The Science of Climate Change in Africa: Impacts and Adaptation

Gordon Conway
Chief Scientific Adviser
Department for International Development, UK

February 2008

Summary

There is still a great deal about climate change in Africa that we do not know.

The African climate is determined at the macro-level by three major global drivers (the Inter Tropical Convergence Zone, The El Niño – Southern Oscillation and the West African Monsoon), but how they interact and how they are affected by climate change is poorly understood.

What we can be sure of is that global warming – expressed through higher sea and land surface temperatures - is affecting their outcomes, increasing the incidence and severity of the droughts, floods and other extreme weather events that they produce.

We also know:

- In general, the drier subtropical regions will warm more than the moister tropics.
- Northern and southern Africa will become much hotter (as much as 4-6ºC) and drier in the summer, with a much greater risk of drought.
- Wheat production in the north and maize production in the south will be adversely affected.
- In eastern Africa, including the Horn of Africa, and parts of central and western Africa average rainfall will increase.
- As a result, vector borne diseases such as malaria and dengue may spread and become more severe.
- Sea levels will rise, perhaps by half a metre, in the next fifty years with serious consequences in the Nile Delta and certain parts of West Africa.

But there is much that we don't know:

- The Sahel may get wetter or remain dry.
- The flow of the Nile may be greater or less.
- The overall fall in agricultural production may be very large or relatively small.

Part of our ignorance comes from a poor understanding of the drivers of the African climate. Part also is due to a severe lack of local weather data, particularly for central Africa. This lack of knowledge makes it very difficult to predict with any degree of accuracy what will happen as a result of climate change at a country, or even sub-regional level in Africa.

This relatively poor state of knowledge has two implications:

1. We urgently need more research, into the dynamics of the global drivers on the one hand and into the detailed consequences at local levels;
2. We need to design adaptation measures to cope with high levels of uncertainty.

In general the best assumption is that many regions of Africa will suffer from droughts <u>and</u> floods with greater frequency and intensity.

Adaptation thus depends on developing resilience in the face of uncertainty. The application of the concept of resilience is similar in many respects to the approach that has been long used in the face of natural disasters such as earthquakes and tsunamis:

- It begins with anticipation, surveying and forecasting,
- moves to developing preventative measures and increasing tolerance,
- and subsequently, after the event or events, focuses on recovery and restoration.
- Throughout the process is the importance of learning.

In general the more time and resources put into the earlier stages of this process, the better.

Most of the population of Africa already experiences a variety of stresses and shocks on a regular basis. In this sense, the impacts of climate change are nothing new. But the scale and, in some situations, the nature of the impacts will change dramatically as the pace of climate change increases. Greater investment in adaptation is needed now to respond to the changes that are already occurring.

To deliver such a package there needs to be more in research into, and support for, hazard mapping and long range forecasts and into the funding of research into drought and flood resistance and tolerance.

Resilience is important at both the national and local levels, involving not only technologies, but also appropriate economic policies and institutional arrangements. It is the poor who will be most vulnerable to the effects of climate change. To some extent the process of development itself will help them to adapt. If people are better fed and in better health, and have access to education, jobs and markets they will have the capacity to be more resilient.

Traditionally poor people have developed various forms of resilient livelihood to cope with a range of natural and man made stresses and shocks. But these may be inadequate in the future or may have been lost in the development process. The urgent need is for governments, NGOs and the private sector to work together to build up the resilience of the poor of Africa.

1. Introduction

Attempting to understand the effects of climate change on Africa is fraught with difficulties. While some things are known and relatively well understood there is still great uncertainty about the key climatic processes and their consequences. There is also much that is simply unknown. In this report I try to explain what the science tells us and what the implications for policy and action are. I will endeavour to do this in language that, hopefully, is accessible to the lay person.

First, it is important to recognise that Africa's climate is *naturally* both highly diverse and highly variable. It encompasses the extreme aridity of the Saharan deserts at one end of the range and the extreme humidity of the Congo rainforest at the other. Interacting with these natural patterns are the combined effects of anthropogenic global warming and human interference more generally. In most instances it is difficult or impossible to disentangle one cause of change from another.

For example, the countries of the Sahel have experienced many multidecadal periods of drought since the last glaciation.[1] We are in one such period now (Figure 1.1). Whether this current period is another natural episode or is the result of environmental degradation or of global warming we do not know. Probably it is a combination of these factors. What we do know is that global warming will exacerbate droughts such as these, increasing their frequency and intensity.

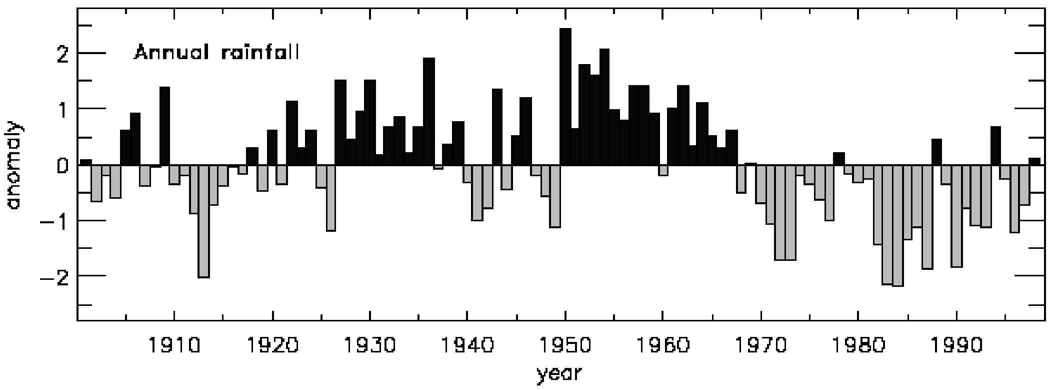

Figure 1.1 Annual rainfall anomalies representing the region 10º - 20º N; 25º W – 30º E, roughly corresponding to the Sahelian zone.[2]

Droughts or floods that last a few months can be highly destructive but when they last decades the effects can be devastating or even irreversible, at

1 Brooks, G. E. 1998. Climate and History in West Africa. In G. Connah (Ed.), Transformations in Africa: Essays on Africa's Later Past, pp 139-159. Leicester University Press, London and Washington.

2 Brooks, N. 2004. Drought in the African Sahel: long term perspectives and future prospects. Tyndall Centre for Climate Change Research. http://www.tyndall.ac.uk/publications/working_papers/wp61.pdf;

least in the short term. The current Sahelian drought has resulted in the Sahelian, Sudanese and Guinean ecological zones shifting 25-35 km further south with loss of valuable grassland, acacia, and other resources that the indigenous people rely upon.[3] One of the most severe consequences has been the Darfur conflict in the Sudan, which had its origins in clashes between pastoralists and sedentary farmers over depleted water resources (see Box 6.2 below).

2. The Global Drivers

Driving the African climate are three critical climate phenomena which are inter-related in complex and still not yet fully understood ways. These are the movement of the Intertropical Convergence Zone, the El Niño-Southern Oscillation and the annual alternation of the Monsoons. Each interacts with the other, determining regional temperature and rainfall regimes. Each, also, has its distinctive pattern that varies either within or between years. They are powerful forces that operate at a global level. Nevertheless it is not yet clear whether their patterns are significantly altered by global warming. What we can be sure of is that global warming – expressed through higher sea and land surface temperatures - is affecting their outcomes, increasing the incidence and severity of the droughts, floods and other extreme weather events that they produce.

The Intertropical Convergence Zone (ITCZ)

The ITCZ lies at the heart of the shifting seasonal patterns of rainfall north and south of the equator. Intense solar heating at the equator causes the sea surface to warm and the air above to rise leaving behind a low-pressure area, the ITCZ, known for centuries by sailors as the *Doldrums*. The rising warm, moist air results in heavy rainfall.

Over the oceans the ITCZ remains more or less at the equator but over land it moves north and south following the seasonal tilting of the globe towards the sun (Figure 2.1). Variation in its location results in the alternation of wet and dry seasons in the tropics. Most important, the movement of the ITCZ affects rainfall in southern Africa and the Sahel of western Africa (see Figure 1.1 above), particularly vulnerable regions because they have only one rainfall season each year. When the ITCZ does not migrate as far south as usual, droughts can occur in Southern Africa; when it migrates further north than usual it brings heavy rain and floods to the Sahel (as happened in 2007).

3 Gonzalez, P. 2001. Desertification and a shift of forest species in the West African Sahel. *Climate Research* 17, 217-228.

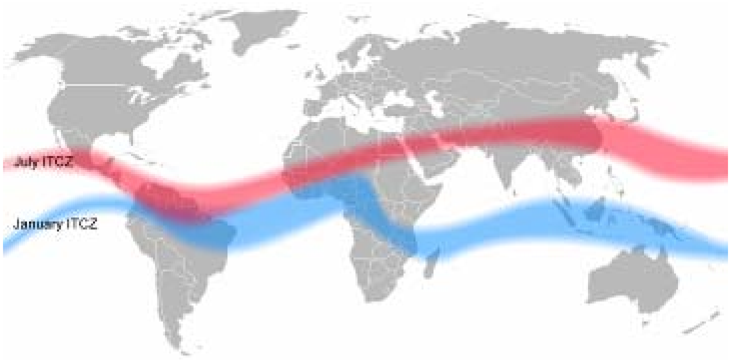

Figure 2.1 The position of the ITCZ in July (red) and January (blue).[4]

The El Niño-Southern Oscillation

Closely linked to the ITCZ is another climate driver known as the El Niño-Southern Oscillation (ENSO). In most years, the easterly trade winds that flow into the ITCZ push the warmed surface waters of the Pacific westward along the equator towards Southeast Asia. This results in the sea surface being higher, by about 1/2 metre, on the Indonesian coast than at the Ecuadorian coast and the temperature 8-10°C warmer. Rain, from the cooling of the rising warm air, falls in the west of the Pacific while the east experiences relatively dry weather.[5]

Sometimes, however, the pattern is reversed, with wide ranging consequences.[6] Every 3-7 years El Niño sets in and the easterly trade winds collapse or even reverse. The water of the western Pacific flows back eastward producing warm seas off the South American coast, but resulting in droughts in Southeast Asia and Australia. The phenomenon is called El Niño, the Spanish for 'the boy child,' because the warm waters have tended to arrive off the South American coast at Christmas time. La Niño, 'the girl child' is the more common phenomenon.

There are many theories as to why this oscillation occurs but there is no consensus of opinion. Recent models produced by the UK Meteorological Office provide fairly good short term predictions of the switchover between La Niña and El Niño, but they are complex, coupled atmospheric/oceanic models and there is no evidence of a simple, single cause.

There has been a tendency towards more prolonged and more frequent El Niños since the early 1990s. This appears to be unprecedented and has caused speculation that it may be a consequence of global warming (Figure 2.2). It is certainly plausible, since both phenomena involve large changes in the earth's heat balance. However, so far, there is no evidence to substantiate the connection.[7]

4http://en.wikipedia.org/wiki/Wikipedia:Graphic_Lab/Images_to_improve/Archive/Dec_2006#Climate

5 Glantz, M.H. (ed.) 2002 *La Niña and its Impacts: Facts and Speculation*. United Nations University Press, New York

6 http://www.pmel.noaa.gov/tao/elnino/nino-home.html

7 Trenberth, K.E. 2002. Climate change and the ENSO cycle; are they linked? In Glantz, op cit, pp 51-56

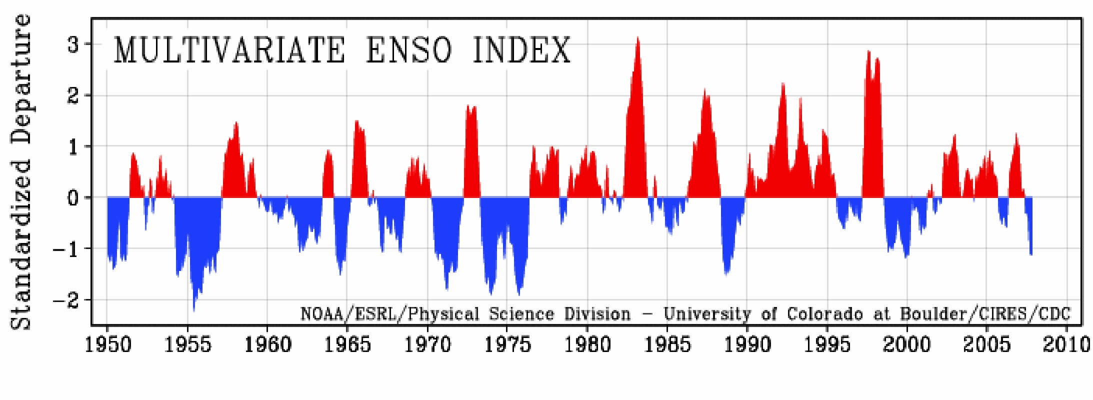

Figure 2.2 The alternation of La Niña (blue) and El Niño (red) events. (The Multivariate ENSO Index is based on six variables measured across the Pacific).[8]

Although ENSO is primarily a Pacific Ocean process, the effects are felt as far away as Africa and, indeed, in most regions of the world. Six months after an El Niño phase the global mean surface air temperature increases. In the tropics and sub-tropics this seems to be a consequence of the heat that is given up to the atmosphere as the water cools down in the La Niña phase. After the severe El Niño of 1997-98 the global temperature went up by over 0.2ºC[9]

During an El Niño year the December to February weather is wetter in eastern Africa but drier to the south, while La Niña produces the reverse. La Niña also produces cooler weather in West Africa (Figure 2.3).

The 1997/98 El Niño was one of the strongest of the 20th century. It caused droughts and forest fires in Indonesia and north-east Brazil, and catastrophic floods in east Africa. Among its many other effects was the extensive coral bleaching that occurred in the Indian Ocean and Red Sea and a massive outbreak of a *Paederus* rove beetle in Nairobi that caused severe dermatitis.[10]

The following La Niña of 1998-2000 brought devastating floods further north in the Sudan and Sahel, and in the south in Mozambique. The floods in the south were then followed by two major cyclones, which also appear to have been generated by La Niña.[11]

---

8 http://www.cdc.noaa.gov/people/klaus.wolter/MEI/
9 Trenberth et al. 2002 The evolution of ENSO and global atmospheric temperatures. *Journal of Geophysical Research*, 107, D8 10.1029/2000JD000298
10 Van Shayk, I.,Agwanda, R.O., Githure, J.I., Beier, J.C. and B. Knols, 2005 El Niño causes dramatic outbreak of *Paederus dermatitis* in east Africa. In Pak Sum Low (ed.) *Climate Change and Africa,* Cambridge University Press, pp 240-247
11 Obasi, G.O.P. 2005 The impacts of ENSO in Africa. In Pak Sum Low (ed.) op cit, pp 218-230; Vitart, F., Anderson, D. and T. Stockdale, 2003, Seasonal Forecasting of Tropical Cyclone Landfall over Mozambique. *Journal of Climate*,16, 3932–3945

La Niña El Niño

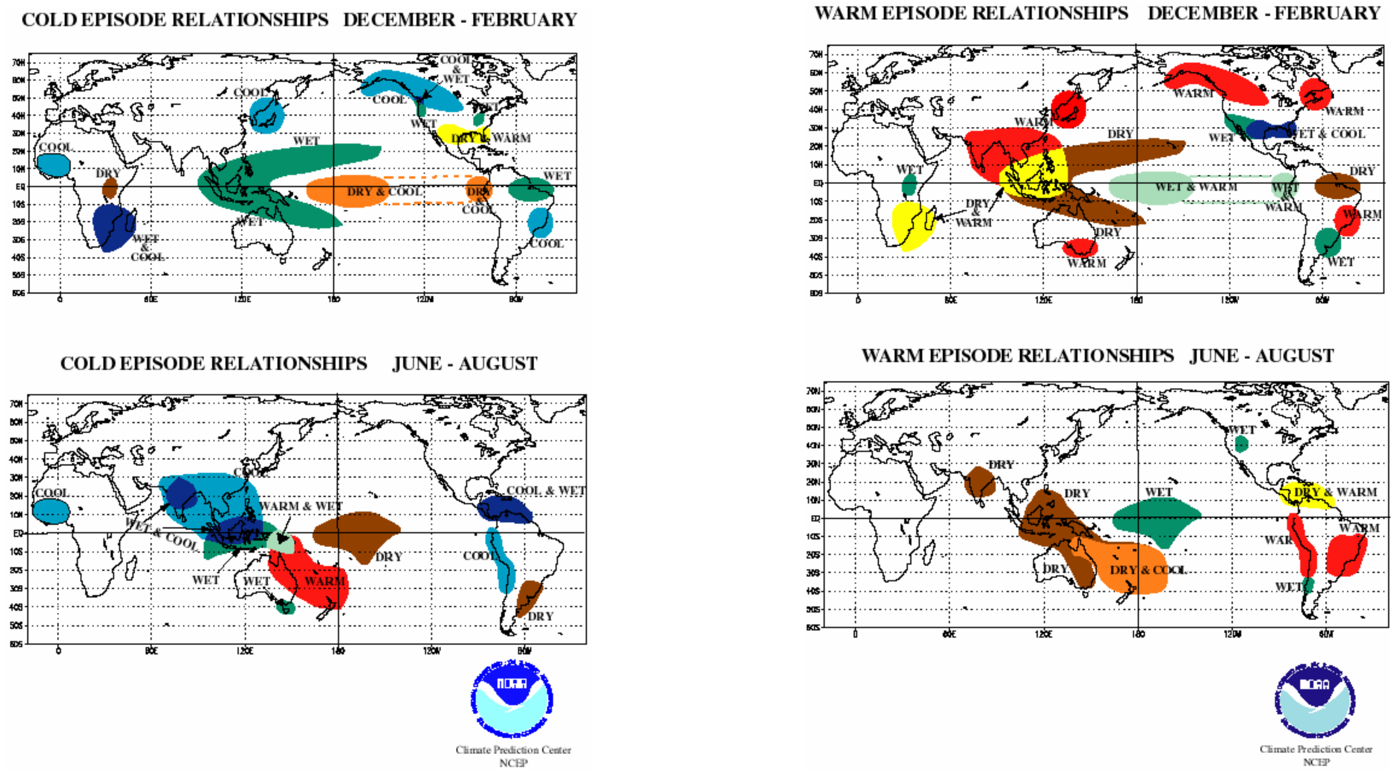

Figure 2.3 Global effects of the El Nino – La Nina phenomenon[12]

12 Glantz, op cit from www.cpc.ncep.gov/products/analysis_monitoring

The West Africa Monsoon

The third driver of the African climate is the West African Monsoon. In common with other monsoons it generates tropical and subtropical seasonal reversals in both the surface winds and associated precipitation. In simple terms, the monsoon occurs because land heats up and cools down more quickly than the sea. However the detailed dynamics are poorly understood.[13]

In the summer, the land becomes hotter than the ocean and as the air over the Sahara starts to rise, cooler, more humid air from the Atlantic Ocean is drawn in, 1000 km to the south. It brings rainfall from May to September in two phases (Figure 2.4). The first in April, May and June centres on the Gulf of Guinea (about 4ºN) and appears to be influenced by sea surface temperatures. Then suddenly, usually in early to mid-July, the rainfall maximum follows the ITCZ northwards into the southern Sahel (about 10°N) over a few days' time (Figure 1). So sudden is the event that it is called the "monsoon jump". The second phase apparently is influenced by easterly atmospheric waves (which are also associated with the ITCZ).

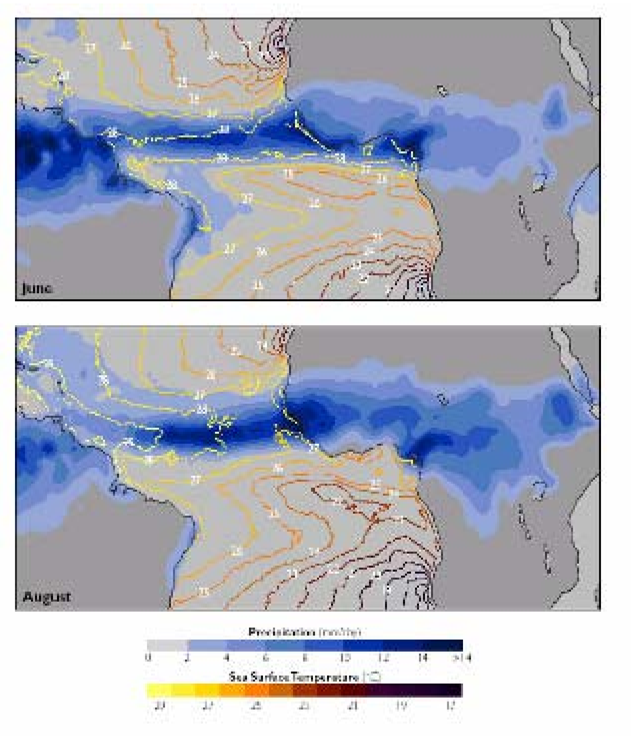

Figure 2.4 The two phases of the West African Monsoon[14]

When sea-surface temperatures are warmer in the South Atlantic than in the North, the monsoon is pulled south, causing the droughts that have characterized the Sahel in the second half of the last century (Box 2.1).

---

13 http://amma.mediasfrance.org/science/index
14 http://www.nasa.gov/centers/goddard/news/topstory/2004/0510africanwaves.html

Box 2.1. A hypothesis to account for the Sahelian drought[15]

The Sahelian drought provides an example of how the main climate drivers interact with one another and with anthropogenic change, including global warming.

In the 1970s the cause of the drought was attributed to systematic and irreversible land degradation and desertification caused by the farmers and pastoralists of the region. But subsequent studies using remote sensing have convincingly dismissed this hypothesis. Desertification has been mostly transient and land degradation plays a smaller although somewhat more complicated role.

The most convincing hypothesis today argues that during the second half of the 20th century the warming of the south Atlantic and the Indian Ocean in contrast to the cooling of the north Atlantic reduced the land-ocean temperature differential. This in turn caused the monsoon to weaken. The ITCZ and its associated deep convection migrated southwards so depriving the Sahel of rainfall.

There may also have been an influence of El Niño and a positive feedback loop involving the Sahelian vegetation (Figure 2.5). As the monsoon weakens, so less vegetation grows, the surface albedo (reflectivity) increases, reflecting back the solar radiation so further weakening the monsoon.

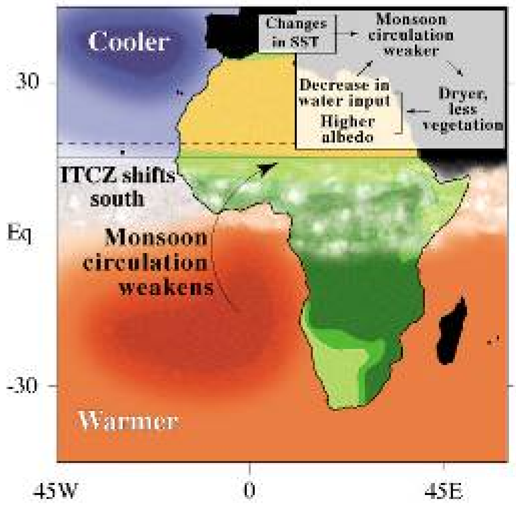

Figure 2.5 Illustration of a hypothesis to account for the Sahelian drought of the second half of the 20th century.[16]

This may well explain the recent Sahelian drought but it leaves open what will happen in the future. Some argue that the south Atlantic has begun to

15 Brooks, N. 2004. op cit. http://www.tyndall.ac.uk/publications/working_papers/wp61.pdf; Giannini, A., Saravanan, R. and Chang, P. 2003. Oceanic forcing of Sahel rainfall on interannual to interdecadal timescales, *Science* 302, 1027-1030.
16 Zeng, N., et al. 1999. Enhancement of interdecadal climate variability in the Sahel by vegetation interaction, *Science* 286, 1537-1540.

cool since the 1990s while the north is relatively warmer. This may reverse the cycle of events producing more rainfall and vegetation in the Sahel. But this is still a very tentative conclusion.

Africa's Impact

Africa's climate is also a driver at a global level. The heat released in the ITCZ is a major source of the planet's atmospheric warming. There is also a correlation between West African rainfall and Atlantic hurricane frequency. The hurricanes appear to be generated by the easterly atmospheric waves that pass over Africa at the time of the monsoon.

Africa is also a not insignificant producer of greenhouse gases. Virtually all of the carbon released to the atmosphere from land use changes now comes from the tropics. Tropical deforestation, including logging and the permanent and temporary conversion of forests to croplands and pastures, releases about 1-2 PgC/yr. This is 15-35% of annual fossil fuel emissions during the 1990s (adding in all the other gases that result from land use change e.g. methane, nitrous oxide etc., tropical deforestation accounts for about 25% of the total anthropogenic emissions of greenhouse gases). Africa contributes about 0.12-0.35 PgC/year.

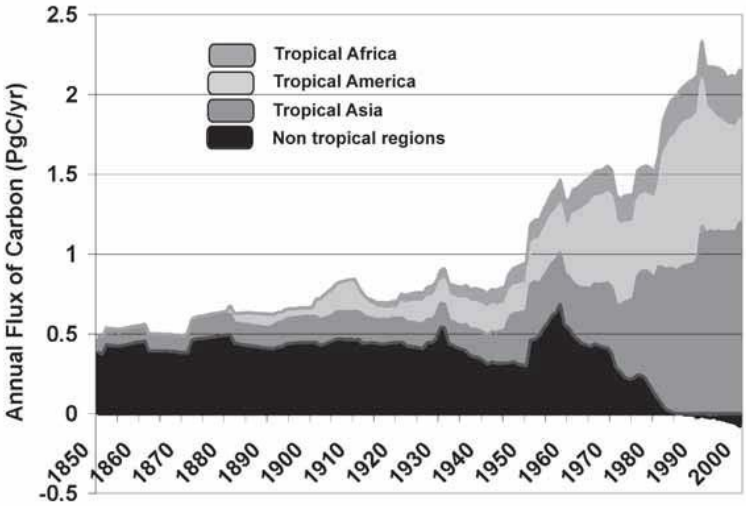

Figure 2.6 Annual emissions of carbon from changes in land use (Note P = 10^{15}).[17]

More significant than the carbon released by deforestation large quantities of carbon are produced by the open burning of the savannahs of Africa. It is estimated that over 50% of the annual carbon released from burning (both of forests and savannahs) comes from Africa (Figure 2.7).

17 Houghton, R.G. 2005 Tropical deforestation as a source of greenhouse gas emissions. In Moutinho, P. and S. Schwartzman (eds.) *Deforestation and Climate Change*. Amazon Institute for Environmental Research, pp13-21

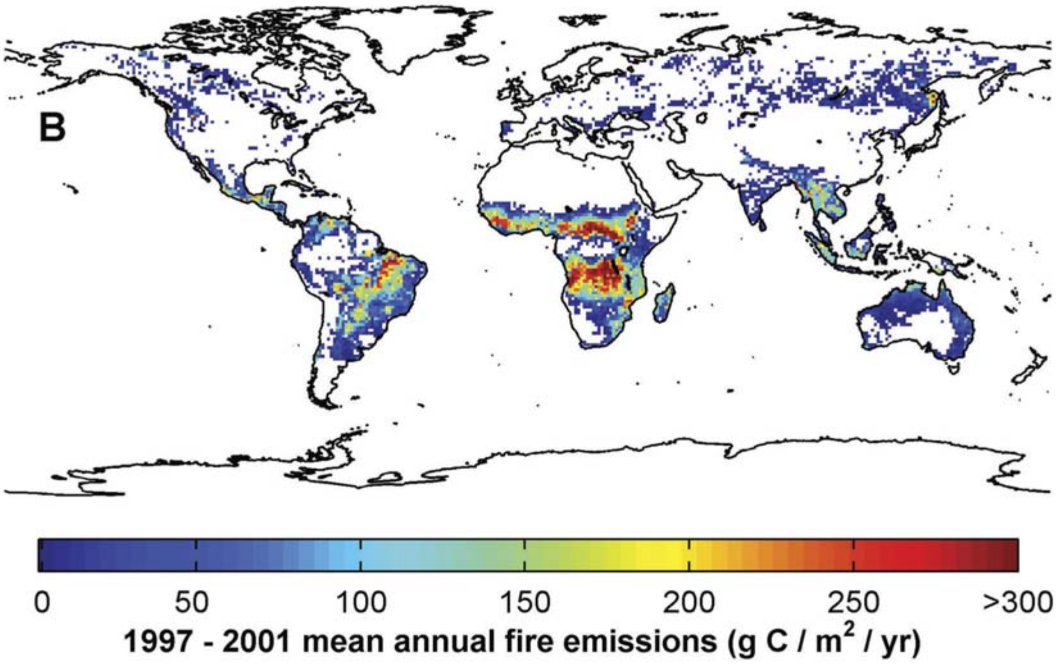

Figure 2.7 Mean annual carbon emissions from fires during 1997 to 2001.[18]

Both biomass burning and wind-borne dust also produces large quantities of aerosols. These affect climate in complex ways. Some aerosols in some circumstances reflect incoming radiation, so cooling the planet, but others trap the heat adding to the greenhouse effect. Dust can either reduce or stimulate rainfall. In low clouds, water attaches to dust particles and prevents droplets from becoming heavy enough to fall. But in high clouds dust particles over wetter regions may provide surfaces for ice crystals to form around them, resulting in greater rainfall.[19] The great Saharan dust storms can be blown long distances influencing the weather on the far side of the Atlantic.

3. The Need for Information

As the above discussion indicates, far too little is known about the African climate, its drivers and their links to global warming. This means we cannot be confident about the major climate trends both at the continental level and for individual countries. For example we do not know whether the Sahel is going to become drier or wetter. We also do not know whether the high frequency of El Niño events is going to continue with consequent effects on the African climate.

At the local level there are a now a number of climate models that provide estimates of climate trends on a fine scale. One such is PRECIS (Providing Regional Climates for Impacts Studies), a portable regional climate model, developed by the Hadley Centre of the UK Meteorological Office, that can be

18 van der Werf, G. R. et al, 2004 Continental-Scale Partitioning of Fire Emissions During the 1997 to 2001 El Niño/La Niña Period, *Science*, 303, 73-76
19 http://www.sciencedaily.com/releases/2003/07/030717090407.htm

run on a personal computer to generate detailed climate change scenarios.[20] Where the General Circulation Models (GCM) work to a resolution between 125 and 250 km, PRECIS works to a resolution of 50 km. PRECIS and similar regional models are extremely valuable tools for understanding local climate dynamics but, it must be stressed, they act by applying the coarse-grained GCM dynamics to a local level. Only in a few locations is the local data sufficient in quality and quantity to provide a basis for the accuracy required at a fine scale.

The limitation is caused by the paucity of regular, detailed information on the African weather. The global network of World Watch Weather Stations which provides real time weather data is very poorly represented. There are only 1152 stations in Africa, a density of about 1 per 26,000 km^2 which is eight times lower than the level recommended by the World Meteorological Organisation. Moreover, the location of the stations is very uneven. Vast areas are unmonitored, including Central Africa and the Horn of Africa (figure 3.1).

This lack of knowledge is what makes it very difficult to predict with any degree of accuracy what will happen as a result of climate change at a country, or even sub-regional level in Africa.

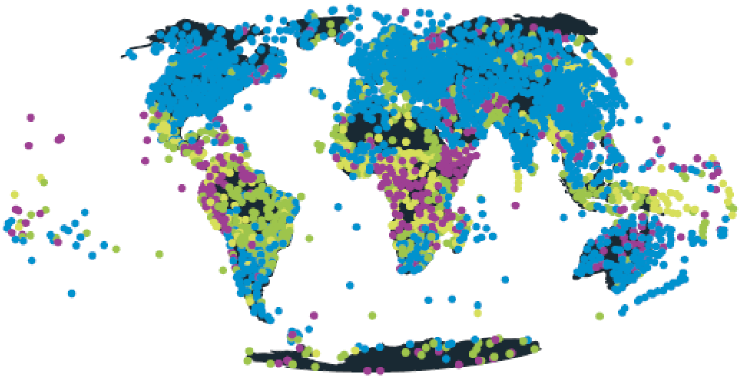

Figure 3.1 Reports received by the World Meteorological Office from World Weather Watch Stations 1998 – 2002.[21]

4. What we do know

Despite these various complications and unknowns we do know, at least in general terms, what is likely to happen in the near future.

20 Jones, R.G. et al. 2004 Generating high resolution climate change scenarios using PRECIS, Met Office Hadley Centre, Exeter, UK, 40pp

21 World Meteorological Office, 2003 *Twenty-First Status Report on Implementation of the World Weather Watch: Forty years of World Weather Watch*, WMO No. 957, p49.

Africa will get
- warmer (colder in a small number of places)
- drier, but with more floods in some regions

and there will be
- more intense tropical cyclones
- higher sea levels
- more storm surges
- and, in general, more climatic variation and extreme weather events

Temperature and Rainfall

There is already evidence that Africa is warming faster than the global average and this is likely to continue (Figure 4.1). The warming occurs for all seasons of the year and although the overall trend is geographically widespread, there are variations. For example, the tropical forests have warmed by 0.29°C per decade. In southern and western Africa there have been more warm spells and fewer extremely cold days. In eastern Africa temperatures have fallen close to the coasts and major inland lakes.[22]

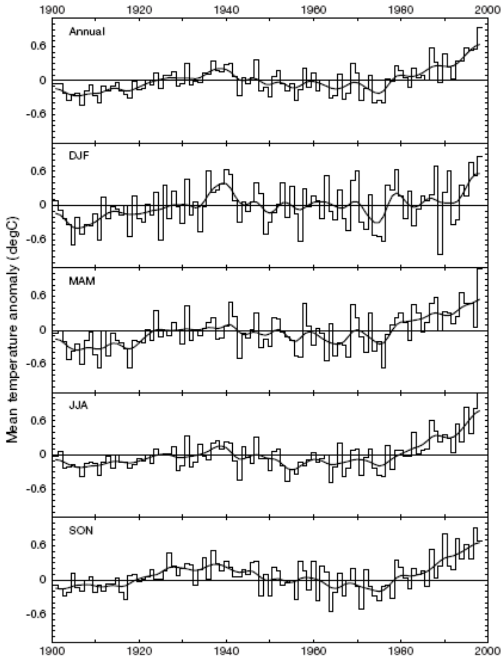

Figure 4.1 African mean temperature anomalies for the past 100 years.[23]

22 Malhi Y. and Wright J. 2004 Spatial patterns and recent trends in the climate of tropical forest regions. *Philosophical Transactions of the Royal Society of London Series, B*, 359: 311-329. Kruger, A.C. and Shongwe, S. 2004 Temperature trends in South Africa: 1960-2004. *Int. J. Climatol.* 24, 1929-1945; New, M. et al., 2006 Evidence of trends in daily climate extremes over Southern and West Africa, *Journal of Geophysical Research - Atmospheres*, 111, King'uyu, S. M., Ogallo, L. A. & Anyamba, E. K. 2000 Recent trends of minimum and maximum surface temperatures over eastern Africa. *J. Clim*. 13, 2876-2886
23 Hulme, M., et al. 2001 African climate change: 1900-2100. *Climate Research* 17, 145-168.

In general the tendency is for the drier subtropical regions to warm more than the moister tropics.[24] Northern and southern Africa will become much hotter (as much as 4-6ºC) and drier in the summer, with a much greater risk of drought. The exceptions are in East Africa, including the Horn of Africa, and parts of Central and West Africa where average rainfall will increase (Figure 4.2).

Increased Variability

The increasing rainfall variability is already apparent.[25] Inter-annual rainfall variability is large over most of Africa and, for some regions, multi-decadal variability is also substantial.

In Zimbabwe, for example, there are more cooler and hotter days, and the length and depth of the drier periods is increasing (Figure 4.3). In the future, the frequency of extremely dry winters and springs in southern Africa will increase as will the frequency of extremely wet summers. As in other parts of the world, we can expect a general increase in the intensity of high-rainfall events associated, in part, with the increase in atmospheric water vapour.[26] In regions of mean drying, there is likely to be a proportionally larger decrease in the number of rain days, but with greater intensity of rainfall.[27]

Many regions of Africa are going to suffer from droughts and floods with greater frequency and intensity.

---

24 IPCC 2007 *Climate Change 2007. The 4th Assessment Report of the IPCC.* Working Group I The physical Science Basis Ch. 11 Regional Climate Projections. Intergovernmental Panel on Climate Change (hereafter IPCC 4 WG I)

25 Hulme, M., R. et al. 2005. Global warming and African climate change: a re-assessment.

In Low, P.S. (ed.) op.cit pp 29-40.

26 Tadross, M.A., Jack, C., and Hewitson, B.C. 2005 On RCM-based projections of change in southern Africa summer climate. *Geophysical Research Letters*,32, 23

27 IPCC 4 WG I Ch 11 op cit.

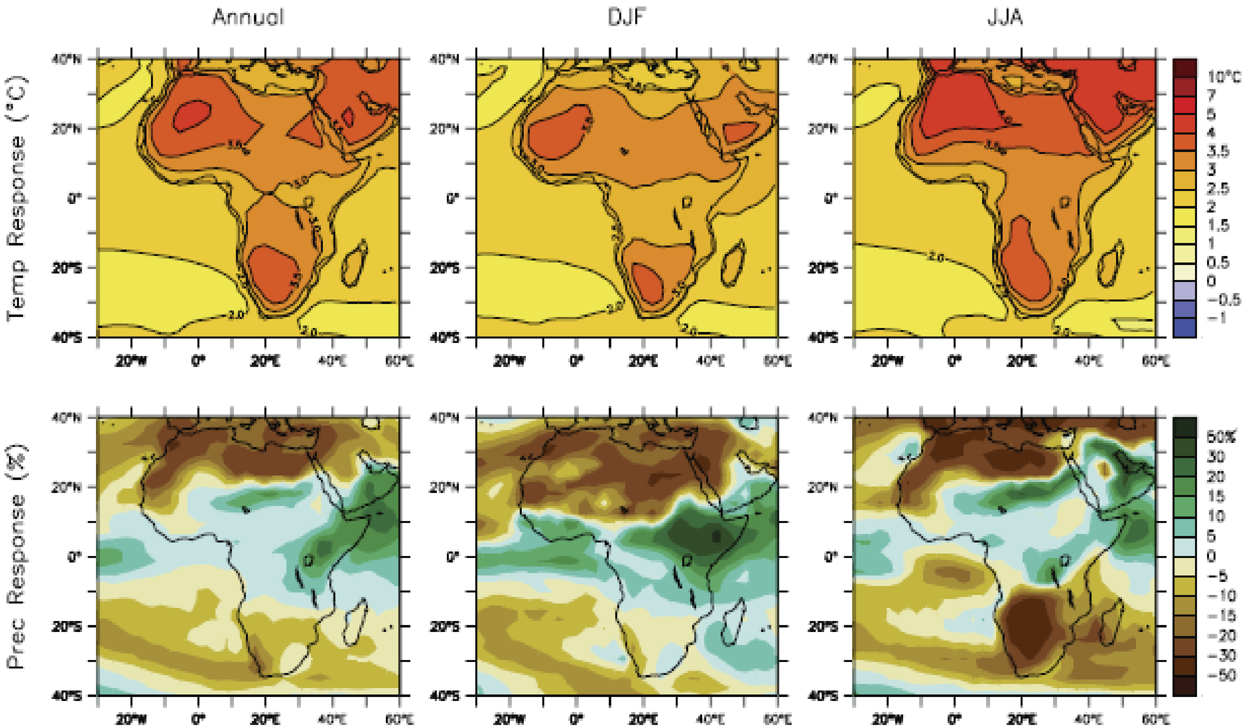

Figure 4.2 Temperature and rainfall projections for Africa, 1980 to 1999 versus 2080 to 2099 for scenario A1B.[28]

28 IPCC 4 WG I Ch 11op cit

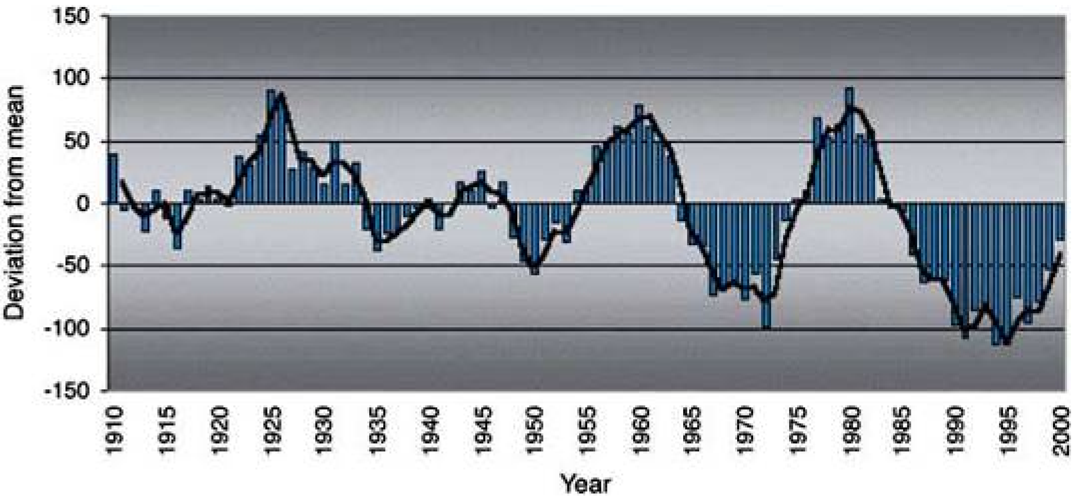

Figure 4.3 Increasing rainfall variability in Zimbabwe (10 year running mean).[29]

The south east coast of Africa is subject to periodic tropical cyclones that originate over the Seychelles from October to June due to the southward displacement of the ITCZ. Rising sea surface temperatures are likely to increase cyclone intensity and there are some estimates of greater cyclone frequency, but cyclones are affected by many factors.[30]

5. The Impacts

The actual and potential impacts of these climatic changes are large and wide ranging, affecting many aspects of people's everyday lives.

Sea-level Rise

Sea levels will rise around the globe as a result of climate change. The primary cause, at least in the near term, is the thermal expansion of the oceans resulting from rising oceanic temperatures. This will deliver a rise of about half a metre by the end of this century.[31]

This prediction does not include many uncertainties. One such is the speed of the melting of the Greenland ice sheet. Current predictions are that it will take many hundreds of years before it is all gone. But some models suggest that as

---

29 FAO 2004 *Drought impact mitigation and prevention in the Limpopo River Basin: A situation analysis* Land and Water Discussion paper 4 Natural Resources Management and Environment Department, FAO, Rome

30 R.E. McDonald, R.E. et al 2005 Tropical storms: representation and diagnosis in climate models and the impacts of climate change. *Climate Dynamics,* 25, 19-36. Lal, M. 2001. Tropical cyclones in a warmer world. *Current Science*, 80, 1103-1104.

31 IPCC 4 WG I Ch 10 Global Climate Projections

local temperatures exceed 3 - 4.5°C (equivalent to a global increase of around 2 - 3°C) above pre-industrial, the surface temperature of the ice sheet will become too warm to allow recovery from summertime melting and the ice sheet will begin to melt irreversibly. [32]

The signs are that the ice is melting faster than expected. Part of the reason is the seeping down of the melt water through the crevices of the melting ice, so lubricating glaciers and accelerating their movement to the sea.[33] A full melting will result in sea levels some 7 metres above present. There is a similar risk posed by accelerated melting of the Antarctic ice sheet but this is less acute.

Africa is less likely to be as damaged by rising sea levels than are many small islands or such delta regions as the Ganges-Brahmaputra and the Mekong Rivers. The most extensive inundation is likely to be in the Nile delta. A one metre rise would affect some 6 million people (Box 5.1).

Box 5.1 The Inundation of the Nile Delta[34]

The Nile Delta is a highly fertile flood plain that supports a very large population with densities as high as 1600 inhabitants per square kilometre. Deserts surround the low-lying, fertile floodplains. Most of a 50 km wide land strip along the coast is less than 2 m above sea level and is only protected from flooding by a 1 to 10 km wide coastal sand belt, shaped by the discharge of the Rosetta and Damietta branches of the Nile. Erosion of the protective sand belt is a serious problem and has accelerated since the construction of the Aswan Dam.

Rising sea levels would destroy weak parts of the sand belt, which is essential for the protection of lagoons and the low-lying reclaimed lands. The impact would be very serious. One third of Egypt's fish catches are made in the lagoons. Sea level rise would change the water quality and affect most fresh water fish. Valuable agricultural land would be inundated. Vital, low-lying installations in Alexandria and Port Said would be threatened. Recreational tourism beach facilities would be endangered and essential groundwater would become salinated.

Dykes and protective measurements would probably prevent the worst flooding up to a 50 cm sea level rise. However, it would cause considerable groundwater salination and the impact of increasing wave action would be very damaging.

32 Gregory, J., and P. Huybrechts 2006, Ice-sheet contributions to future sea-level change, *Phil. Trans. Roy. Soc. A,* 364, 1709.

33 Hanna, E., P. et al. 2007 Increased runoff from melt from the Greenland Ice Sheet: a response to global warming, *J. Clim.,* in press. Rignot, E. and Kanagaratnam, P. 2006, Changes in the Velocity Structure of the Greenland Ice Sheet, *Science* 311, 986-990

34 http ://www.grida.no/climate/vitalafrica/english/16.htm

Figure 5.1 Impacts of sea level rise on the Nile delta.

There are also likely to be severe consequences along the West African coast (Figure 5.2). Banjul, the capital city of Gambia could be completely submerged in the next 50 years or so.[35]

Figure 5.2 Effects of one metre sea level rise in West Africa. Inundated areas coloured in red.[36]

In Ghana the coastal zone occupies less than 7% of the land area but contains 25% of the population and so even relatively small rises could have damaging effects on the economy (Table 5.1).

35 Nicholls, R.J. and Leatherman, S.P. 1995 Global sea-level rise. In Strzepek, K.M. and Smith, J.B. (eds.) *As Climate Changes; International Impacts and Implications*. Cambridge University Press, Cambridge, 92-123; Jallow, B.P., Barrow, M. K. A. and S.P. Leatherman 1996 Vulnerability of the coastal zone of The Gambia to sea level rise and development of response strategies and adaptation options, *Climate Research*, 6: 165-177

36ww.geo.arizona.edu/dgesl/research/other/climate_change_and_sea_level/sea_level_rise/africa/images/lg/slr_af_1meter_lg.htm

Table 5.1 Physical consequences of sea level rise in Ghana[37]
Permanent connection of lagoons to sea
Penetration of salt water inland
Increased coastal erosion
Salinification of freshwater lagoons and aquifers
Increased depth of water table in coastal areas
Destruction of wetlands and associated industries
Accelerated loss of the capital, Accra

A further, say six metre rise, occasioned by a more rapid than expected acceleration in the melting of the Greenland and /or Antarctic ice caps, could have even more serious consequences.

Glacier Melting

The glaciers on Mt. Kilimanjaro in Tanzania are melting fast and will have disappeared by 2020 (Figure 5.3).[38] However, the major change in hydrology on the mountain and its environs is not due to the glacier melt but to the dramatic shift, as a result of climate change, in the vegetation zones on the mountain.

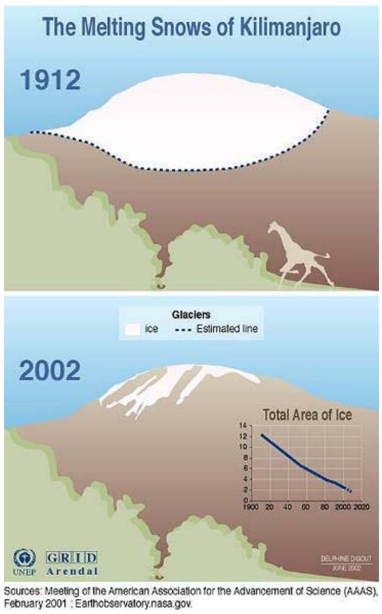

Figure 5.3 Melting of the glaciers on Mt Kilimanjaro, Tanzania[39]

37 Armah, A.K., Wiafe, G. and D. Kpelle 2005 Sea-level rise and coastal biodiversity in West Africa: a case study from Ghana. In Pak Sum Low (ed.) op cit, pp 204-217; Appeaning-Addo, K., Walkden, M., and Mills, J. (in press) Detection Measurement and Prediction of Shoreline Recession in Accra, Ghana. *ISPRS Journal of Photogrammetry & Remote Sensing*

38 Thompson, L.G., et al., 2002 Kilimanjaro ice core records: evidence of Holocene change in tropical Africa. *Science*, 298, 589-593

39 American Association for the Advancement of Science, February 2001;Earthobservatory. NASA. Gov.

Floods and Droughts

Floods will become more common in Africa, in part because some regions will experience higher rainfalls, but even in drier regions there is likely to be a higher frequency of more intense downpours which will create flooding. 2007 saw heavy flooding in both eastern and western Africa (Box 5.1).

Box 5.1. The African Floods of 2007

The floods that occurred across the Sahel of Africa in the summer of 2007 were caused by the heavy rainfall and thunderstorms within the rain belt of the ITCZ which was further north than usual (Figure 5.3). Much of the land was dry from the years of previous drought and the record rainfalls resulted in high levels of run off (Figure 5.4).

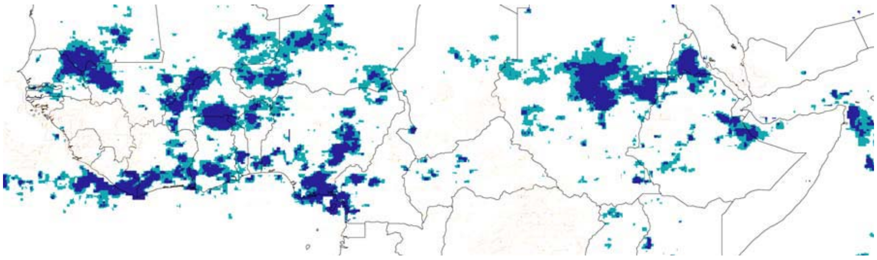

Figure 5.3 Regions across Africa where the rainfall was a 1 in 20 year event or rarer (shown in blue) for July and August 2007.[40]

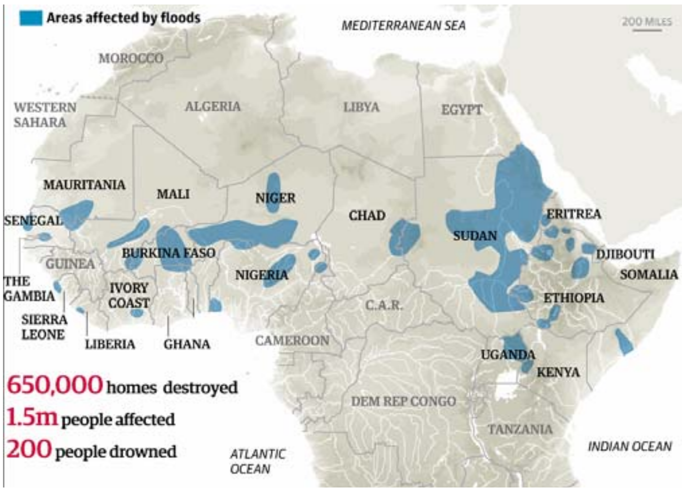

Figure 5.4 Map of the 2007 floods.[41]

There are many direct and indirect consequences of floods:

- Immediate deaths and injuries from drowning

40 Famine Early Warning System: http://earlywarning.usgs.gov/adds/
41 http://www.guardian.co.uk/graphic/0,,2173042,00.html

- Non-specific increases in mortality
- Infectious diseases e.g. increased malaria
- Exposure to toxic substances
- Damage to infrastructure e.g. roads, dams, power generation
- Damage to crops and livestock
- Community and personal breakdown
- Increased demands on health systems and social security

Perhaps of even greater importance for Africa will be the rising incidence of droughts, both short and long term. The worldwide percentage of land in drought has risen dramatically in the last 25 years (Figure 5.5)

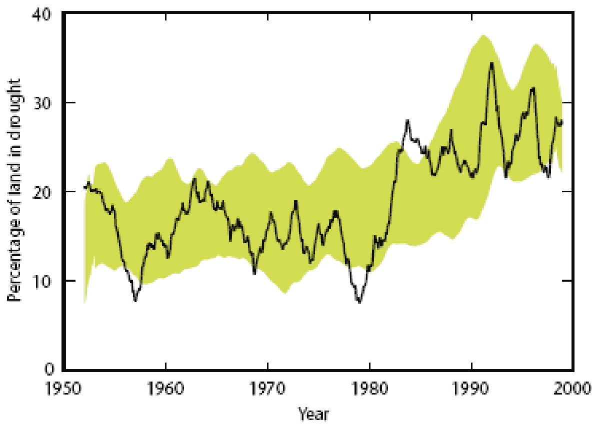

Figure 5.5. Global area of land under drought since 1950[42]

Many of the consequences are similar to those for floods, but the most significant impact in Africa is likely to be on agricultural production.

Water Resources

There are a dozen major river basins in Africa but the impact of climate change is likely to vary depending on the rainfall regime (Fig 5.6).

42 http://www.metoffice.gov.uk/research/hadleycentre/pubs/brochures/COP12.pdf

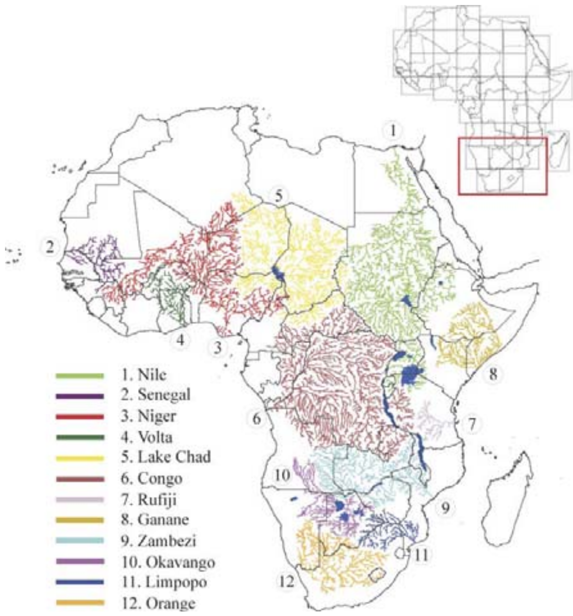

Figure 5.6 The twelve major river basins of Africa[43]

Those river basins receiving a low rainfall (below 400mm a year) have virtually no perennial drainage (coloured in red in Figure 5.7). Between 400 and 1000 mm, there exists an intermediate unstable regime (coloured in yellow) in which the drainage density varies greatly with rainfall. Above 1000 mm (coloured in green) there is a slight increase in drainage with increasing rainfall.

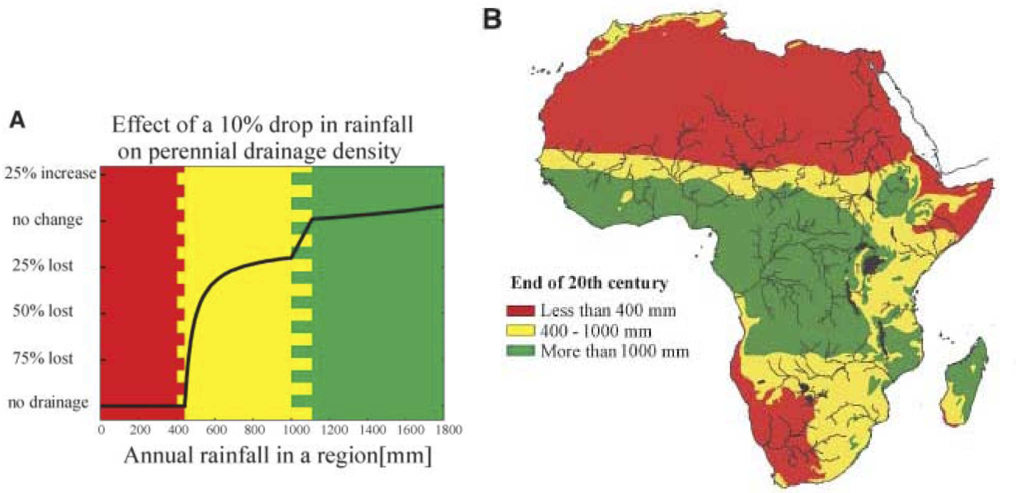

Figure 5.7 Rainfall and drainage regimes in Africa[44]

The intermediate unstable zone is likely to experience the greatest impacts from climate change. For example, if in a region receiving 600 mm per year the precipitation decreases to 550 mm year the drainage will be cut by 25%, whereas

43 De Wit, M. 2006 Change in Surface Water Supply across Africa with predicted climate change, *Science* 311, 1917
44 De Wit, op cit

a change from 500 mm year to 450 mm would cut the drainage by half. River flows will fall accordingly.

Most of southern Africa lies in either the unstable or the dry regime. The Orange River, the fifth largest river in Africa and one of the 50 largest ones globally, is likely to be severely affected. The river has run dry in the past and has experienced very low flows in recent years.

On the other hand, rivers in eastern Africa may experience increased drainage density because of the higher predicted rainfall. The flow of the Nile is difficult to assess and current models vary considerably in their predictions.[45]

Water scarcity thresholds are based on estimates of the water requirements for domestic, agricultural, industrial and energy sectors and the needs of the environment.[46] A country is assumed to experience water scarcity when the level available is below 1000m^3 per capita per year and absolute scarcity is defined as below 500m^3. On this basis it will be north Africa that suffers most, with the situation improving in northeast Africa (Figure 5.8).

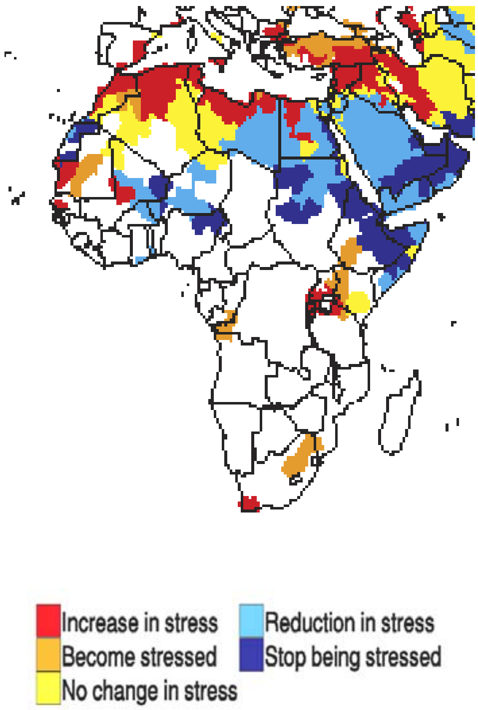

Figure 5.8 Change in water stress by 2085 using a Hadley Circulation model (HadCM3 A2a)[47]

45 Strzepek, K. et al 2001 Constructing “not implausible” climate and economic scenarios for Egypt. *Integrated Assessment* 2, 139–157
46 Warren, R. et al 2006 *Understanding the regional impacts of climate change*. Research Report Prepared for the Stern Review on the Economics of Climate Change. Tyndall Centre for Climate Change research, Working Paper 90
47 Warren, R. et al op cit

Agriculture

Agricultural production and food security in many parts of Africa are likely to be severely compromised by climate variability and climate change, in particular by damaging high temperatures and the greater incidence of drought. Many crops in Africa are grown close to their limits of thermal tolerance. We already know that just a few days of high temperature near flowering can seriously affect yields of crops such as wheat, fruit trees, groundnut and soybean.[48] Such extreme weather is likely to become more frequent creating high annual variability in crop production. But more prolonged high temperatures and periods of drought will force large regions of marginal agriculture out of production.

The maize crop over most of southern Africa already experiences drought stress on an annual basis. This will get worse and extend further southwards, making maize production in many parts of Zimbabwe and South Africa very difficult if not impossible. Wheat yields in North Africa will also be threatened.

Drought in southern Africa may be particularly severe in El Niño years. The effects of drought are already well known. For example, in the 1980s protracted drought killed 20-62% cattle in countries as widespread as Botswana, Niger and Ethiopia.[49]

Maize yields in Zimbabwe have long been highly correlated the ENSO cycle as measured by sea surface temperatures off the Peruvian coast. The drought tends to hit in February just at the most susceptible time for the development of the maize grain. So strong is the correlation that it is possible to predict, with 70% probability, the Zimbabwean crop in March using the sea surface temperatures in the eastern Pacific in the previous September (Figure 5.9).

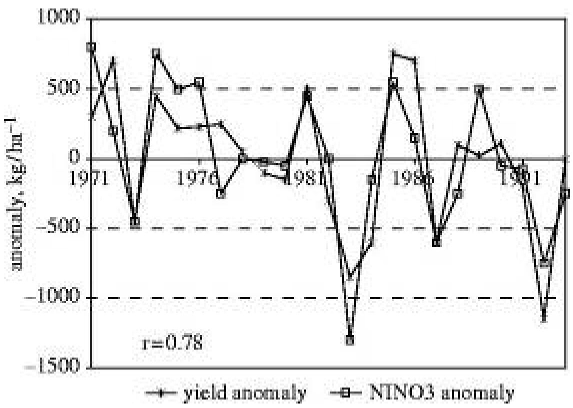

Figure 5.9 Correlation between sea surface temperatures and Zimbabwean maize yields.[50]

---

48 Challinor, A.J. et al 2006 Assessing the vulnerability of crop productivity to climate change thresholds using an integrated crop-climate model, In: Schellnhuber, J., et al (ed), *Avoiding Dangerous Climate Change*, Cambridge University Press pp.187-194.
49 IPCC 4 Ch11 op cit
50 Cane, M.A., Eshel, G. and R.W. Buckland 1994 Forecasting Zimbabwean maize yields using eastern equatorial Pacific sea surface temperature. *Nature*, 370, 204-205

In southern Africa and across western and north-central Africa lower rainfall may also cause the length of the growing season to shorten, threatening the probability of getting a second crop in some areas and even the viability of a single crop in others (Figure 5.10).

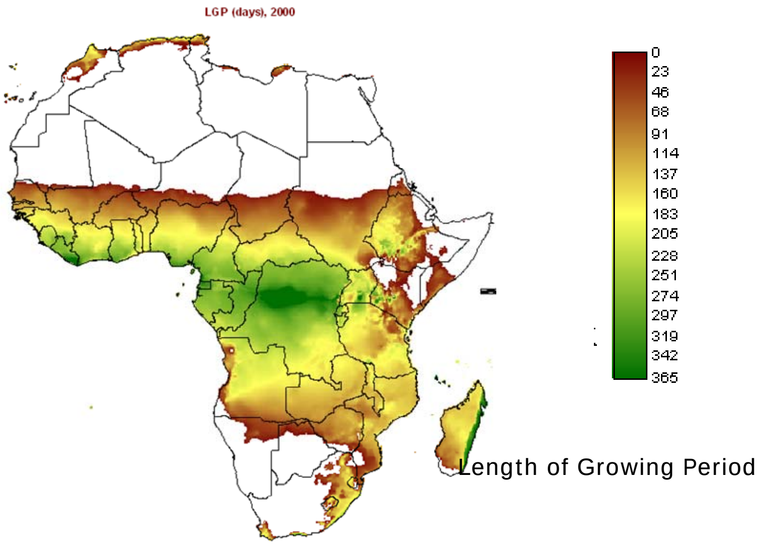

Figure 5.10. Length of the growing season (no of days) in Sub-Saharan Africa[51]

Just how severe will be these various impacts on agriculture will depend on the so-called "carbon fertilisation" effect. Carbon dioxide is a basic building block for plant growth and hence we would assume that rising levels will increase crop yields. Greenhouse and field chamber experiments show this to be the case but the latest analyses of more realistic field trials suggest the benefits of carbon dioxide may be significantly less than initially thought – an 8 to 15% increase in yield for a doubling of carbon dioxide for responsive species (wheat, rice, soybean) and no significant increase for non-responsive species, such as maize and sorghum which are widely grown in Africa.[52] Hence this offsetting factor may be less than has previously been assumed.[53] Estimates of yield losses (with CO_2 fertilisation) for wheat are18% in northern Africa and for maize in southern Africa are 22%.[54]

---

51 ILRI 2006 *Mapping climate vulnerability and poverty In Africa*. Report to Department for International Development. International Livestock Research Institute, Nairobi, Kenya

52 Long S.P. et al. 2006 Food for thought: Lower-than-expected crop yield stimulation with rising CO2 concentrations. *Science*, 312, 1918-1921; Long S.P. et al. 2007 Crop models, CO2, and climate change - Response. *Science*, 315, 460-460.

53 Warren R., et al op cit
54 Warren et al op cit

Health

There is a wide range of actual and potential impact soft climate change on health, some more serious than others (Figure 5. 11).[55]

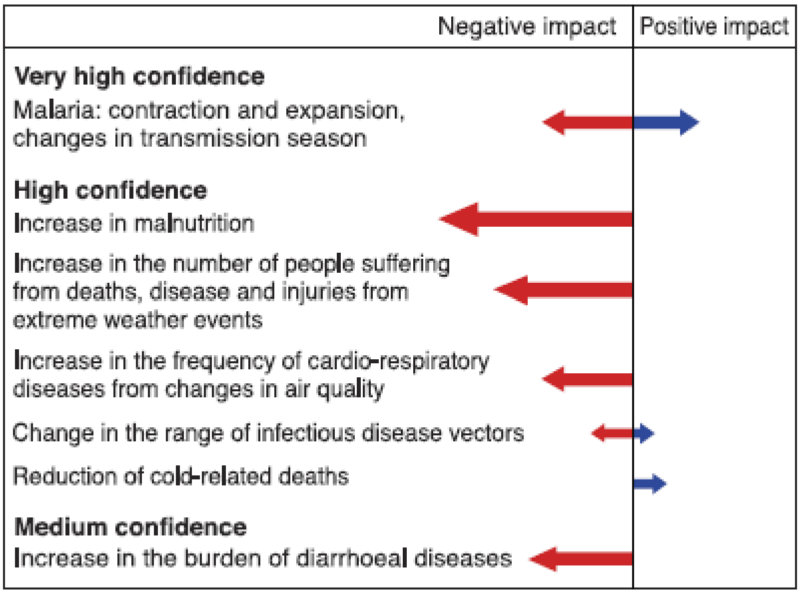

Figure 5.11 Global estimates of impacts of climate change on human health[56]

High temperatures can have a direct effect on human health. In all urban areas temperature rises above 30°C will result in significant loss of life. Although the relationship described in Figure 5.12 is for New Delhi, major African cities will be similarly affected.

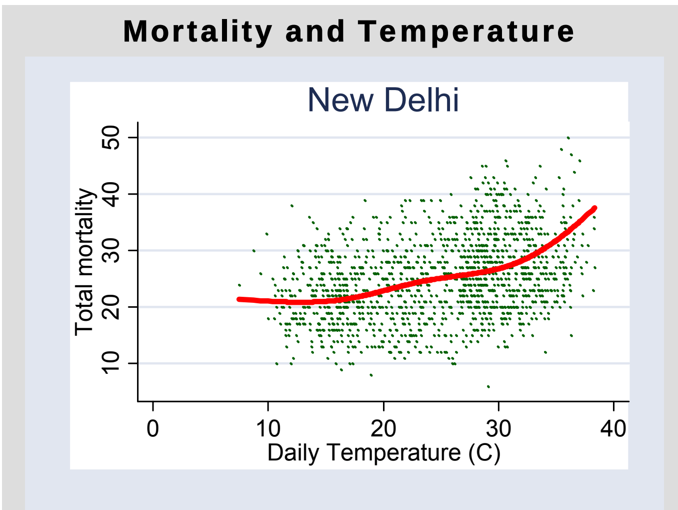

Figure 5.12. Effect of high temperatures on human mortality[57]

---

[55] McMichael, A.J., et al. 1996 Climate Change and Human Health WHO/EHG/96.7. 297 p
[56] IPCC 4 WG II Chapter 8 Health.
57

Most other health effects are likely to be indirect. Diseases carried by insects and other vectors are especially susceptible to the effects of climate change. For example, the geographical distribution and the rates of development of mosquitoes are highly influenced by temperature, rainfall and humidity. The malaria vector *Anopheles arabiensis* has been observed in the central highlands of Kenya, where no malaria vectors have previously been recorded.[58] Increased temperatures and more prolonged rainy seasons may extend the transmission period of the disease.

In general we may expect an extension of the range of malaria carrying mosquitoes and malaria into higher elevations, particularly above 1000m.[59] There have been resurgences of malaria in the highlands of East Africa in recent years. Many factors are probably involved - poor drug treatment implementation, drug resistance, land-use change, and various socio-demographic factors including poverty. But there is also a strong correlation with climate change. [60] Figure 5.13 reveals that the temperature in the highlands of East Africa has risen by 0.5ºC since 1980 – much faster than the global average - and this is correlated with a sharp increase in mosquito populations. There is also a greater rainfall there in the September to November period and with the increased warmth this may accelerate mosquito larval development.[61]

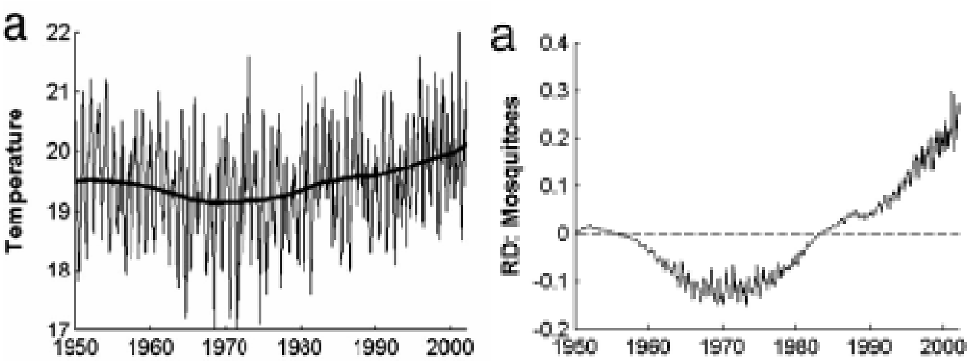

Figure 5.13 a) Temperature and b) mosquito population increases at Kericho in Western Kenya[62]

58 Chen H. et al. 2006. New records of *Anopheles arabiensis* breeding on the Mount Kenya highlands indicate indigenous malaria transmission*. Malaria Journal* 5,17.

59 Tanser, F.C., B. Sharp and D. le Sueur, 2003: Potential effect of climate change on malaria transmission in Africa. *Lancet*, 362, 1792-1798; Beniston, M. 2002 Climatic change: possible impacts on human health. *Swiss Med Wkly*, 132, 332-337.

60 Githeko, A.K. and Ndegwa, W., 2001. Predicting malaria epidemics in the Kenyan highlands using climate data: a tool for decision makers. *Global Change &Human Health*, 2 , 54-63; Patz J.A, et al. 2002 Regional warming and malaria resurgence. *Nature* 2002, 420, 627-8; Patz, J.A and S. H. Olson. 2006 Malaria risk and temperature: Influences from global climate change and local land use practices. *PNAS* 103, 5635-5636; Abeku et al., 2004 Malaria epidemic early warning and detection in African highlands. *Trends Parasitol* , 20, 400-405 ; Zhou et al., 2004 Association between climate variability and malaria epidemics in the East African highlands*. PNAS*, 101, 2375-2380; Hay et al., 2002 Climate change and the resurgence of malaria in the East African highlands. *Nature* 415, 905-909

61 Schreck, C. J. III, and F. H. M. Semazzi, 2004 Variability of the Recent Climate of Eastern Africa. *International Journal of Climatology,* 24, 681 – 701.

62 Pascual, M. et al. 2006, PNAS, 103, 5829-5834

Dengue, another mosquito borne disease (carried principally by *Aedes aegypti*) is also likely to increase. Recent models based on predicted rises in relative humidity show a considerable expansion of the geographical range of the disease, particularly through Central and Eastern Africa (Figure 5.11).

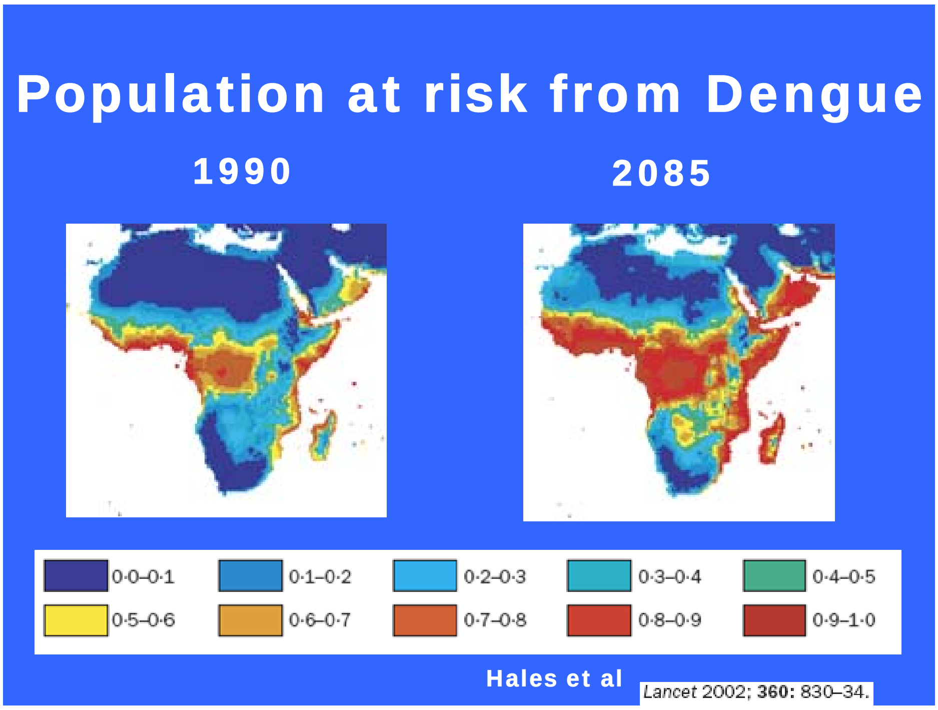

Figure 5.14. Predicted expansion of Dengue in Africa. (this projection uses the IPCC IS92a scenario that delivers a three fold increase in CO_2 by 2100).[63]

Other infectious diseases that may also increase in range and intensity include water-borne diseases such as cholera and other diarrhoeal diseases, rodent – borne diseases, meningococcal meningitis,[64] Ross River virus and Rift Valley fever.[65]

Biodiversity and Ecosystems

Africa is made up of a wide variety of ecosystems, ranging from savannahs and tropical forests to montane ecosystems and from coral reefs to great inland lakes and rivers. Within these ecosystems are estimated to be about one-fifth of all known species of plants, mammals, and birds, as well as one-sixth of amphibians and reptiles.

63 Hales et al 2002 *Lancet* 360, 830-834

64 Molesworth, A.M., et al. 2003 Environmental risk and meningitis epidemics in Africa. *Emerg. Infect. Dis*., 9, 1287-1293.

65http://kim.foresight.gov.uk/Previous_Projects/Detection_and_Identification_of_Infectious_Diseases/Reports_and_Publications/Final_Reports/T/t7_1.pdf

One estimate suggests that, globally, approximately 15-40% of land plant and animal species will become extinct by 2050 as a result of climate change.[66] In Africa the ecosystems of dry and subhumid lands are particularly at risk because quite small changes in temperature and rainfall patterns can have deleterious impacts on the viability of plants and animals. Most drylands are already under stress from cultivation, livestock grazing and other human activities.

For example, the succulent *karoo* of the west coast of South Africa and Namibia is home to about 3000 species of plants that occur nowhere else. A large fraction of the world's succulent flora lives in the karoo thriving on its unique dry, winter-rainfall climate. The region is likely to shrink or completely disappear as a result of climate change.[67]

Many animal species will also be affected, including some of the mammals of the African National Parks, such as the Kruger. Overall between 25-40% of animals in sub-Saharan African national parks are endangered.

Marine ecosystems are very vulnerable. Coral reefs off the African coasts are at risk. More generally such ecosystems are likely to suffer damage from increasing acidification as a direct consequence of increased CO_2 concentrations.

On land perhaps one of the biggest losses, with most widespread consequences, will be of forests, particularly along the edge of the Congo Basin, partly driven by logging, both legal and illegal, and partly by increasing aridity. Such deforestation creates:

- Less biodiversity
- Less rainfall
- More soil erosion
- More floods
- Emergence of zoönotic diseases

and, most important, more greenhouse gases. Globally deforestation contributes to 20% of greenhouse gases. This in turn produces more droughts and hence creates a vicious circle.

6. The Processes of Adaptation

It is the poorest countries and the poor especially who are most vulnerable to climate change. African countries are particularly at risk for a variety of reasons (Box 6.1)

---

66 Thomas, C.D. et al 2004 Extinction risk from climate change *Nature* 427, 145–148
67 http://www.scienceinafrica.co.za/2002/december/change.htm

Box 6.1 The Vulnerability of African countries to Climate Change[68]

- Most African countries are highly dependent on natural resources and their agricultural sector for food, employment, incomes, tax revenue and exports. Changes in weather conditions which damage the agricultural sector will thus have a major impact on incomes and livelihoods.
- Poor countries and poor communities tend to have a higher share of their assets and wealth tied up in natural resource and environmental assets, so anything which damages the natural resource base will clearly damage these countries more.
- One third of Africa's productive area is already classified as "dryland", and climate change will likely bring less rainfall and a shorter growing season, extending such drylands over a larger area.
- Many parts of Africa are already short of water – a shortage which will likely further increase.
- Government and institutions are weak, and poorly resourced. So many people will have to cope on their own. The brain drain of well-qualified people further limits their capacity.
- Most people operate at low levels of income with limited reserves, and lack formal insurance cover.

Most of the population of Africa already experiences a variety of stresses and shocks on a regular basis.[69] Globally the number of disasters has grown rapidly over the past three decades, with Africa accounting for 20% of the total.[70] About half of Africa's natural disasters are due to extreme weather; climate related disasters form about half of the natural disasters. In the decade 1993-2002 some 16,000 people died out of a total of 137 million affected (Table 6.2)

Type	Killed	Affected
Flood	9,642	19,939,000
Drought/ famine	4,453	110,956,000
Windstorms	1,335	5,687,000
Extreme Temperatures	147	8,000
Total	**15,713**	**136,590,000**

Table 6.2 Extreme weather related disasters in Africa for the decade 1993-2003[71]

Disasters caused by extreme weather are nothing new. But the scale and, in some situations, the nature of the impacts will change dramatically as the pace of change increases. More and more people will experience:

68 Toulmin, C. 2007 *Africa's development prospects up in smoke?* Colin Trapnell Memorial Lecture, Green College, Oxford
69 Cornford, S.G. 2003 The socio-economic impacts of weather events in 2002. *WMO Bulletin*, 52, 269-290; Basher, R. and Briceňo, S. 2005 Climate and Disaster risk reduction in Africa. In Pak Sum Low (ed.) op cit, 271-283
70 EM-DAT data set, Centre for Research on the Epidemiology of Disasters (CRED), Université de Louvain, Belgium
71 EM-DAT, http:www.cred.be

- Increased water and food insecurity,
- Adverse impacts on health and on social and economic services delivery,
- Outbreaks of vector borne diseases;
- Damaged and degraded infrastructure,
- Threatened human settlements and human life
- Destroyed biodiversity and damaged ecosystems

The challenge faced by governments, communities and families is how to become more resilient to these increasing stresses and shocks. In part, the answer is the process of development itself.

If people are better fed and in better health, and have access to education, jobs and markets they will be more resilient to climate change. Development in the era of climate change thus goes beyond the Millennium Development Goals to include:

- Promoting growth and diversification of economic activity;
- Enhancing resilience to disasters and improving disaster management;
- Promoting the sharing of risk, including social safety nets for the poorest.

Adaptation to climate change is, inevitably, as complex a process as the phenomenon of climate change itself. Each of the various impacts listed earlier needs to be assessed and the most appropriate countermeasures designed, taking account of their effectiveness, their costs and their socio-political acceptability.

The Challenges for Adaptation

About 70% of people in sub-Saharan Africa are rural and it is their livelihoods that will be most at risk from climate change. About a third of the African population experience chronic hunger. In addition there are periodic famines in some regions, either caused by civil unrest, poor governance or failure of the rainfall. Commonly famine is a combination of all three factors (Box 6.1).

Box 6.2. The Causes of Famine and Conflict in Darfur[72]

The Darfur region lies in the west of Sudan, along the borders of Libya, Chad and the Central African Republic. It has long been inhabited by two groups of people – subsistence farmers who makeup 60% of the total and nomadic or semi-nomadic herders of livestock. Traditionally they have lived together in relative harmony, the herders crossing the land of the subsistence farmers and using their wells.

The drought impacting the Sahel as a whole (see Figure 1.1) has also severely affected the Darfur region culminating in a major drought and subsequent famine in 1984/5. 95,000 people died out of a total of some 3 million.

[72] De Waal, A. 2004 Tragedy in Darfur: On understanding and ending the horror. *Boston Review,* October/November 2004; http://bostonreview.nrt/BR29.5/dewaal.html; De Waal, A. 2006 *Famine that Kills: Darfur, Sudan*, 1984-5, Oxford University Press

The consequent shortages of food and water and the ensuing land degradation triggered further southward migration of the herders and increasing conflicts for land and water between them and the subsistence farmers. This was made worse by population growth.

The conflicts escalated when the *Janjaweed* militia, with government support, began to force the farmers from their homes and take possession of the wells. The UN estimates that to date 450,000 people have died through violence or disease and as many as 2.5 million have been displaced.

Drought can have catastrophic effects on rural communities. For example in North-Eastern Ethiopia, drought induced losses in crop and livestock between 1998 and 2000 were estimated at $266 per household – greater than the annual average cash income for more than 75% of the households.[73]

Chronic hunger is likely to be made worse by climate change. This is in large part because the proportion of arid and semi-arid lands will increase – by 5-8% by the 2080s - and partly because of depleted water resources.[74] Projected reductions in yield in some countries could be as much as 50% by 2020, and crop net revenues could fall by as much as 90% by 2100, with small-scale farmers most vulnerable.[75]

At present deaths from malaria in Africa amount to nearly 1 million people per year to which must be added other infectious diseases such as measles and dengue.[76] In addition mortality from diarrhoeal diseases is nearly 700,000 per year, partly as a result of poor quality drinking water and poor sanitation, in turn affected by the availability of adequate water resources. Only about 60% of the African population had access to improved water supplies in 2000.[77] Scarcer water resources will make this more difficult to rectify.

The impact of increased disease could be costly. One estimate puts the population at risk from malaria in Africa as rising from 0.63 billion in 2005 to 1.15 billion in 2030.[78] The current economic burden of malaria already approximates to an average annual reduction in economic growth of 1.3% for those African countries with the highest burden.[79]

---

73 Carter, M.R., et al.2004 *Shock, sensitivity and resilience: tracking the economic impacts of environmental disaster on assets in Ethiopia and Honduras*. Wisconsin: BASIS.
74 IPCC 4 WGII Ch 9 Africa
75 IPCC op cit
76 Ezzati, et al. (eds.) 2004 *Comparative quantification of health risks: global and regional burden of disease due to selected major risk factors,* Vols. 1 and 2. World Health Organisation
77 WHO/UNICEF, 2000 Global water supply and sanitation assessment 2000 report, Geneva; Vörösmarty, C.J., et al. 2005 Geospatial indicators of emerging water stress: An application to Africa. *Ambio.* 34, 230-236.
78 http://www.foresight.gov.uk/Previous_Projects/Detection_and_Identification_of_Infectious_Diseases/Reports_and_Publications/Final_Reports/T/t5_8.pdf
79 Gallup, J. L. and Sachs, J. D. 2001 The economic burden of malaria. *American Journal of Tropical Medicine and Hygiene* 64, 85-96.

Sea level rise will only affect a small proportion of Africa's land mass, but the impact will be considerable. Forty percent of the population of West Africa live in coastal cities, and it is estimated that the 500 km of coastline between Accra and the Niger delta will become a continuous urban megalopolis of more than 50 million inhabitants by 2020. [80] By 2015, three coastal megacities of at least 8 million inhabitants will be located in Africa with many of the poorest populations located in the most flood prone districts.

Other costly impacts will be on infrastructure – roads, rail tracks, bridges and power installations damaged by flooding. The degradation of ecosystem services and losses of biodiversity will also have an economic impact, reducing the capacity of the land to recover from floods and droughts.

Building Resilience

At the core of adaptation is the concept of resilience which encompasses the abilities of countries, communities, households and individuals to cope with climate change

Resilience focuses on a desired pathway of development – measured as yield, or agricultural production or household income or GDP per capita or some other agreed upon statistic. This is then subject to a stress or shock – a flood or drought, erosion of a river bank, increased siltation or a cyclone or tornado.

In Figure 6.1, development is illustrated as an increasing trend. Along comes a stress or shock which in some circumstances can be fully resisted; a dam or barrage may prevent a flood. More commonly the development path is adversely affected and growth falls, perhaps recovering fast or perhaps slowly. In some cases the shock is too great, recovery may not occur and the development path collapses. For each stress or shock there is an appropriate countermeasure (Figure 6.1).

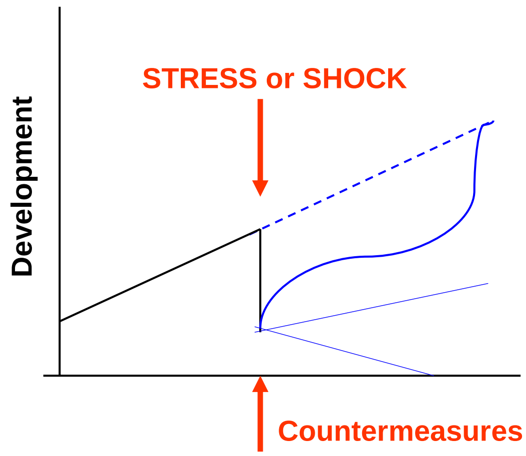

Figure 6.1. The patterns of resilience

[80] IPCC4 Working Group II Impacts, Adaptation and Vulnerability. Ch 9 Africa (hereafter IPCC 4 WG II)

In general, developed countries are likely to resist or recover more rapidly than developing countries. The latter may experience a greater impact and recovery will be slow or not at all (Figure 6.2)

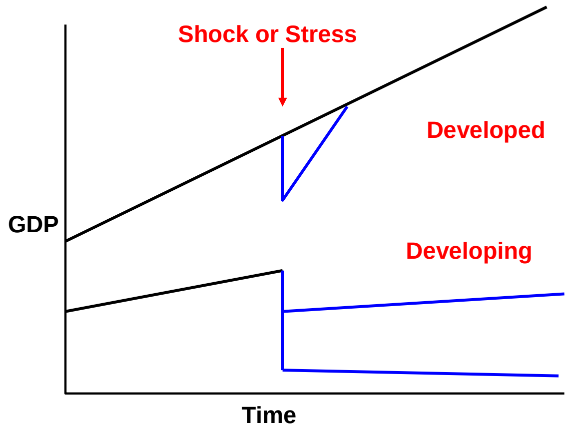

Figure 6.2 Resilience in developed and developing countries.

Resilience has the advantage of being both a qualitative and quantitative concept. The strength of stress and shock can be measured, as can the path of resistance or recovery – or sometimes collapse. Costs can be assigned to the shocks and countermeasures, benefits to the subsequent development pathway and hence the different countermeasures assessed in terms of both costs and benefits.

The countermeasures that contribute to greater resilience can take many different forms, some social or economic, others technological, including:

- Institutional - land use zoning, warning systems,
- Economic - weather insurance, micro-credit schemes
- Physical - cyclone shelters, embankments
- Medical - vaccines
- Environmental - mangrove shelterbelts
- Agricultural - drought and flood resistant varieties
- Livelihood - income diversity, rural-urban linkages, ability to migrate
- Education - information and development of skills
-

It is useful to categorise the countermeasures on a time scale relevant to the incidence of the stress or shock (Figure 6.3)

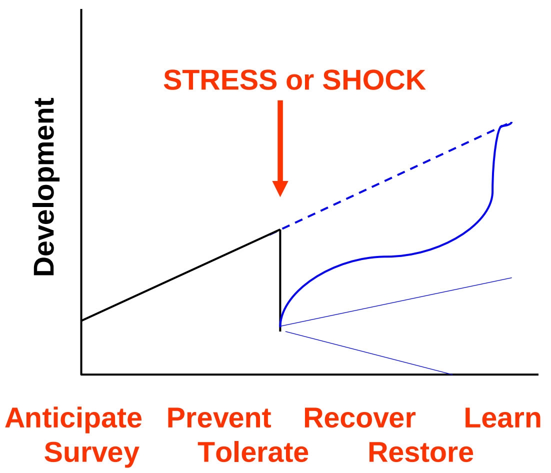

Figure 6.3 The timescale of countermeasure interventions

This conceptualization closely follows the steps taken in modern disaster management to cope with such hazards as earthquakes and cyclones. Developing resilience to climate change thus builds on the various approaches to disaster preparedness that have been successfully practised over the years.[81]

Forecasting and Surveys

Anticipation of stress and shock consists, in part, of a process of surveying to determine the likely location and probability of potential disturbances. Such inventories can be depicted as hazard maps, some on a large scale, often produced by government agencies. Figure 6.4 depicts the spatial hazard of drought for maize growing.

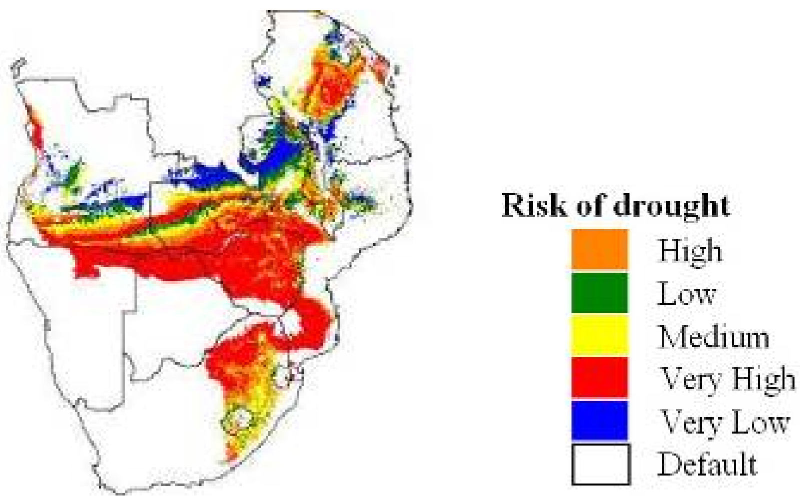

Figure 6.4 Risk of drought during the grain filling stage of maize in southern Africa[82]

81 ISDR 2003 *Disaster Reduction in Africa – ISDR informs*. UN Secretariat of the International Strategy for Disaster Reduction, Nairobi, Kenya, 55 pp
82 CIMMYT. *Atlas of Maize in Africa*. International Maize and Wheat Improvement Center (CIMMYT), Mexico

Other surveys, on a smaller scale, can be produced by local communities for their own planning. The advantage of these is that if a flood or other hazard arises, potentially affected communities can rapidly respond.

Anticipation also involves the production of long range weather forecasts which are then used to put in place adaptive measures. The UK Meteorological Office has been developing such forecasts for Africa. They are made possible because of the relationship between sea surface temperature (SST) and large scale weather patterns. The slow changes in SST can be predicted up to six months in advance (Figure 6.5).

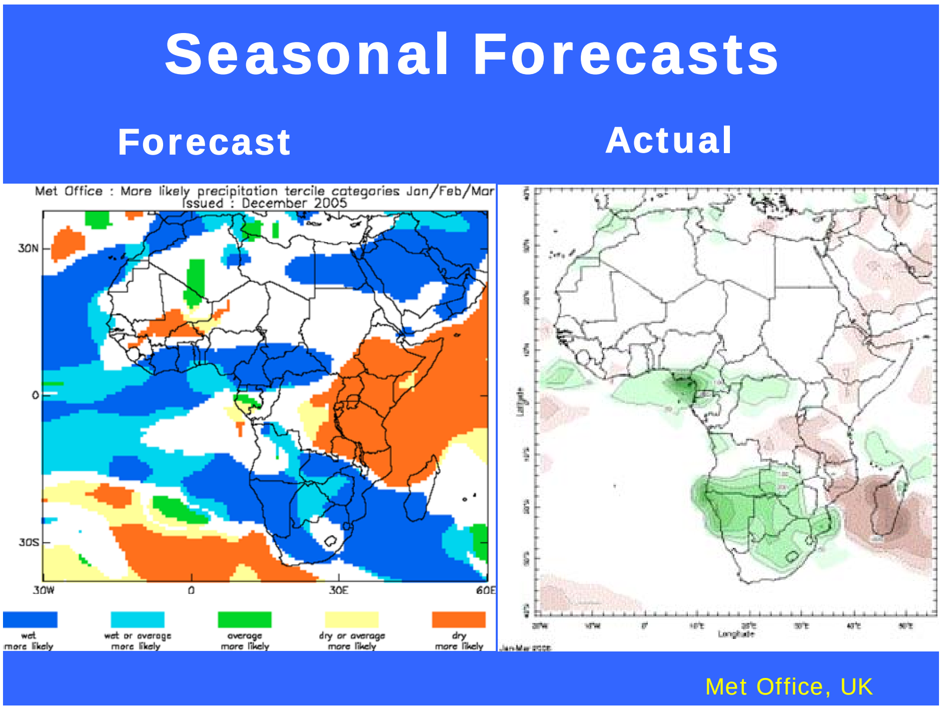

Figure 6.5 Long range forecast for Africa made by the UK Meteorological Office in December 2005 for the following three months and the actual outcome

Prevention and Tolerance

Drought can be prevented by various water harvesting and saving systems - devices, ranging from large scale reservoirs to village tanks with accompanying systems of delivery. The design and construction of such systems is relatively well known; often the challenge is to ensure they are sustainable and easily accessed by the poor as well as the rich.

Drought tolerance in agriculture usually is achieved by crop breeding (Box 6.2) or by the design of appropriate cropping systems (Box 6.3).

Box 6.2 The development of drought tolerant maize varieties

In recent years, the International Maize and Wheat Improvement Center (CIMMYT) has cooperated with national agricultural research systems, the private sector and farmers themselves to breed over 50 new varieties of maize, currently planted on over 1 million hectares in southern and eastern Africa. The varieties are typically tolerant of drought, low soil fertility, parasitic weeds and other stresses.

They were developed in a network of 'stress breeding sites' which involved 'mother-baby' trials. The mother trials, involving up to 12 varieties, were located close to the community and managed by schools, colleges or extension agents. The baby trials comprised 4-6 varieties in the fields of farmers who used their own inputs and equipments.

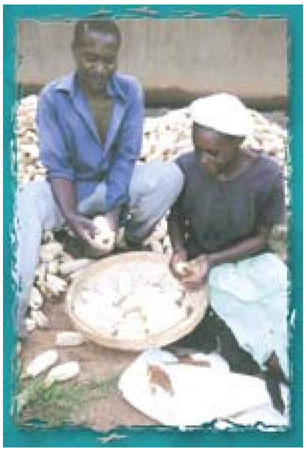

Figure 6.6 Assessing the harvest of a mother and baby trial

Box 6.3 Conservation Farming in Zimbabwe

It has become common if not standard practice, since colonial times, to till the soil with a moleboard plough before maize is sown. On the poorer soils, at least, this destroys the soil structure and increases water loss. Many argue that the practice is responsible for the long term decline in Zimbabwe's soil fertility.

The alternative is to minimally till the soil and leave the crop residues in place as mulch for the next crop (Figure 6.7). Prior to seeding, farmers use hoes to prepare small basins in which fertiliser (inorganic and/or manure) are placed followed by one or two maize seeds. One or two selective weedings may be needed but that is all.

Figure 6.7 Conservation Farming in Zimbabwe

The benefits begin in the first year. After three years they are dramatic. In one pair of plots in southern Zimbabwe the soils remain dry and sandy under conventional production but are moist and structured in the conservation plots. Yields are doubled – in some cases the conventional will fail altogether.

Figure 6.8 Conservation plots in Zimbabwe after 3 years. a) conventional tillage, b) minimum tillage

(In Zimbabwe the technology is being developed by CARE International, CIMMYT and ICRISAT)

Resilient Livelihoods

Experience shows that one of the best defenses against shock is to diversify the livelihood – to increase the diversity of crops and livestock on a farm or more generally to have a wider set of sources of income for the household. It means having another crop that will grow and survive if a drought or flood has knocked out one crop, or more generally having off-farm sources of income to complement the farm income should the latter be destroyed.

Local communities have often built resilience to disasters into their social networks and systems. For example, strategies for coping with drought often involve a diverse range of subsistence and income generating activities (Box 6.4).

Box 6.4 Drought coping mechanisms in Kenya.[83]

The Kitui District of eastern Kenya suffered from poor rainfall in 1995 and 1996 and ran out of food between the harvest in July of 1996 and the next harvest in February of 1997. Only two out of a random sample of 52 households had a maize crop that lasted them through this period.

The farmers,when interviewed listed a large number of coping activities:

- Skilled work
- Selling land
- Collecting honey for consumption and sale
- Making bricks for sale
- Engaging in food producing or money making group activities
- Business, such as selling snacks
- Burning charcoal for sale
- Salaries of householder or remittances
- Handicrafts for sale
- Selling or consuming exotic fruits from the farm
- Receiving credit
- Borrowing food or money from relatives
- Borrowing food or money from neighbours
- Engaging in casual labour
- Selling livestock
- Collecting indigenous fruit for consumption or sale
- Receiving food aid from government or other organisations

Each household averaged about six activities during the drought. After the drought this dropped to three but diversity remains a common feature of the livelihoods.

There are clearly lessons to be learnt from people who have had to cope with regular stresses. But such resilience has been steadily eroded away over recent

83 Eriksen, S. 2005 The role of indigenous plants in household adaptation to climate change: the Kenyan experience. In Pak Sum Low (ed.) op cit, pp 248-259

decades under the impact of migration, family breakdown, famine relief, poverty and disease, such that people have become much more dependent on outside aid.[84] A major challenge for governments, donors and particularly for NGOS is to help communities rebuild their resilient mechanisms. For example, many of the activities in Box 6.4 rely on the informal sector and governments can help by creating links to the formal sector and by providing skills, knowledge and access to markets.

Often women play a key role in creating resilient livelihoods. They may be primarily responsible for home gardens and for higher value vegetable and fruit crops that help to diversify the agricultural production. Skills such as weaving and handcraft manufacture can provide a source of income when agriculture fails. This stresses the importance of seeing livelihoods as a whole family affair involving both men and women and, as they grow older, the children. Any programme of enhancing livelihoods has to take this wider holistic view.

Learning

Finally, building resilience is about learning. Hopefully enough small scale stresses and shocks will be experienced by a country or a community to enable them to assess their planning and reactions and to understand the dynamics of resilience in their particular circumstances. This means putting learning processes into place at all levels, ensuring there is effective monitoring and developing a sense of collective responsibility. In the longer run, this will help to create a development process that is both resilient and self-learning, and hence sustainable.

Conclusions

There are some things we know about the impact of climate change on Africa. We know that northern and southern Africa will become much hotter (as much as 4-6ºC) and drier in the summer, with a much greater risk of drought. Wheat production in the north and maize production in the south will be adversely affected. In eastern Africa, including the Horn of Africa, and parts of central and western Africa average rainfall will increase. As a result, vector borne diseases such as malaria and dengue may spread and become more severe. We also know that sea levels will rise, perhaps by half a metre, in the next fifty years with serious consequences in the Nile Delta and certain parts of West Africa.

But there is much that we don’t know. The Sahel may get wetter or remain dry. The flow of the Nile may be greater or less. We don’t know whether overall the fall in agricultural production will be very large or relatively small. Part of our ignorance comes from a still poor understanding of the drivers of the African climate, their interactions and the effects upon them of global warming. Part also is due to a severe lack of local weather data, particularly for central Africa.

There are many other known unknowns. Will climate change experience tipping points, for example an accelerating and irreversible ice loss from the Greenland ice

84 Toulmin, op cit.

cap and the Antarctic shelf, resulting in much greater rises in sea levels? Will El Niño become a more permanent phenomenon with consequences for Africa's rainfall patterns?

There are also, probably, many unknown unknowns – potential tipping points that we are unaware of, zoonotic (animal origin) diseases that may erupt as a result of climate change.

This relatively poor state of knowledge has two implications: first we urgently need more research, into the dynamics of the global drivers on the one hand and into the detailed consequences at local levels; second we need to design adaptation measures to cope with high levels of uncertainty.

In general the best assumption is that many regions of Africa will suffer from droughts and floods with greater frequency and intensity. The implication is that we have to plan for the certainty that more extreme events will occur in the future but with uncertain regularity.

Adaptation thus depends on developing resilience in the face of uncertainty. The conceptualisation of resilience presented above is similar in many respects to the approach that has been long used in the face of natural disasters such as earthquakes and tsunamis. It begins with anticipation, surveying and forecasting, moves to developing preventative measures and increasing tolerance, and subsequently after the event or events focuses on recovery and restoration. At the end is the importance of learning. In general the more time and resources put into the earlier stages of this process, the better.

Resilience is important at both the national and local levels, involving not only technologies, but also appropriate economic policies and institutional arrangements. It is the poor who will be most vulnerable to the effects of climate change. To some extent the process of development itself will help them to adapt. If people are better fed and in better health, and have access to education, jobs and markets they will have the capacity to be more resilient. Traditionally poor people have developed various forms of resilient livelihood to cope with a range of natural and man made stresses and shocks. But these may be inadequate in the future or may have been lost in the development process. The urgent need is for governments, NGOs and the private sector to work together to build up the resilience of the poor of Africa.