be available at the AMCEN meeting in October 2009.

4.2.2 Potential flows of climate finance

Current OECD aid sees 40 per cent going to Africa. Under the minimal ambition scenario, Africa could expect to receive US$4 billion per year in additional public finance for climate adaptation by 2020.

Under this scenario, 80 per cent, or US$3.2 billion, of the total funding would be targeted at adaptation. This is extremely low in the context of Africa's urgent adaptation financing needs, as set out above.

The costs associated with existing African NAPAs total around US$0.5 billion alone. Extending this to African countries that are not categorised as Least Developed Countries (LDC), and adding the estimated costs of immediate adaptation, i.e. US$1-2 billion per year, would only allow for existing priorities to be met and not future ones.

Also, given that the additional US$10 billion would only be provided 'by 2020', based on the mitigation scenarios set out above, it is questionable whether sufficient funding would come on line in time for these estimated adaptation figures to remain valid. So, if funding did not come on line until 2020 then the cost of adaptation in Africa would be higher, given that the very limited efforts undertaken in the meantime would worsen the damages. The financing levels set out under the minimal ambition scenario would therefore not meet the estimated costs of making future investment 'climate resilient'. This could reach at least US$7-10 billion per year by 2030 and potentially much more (see Box 1 left).

In terms of financial flows from carbon markets, Africa can only expect to receive limited benefits if current mechanisms don't change radically. The CDM currently represents the primary market for carbon finance, followed by the secondary carbon market, or Voluntary Carbon Market (VCM). In 2008, only 1 per cent (US$7.05 million) of projects supplying voluntary emissions reductions (VER) credits to the VCM were in Africa. This market share has been declining steadily since 2006.

A lack of technical capacity and up-front funding are cited as two major obstacles to generating Voluntary Emissions Reductions (VER) in Africa. African VER credit prices have halved over the last year, contrary to the global average, and the voluntary carbon market shows little potential for providing significant climate finance (Hamilton et al., 2009).

By September 2008, there were just 27 approved CDM projects in Africa, representing 2.31 per cent of global market share (UNFCCC, 2007). The sale of Carbon Emissions Reductions (CER) from these projects is expected to generate around US$41.2 million by 2012 (CDM Executive Board, 2008).

According to a recent report, if developed country targets aim for a 25 per cent mitigation, carbon markets will only contribute to 15 per cent of developing countries' global financing needs through direct offset purchases, or up to 50 per cent with auction revenue and market intervention multipliers (The ClimateWorks Foundation, 2009). Current Annex 1 ambition is far lower than a 25% cut in emissions.

This would leave another 50-70 per cent of financing needs to other public and international funds. Given Africa's disproportionately small share in these carbon markets, it is unlikely that even 15 per cent of the continent's financing needs would be met. It will also be important to limit the amount of international offsets purchased by developed countries, to ensure that offsets do not become substitutes for delivering full domestic mitigation commitments (The ClimateWorks Foundation, 2009). This means the vast majority of Africa's climate finance needs will have to be met from international public finance.

There are other reasons why the CDM in its current form is not expected to increase low-carbon investments to Africa.

Given the continent's low emissions, few projects are able to generate the CER required to attract investors, and Africa has found itself sidelined in a market dominated by others.

The CDM doesn't currently provide for financial facilities such as up-front funding facilities and capacity building programmes. These would support Africa to build the specific capacities needed to attract financing from global carbon markets (Stern, 2009).

CDM procedures also need to be simplified, and practical methodologies developed to permit the bundling of credits, such as from small-scale renewable energy projects, quicker administration and validation procedures (COMESA, 2009).

At the same time, there is huge unrealised potential for carbon sequestration – the process of long-term storage of carbon dioxide or other forms of carbon – in Africa through sustainable land-use practices, such as forest management, agro-forestry and agriculture. These make up almost 60 per cent of the continent's mitigation potential (Stern, 2009) and could generate annual revenues of close to US$1.5 billion per year (World Bank, 2009).

However, many unresolved issues remain regarding how measurable and reliable soil carbon sequestration can be. It is also questionable whether finance from CDM projects (including carbon sequestration) would actually reach the African community, government, civil society or private sector structures who need it for their adaptation efforts. Until now, mostly large companies based in South Africa have managed to raise funding under the CDM and hardly any of the money supports development efforts.

Carbon markets need to be dramatically reformed if they are to provide socially responsible opportunities relevant for Africa. This could include provisions for up-front funding and approaches that allow small projects to be 'bundled' so that together they generate sufficient carbon emissions to qualify for carbon credits to enable Africa to attract carbon market finance (African Climate Appeal, 2009, and COMESA, 2009).

4.3 Scenario 2 – Inadequate ambition

As with scenario 1, it is not possible to map the exact long-term temperature changes associated with a 30 per cent emissions reduction by Annex 1 countries by 2020. However, it is possible to develop a broad indication by looking at alternative overall ambition levels.

Under this scenario, it is likely that Africa will have to adapt to higher temperature rises, given that reductions of between -30 per cent to +5 per cent, relative to 2000 emissions, are estimated to lead to global mean temperatures of 2.8-3.2°C above pre-industrial levels (see Table 5).

4.3.1 Likely costs of significant climate actions taken by African governments

Under this scenario, significant climate actions by African governments will need to focus on a complete range of adaptation strategies, as set out in Chapter 2. This will include 'no-regrets' adaptation strategies and impact-focused measures.

Estimates of potential adaptation financing needs for Africa by 2030 were outlined in Box 1 left. In practice, these will not vary much between scenarios, as the temperature change for this period is already locked into the system.

However, the financing needed for building in adaptation for increases after 2030 will vary significantly between the scenarios, and should be lower under a more stringent emissions reduction scenario.

4.3.2 Potential flows of climate finance

If US$100 billion a year is provided by Annex I countries, Africa could expect to receive a total of $40 billion a year. Half would be intended for adaptation and half for mitigation.

With US$20bn going towards adaptation, this would only meet the minimal requirements for adaptation funding according to the AdaptCost adaptation financing estimates (see Box 1 left). This sum would not meet the upper estimates of finance required to meet the costs of social protection (policies and programmes that aim to reduce peoples' exposure to risks by creating income earning opportunities) and the adaptation deficit (the current lack of investment required to reduce vulnerability to climate change). Social protection and adaptation deficit costs are not only related to climate change. They encompass measures that would be required for poverty reduction even in the absence of climate change.

With regards to mitigation, Stern (2009) estimates that incremental financing of around US$9-12 billion per year is necessary for low-carbon development growth in Africa by 2015. Between US$31-41 billion per year will be needed up to around 2030, in addition to Overseas Development Assistance (ODA). An additional US$15-90 million per country involved in forestry would be required to develop REDD capabilities.

The majority of these investments would need to be targeted at the forestry, energy and urban infrastructure sectors (Stern, 2009). Mitigation actions in forestry and energy could bring additional benefits for building adaptive capacity, such as reduced deforestation, and an improved health sector and water supply.

Although proposed funding streams under this scenario (US$20 billion per year for mitigation) would not fully meet these requirements, some significant spending could be undertaken towards low-carbon development. With a commitment to greater mitigations reductions, developed countries may start buying up more carbon credits and thereby increasing finance flows from carbon markets. However, adequate mechanisms would first need to be put in place, such as up-front funding provisions, capacity building and integration of an effective REDD regime.

4.4 Scenario 3 – Adequate ambition

As in the two previous scenarios, it is not possible to map the exact long-term temperature changes associated with a 30 per cent emissions reduction by Annex 1 countries by 2020. However, it is possible to develop a broad indication by looking at alternative overall ambition levels.

Under this scenario, it is more likely that Africa will have to adapt to lower temperature rises than in the two previous scenarios. It is only with this level of action that the possibility of keeping warming below 2˚C or lower exists. However global mean temperature rises are still likely to exceed 2˚C above pre-industrial levels, and will almost certainly exceed 1.5˚C, with the greater costs to Africa implicit in that.

4.4.1 Likely costs of significant climate actions taken by African governments

Under this scenario, significant climate actions by African governments would need to represent the full range of adaptation strategies, as set out in Chapter 2. This will include a variety of 'no-regrets' actions, including shifting to agro-ecological food production, strengthening the health sector, and restoring and conserving natural resources and animal populations. Some larger scale impact-focused measures may also be needed.

Estimates of potential adaptation financing needs for impacts in Africa in 2030 were outlined in Box 1. In practice, these will not vary much between scenarios, as the temperature change for this period is already locked into the system.

However, the financing needed for building in adaptation for increases after 2030 will vary significantly between the scenarios, and should be lower under a more stringent emissions reduction scenario.

Developing countries would be expected to take significant mitigation actions, the incremental costs of which will also be met between now and 2020. Mitigation actions are likely to focus on low-carbon development and 'no regrets' actions, such as energy efficiency and renewable energy in the power sector, carbon sequestration and sustainable land-use practices.

4.4.2 Potential flows of climate finance

This scenario assumes that all incremental adaptation costs would be met by developed countries. Based on the AdaptCost adaptation financing estimates (see Box 1), Africa would need to receive US$10 billion per year by 2030, although upper estimates could be in excess of US$30 billion. If the additional categories of social protection and addressing the current adaptation deficit are included, the total cost could potentially reach US$60 billion per year by 2030.

In relation to significant mitigation action taken by Africa, financing to meet incremental costs of US$9-12 billion per year would be needed for low-carbon development growth by 2015 and $31-41 billion per year in the longer term, up to around 2030. An additional $15-90 million per forestry country would be required to develop capabilities for REDD (Stern, 2009).

5. Recommendations

The recommendations in this report set out:

- key commitments African governments should seek to secure from the UNFCCC negotiations in Copenhagen in December 2009, and
- proposed policy changes that African governments can make in light of the climate challenge, and further research priorities.

5.1 Priorities for African governments under the UNFCCC process

Climate change is a critical issue for Africa and a global deal on climate change must reflect the region's interests.

Climate change and climate variability are already having serious impacts in Africa. Much of the population is suffering as a direct result of increased temperatures, changing rainfall patterns and sea level rises.

Future climate effects are expected to vary across different regions. However, the net impacts will be negative, particularly for the poorest and most vulnerable people. Africa includes some of the world's poorest nations. The continent also has a quickly growing population, and its natural resources are being depleted through environmental degradation. These factors are severely impeding Africa's ability to cope with, and respond and adapt to future climate changes.

A global deal on climate change must acknowledge the serious threat climate change poses to poverty reduction and sustainable development in Africa. At the same time, Africa must ensure that its voice is heard at the negotiations in Copenhagen. The continent must present a united front in pushing for immediate emissions cuts, significant adaptation financing and low-carbon development, and improved financing mechanisms.

Developed countries must make immediate and significant emissions reductions, and commit to cuts of at least 45 per cent by 2020 and 85-95 per cent by 2050 (relative to 1990 levels).

Developed countries have committed, on average, to emissions cuts of 15 per cent by 2020. This is likely to lead to a global average temperature rise of more than 4°C above pre-industrial levels, with significant impacts for Africa.

The continent's agricultural sector will be particularly hard hit, with serious knock-on effects on food production, malnutrition levels, and regional economic growth and development.

To minimise future climate change impacts on Africa, developed countries must adopt stringent policies to reduce emissions by at least 45 per cent by 2020 and 85-95 per cent by 2050, relative to 1990 levels.

Immediate entitlement to substantial adaptation funds for Africa must be secured.

Adaptation funding is not a question of aid: it is an international obligation. While the figures remain uncertain, the estimated potential economic costs of climate change for Africa is 1.5-3 per cent of its GDP by 2030.

Africa's potential adaptation financing needs to address these costs are also highly uncertain, but they are likely to constitute **a minimum of US$10 billion a year immediately, increasing to at least US$30 billion a year by 2030.**

Under the UNFCCC, developed countries are responsible for providing adaptation finance required by developing countries immediately through adequately structured financial mechanisms. African governments should be lobbying for this commitment at Copenhagen.

Global civil society is demanding that adaptation finance must be provided as a grant additional to ODA targets. A fair global climate agreement in Copenhagen will require developed countries to support developing countries in the form of public finance, for both adaptation and mitigation.

However, most developed countries actually intend to count providing climate finance towards the 0.7 per cent of Gross National Income (GNI) ODA targets. This would mean that climate finance from developed countries would come out of future aid budgets, leaving funds unavailable for tackling poverty and providing basic education or healthcare.

Any promise by developed countries to deliver public finances to support climate mitigation and adaptation in developing countries out of future ODA budgets is an empty promise, as it will merely shift priorities within future ODA budgets. However, this could happen – unless the Copenhagen Agreement clearly excludes this possibility.

Developed countries often agree that finance should be 'new and additional', but that is more likely to mean 'additional to existing flows of ODA.

Additional climate finance provided by developed countries in addition to those required to meet their 0.7 per cent ODA targets is essential for a number of reasons:

1 Climate change is an additional burden for developing countries already striving to reduce poverty and encourage urgent development. The goal of developed countries providing 0.7 per cent of their GNI in aid was agreed prior to any evidence about the impacts and additional costs of dealing with climate change. It did not therefore take into account the levels of financial support required to assist developing countries in mitigation and adaptation activities. For example, climate change now adds an 'adaptation premium' to the price of development, as climate change requires new investments in agriculture, greater social and private insurance provision, climate-proofing buildings and infrastructure, etc. These are the additional costs of adaptation. To now plunder aid budgets to pay for the top-up costs of adaptation will mean less money being available for development and poverty reduction. To argue against additional adaptation finance is to argue against development.

2 Funding for climate change adaptation and mitigation is fundamentally different to aid and development financing. It is not a matter of welfare and economic assistance for people who happen to be less well off than people in developed countries – it is essentially compensation for the effects of developed countries' pollution over the past two centuries.

3 Developed countries are already struggling, and failing, to meet their 0.7 per cent ODA targets. It is therefore unlikely that this target will be increased in the foreseeable future, if ever. If providing climate finance becomes a binding obligation under the Copenhagen Agreement, developed countries will have an incentive to shift ODA investments to mitigation and adaptation, at the expense of aid budgets.

4 If developed countries can count public finance for mitigation towards their ODA targets, they have an incentive to divert substantial amounts of ODA to advanced developing countries in order to tap into their mitigation potential. Substantial amounts of ODA would then begin to flow to advanced developing countries, excluding those that need development finance most, such as the Least Developed Countries.

5 If developed countries can count public finance for adaptation or mitigation towards their ODA targets, less ODA finance will be available for combating high levels of poverty in developing countries. Poverty was an underlying reason for high vulnerability to risks long before climate change became evident. ODA is urgently needed to continue addressing these prior levels of vulnerability, which result from historical underinvestment in development. That way, poor people can develop resilience to new pressures that ultimately will allow them to escape poverty. Diverting ODA for climate change purposes would result in a finance gap for addressing vulnerabilities that predate climate change. A recent study suggests that this could increase adaptation costs significantly – possibly by a factor of two or three (Parry et al., 2009).

6 Industrialised countries point out that, for example, adaptation is simply development in a hostile climate. Of course, adaptation interventions cannot be considered as separate to development on the ground. Projects to raise or diversify incomes, boost healthcare and education opportunities, and reduce vulnerability to new pressures will help people to develop and adapt. But while adaptation should be delivered in consistence with poverty reduction and development programmes, it does not follow that the funding for it should not be additional to ODA.

Carbon markets do not provide the public finance Africa needs to develop in a low-carbon, sustainable way: fundamental reforms of financing mechanisms are required.

Between US$510-675 billion between now and 2030 are required for low-carbon development growth in Africa. In 2008, Africa received less than 2.5 per cent of financial flows from international carbon markets. Representing around US$22 billion, the CDM is not providing the capital Africa needs to develop in a low carbon, sustainable way.

International negotiations must therefore agree alternative and innovative funding mechanisms to support low-carbon development in Africa. Significant public finance will be needed for clean development, and the CDM will need substantial reform if it is to play a role.

5.2 Priorities for African governments to implement nationally and regionally

African nations must establish common targets for demands on emissions cuts and adaptation financing.

To secure a fair international climate change deal post-Kyoto, African governments must establish common targets for demands on emissions cuts and adaptation financing. This should be supported by increased cooperation, between countries and across the region, on climate change challenges and resource requirements. Regional and national efforts must aim to improve current economic cost assessments and provide a fuller picture of the full economic impacts of climate change in Africa.

African governments must develop overarching climate change policies, plans and programmes targeted at poverty eradication and sustainable development.

African governments have a responsibility to their citizens to ensure that adequate plans for addressing current and future impacts of climate change are designed and implemented through consultation with all stakeholders. This should include implementing laws, policies and practices to support small-scale producers, and localised biodiverse, agro-ecological food production.

The influence of corporations that dominate Africa's agricultural input sector must also be regulated. Immediate and future financial support must reach the most vulnerable people and funding should be filtered effectively to those individuals, structures, and organisations most suitably placed to identify and carry out the different actions required.

Investments should be made into improving energy access for the poor through decentralised off-grid renewable energy schemes. These can bring many development benefits. Creating fair market opportunities and ensuring secure tenure and access rights for communities in poor and marginal areas will also be critical to tackling poverty under future climate conditions.

National Adaptation Programmes of Action must prioritise poor people and be underpinned by equity and justice.
The social distribution of climate change impacts is clear. Africa's most vulnerable people are already feeling the effects and will be hardest hit. Prevailing political and social systems also tend to disadvantage poor people, who typically have little access to, and influence over, decision-making processes.

These factors combine to limit poor and vulnerable people's capacity to cope with, respond and adapt to changes in the climate. Most poor people operate outside formal economies. Development that only focuses on economics therefore faces serious limitations in addressing climate change and poverty.

African governments must commit to developing adaptation policies that prioritise poor people's needs, actions for poverty reduction and sustainable development. Efforts to address power relations explicitly – such as gender equality, social justice and human rights – and promoting equal and fair access to resources and services must also underpin adaptation strategies.

5.3 Further research priorities

Improving climate modelling and forecasting in Africa.
Africa lacks both regional and local climate data. There is therefore an urgent need for improved climate modelling and forecasting on the continent, which can provide a basis for informed decision-making and the implementation of adaptation strategies.

Research priorities vary between regions. Some areas have an urgent need to increase the density of weather monitoring stations. The records that such infrastructure provides will form a good basis for improved future forecasting and climate models.

Other parts of Africa need to develop a culture of seasonal forecasting among researchers and scientists.

In most locations there is also another challenge – building relationships between forecasters and communities so that meaningful information can be applied to adaptation efforts. This is a real problem that involves building bridges between these different groups. Forecasting information should not only reach communities – it should, crucially, also be developed in partnership with communities, responding to their needs and integrating their knowledge.

Identifying and supporting Africa's adaptive capacity.
The development sector – and particularly NGOs – could be involved in researching, identifying and supporting the adaptive capacity of different groups, individuals and sectors in different social and political contexts across Africa. This research should include questions regarding the power relationships between groups, the protection of human rights, the role of social networks and the importance of government accountability and capacity.

The main aims are to assess or map information flows as a key element of adaptive capacity, and to understand what constitutes appropriate mechanisms for enhancing or addressing barriers to different information flows at different scales, for example within civil society networks or local forums. This can redress power imbalances across networks in favour of vulnerable communities.

Investigating potential changes in economic and social systems under climate change scenarios.

This report has not uncovered conclusive information about potential economic and social changes in the future under different climate change scenarios. While fundamental and rapid changes to these systems can be expected, this remains an area of uncertainty. This is particularly true in a 4°C average global temperature rise scenario.

Given that considerations of economic and social changes have not been accounted for in any cost assessments to date, the figures in this report are likely to be underestimates. Further investigation to try and understand what changes may occur to economic and social systems in order to estimate more accurately the likely costs of climate change is strongly recommended.

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