Facing the Weather Gods

The Impacts of Climate Change in Africa

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Paul Johnston, David Santillo, Stephanie Tunmore,
Greenpeace Research Laboratories,
Innovations Centre Phase II
University of Exeter
Rennes Drive
Exeter EX4 4RN
UK

Dianne Mcalpine, Fiona Musana, Rianne Teule,

Greenpeace Africa
PostNet Suite 125
Private Bag X09, Melville
Johannesburg, 2109
South Africa

Greenpeace Research Laboratories Technical Review 1/2011

Executive Summary

Although the greenhouse gases responsible for climate change are uniformly distributed in the atmosphere, this does not mean that impacts will be uniform across the globe. The continent of Africa is treated as a single region by the IPCC in its reports, though in reality it has a huge landmass with many distinct climatic zones ranging from moist tropical equatorial systems through seasonally arid tropical to sub-tropical (Mediterranean) climates. These are in turn influenced by complex interactions between three major, globally significant drivers (the Inter Tropical Convergence Zone (ITCZ), the El-Niño-Southern Oscillation (ENSO) and the West African Monsoon), among others, interactions which remain only partially understood. Add to this the facts that weather and climate observation networks remain limited over much of the continent and that ground-truthing of climate models to the necessary local and regional scales is therefore severely restricted, and the picture is one of considerable complexity and uncertainty. This conspires against the formulation of robust, evidence based policies to address climate change across the African regions.

Nonetheless, it is certain that climate change impacts will occur, and they are expected by many scientists to be severe. Not only because of the direct negative effects, but because of the high reliance in Africa on agriculture coupled with a limited scope for adaptive strategies to be devised and implemented.

Based on projections such as those in the IPCC's 4th Assessment Report (AR4), it is thought very likely that the continent as a whole will experience higher temperature rises than the global average, becoming warmer and drier, but with the possibility of tropical cyclones becoming more intense and an overall greater variation in climate with more extreme weather events being recorded. There are some indications of increasing variance in rainfall across the global tropics as a whole, suggesting that extremes of wet and dry may be becoming more commonplace and that this may be an emerging "signature" of climate change. Overall, it has been estimated that access to surface water resources could be seriously impacted over around 25% of the continent.

Available model projections suggest important regional differences in climate trends and impacts. For example;

- In Mali, models suggest that mean annual temperature will increase by 1.2°C-3.6°C by the 2060s and up to 5.9°C by the last decade of the 21st century, with a significant increase in the frequency of hot days and nights. The country is expected to become progressively drier overall, especially in the north, with rain in the south being delivered in fewer days of higher rainfall.

- Similarly projections for Kenya suggest increases of 1.0°C-2.8°C by the 2060s and 1.3°C-4.5°C by the 2090s. Rainfall projections are uncertain but suggest an increase by up to 48%, though again with a greater proportion falling during shorter periods of intense rainfall.

- For South Africa, mean annual temperatures are projected to increase by between 1.1°C and 2.4°C by the 2060s and by 1.6°C-4.3°C by the end of the 21st century, with a marked increase in the number of hot days over the whole year. A small decrease in annual rainfall is projected but with wide variation across the country resulting from the climatic heterogeneity of South Africa.

As is therefore the case for physical factors affected by climate change, effects upon agriculture are expected to vary across the continent, but are likely to be most pronounced in areas where temperature and water availability are already major constraining factors. Africa is highly dependent upon rain fed agricultural production and, according to one recent global analysis, has the highest increase in risks of drought over the period to 2100 resulting in significant crop yield reductions. Many African crops including wheat, maize, groundnut and soybean are already grown close to the limits of their temperature or water stress tolerances. Low or unusually timed rainfall can severely impact the yield of crops, while unusually high but short duration temperature events can also decrease yields.

The uncertainties in the model outputs and the sometimes equivocal predictions for agriculture in Africa, where both positive and negative impacts are possible, are compounded by the limited perspectives encompassed by the models, which fail to take proper account of many of the non-climatic impacts that may take place. The IPCC AR4 also projects a variety of changes in African forests, with some gains and some losses, although the precise nature of the changes due to climate change is likely to be contingent upon changes in land-use, another highly important factor, until around 2050.

Traditional and supportive inter-relationships between pastoral communities and those involved in cultivation, which have endured and provided some level of adaptive capacity over many hundreds of years are already strained as a result of previous droughts. These may begin to breakdown altogether under additional stress of climate change and its impacts on water and grazing availability and the success of harvests. The pressures on families to migrate to urban areas may be expected to grow further, making the challenge of tackling poverty an even greater one. Although all members of subsistence communities may suffer as a result of rising temperatures and increased variability in rainfall patterns, women may be expected to experience disproportionate impacts in relation to further increases in responsibility and daily workload. For many African women and girls, the situation is exacerbated by lack of access to education, health and livelihoods.

© Greenpeace / Thomas Einberger. Tree in the rainforest. DRC 2008.

One consensus is that all African agriculture is potentially vulnerable to climate change and that responses in the form of policies and adaptation strategies need to be informed from a widened scientific and technical base. Regional increases in rainfall projected in some models might not produce unambiguous benefits while a substantial increase in drought severity and frequency would "most likely exacerbate and accelerate the current 'downward spiral' of underdevelopment, poverty and environmental degradation". Even under steady conditions, agriculture in Africa will need to undergo a fundamental shift in order to meet demands from a growing population and one that is becoming progressively more urbanized. Any such adaptation strategies will inevitably require a considerable degree of institutional support on a continent arguably the least well resourced to provide it and where climate change could rapidly foreclose many of the development options currently seen as realistic and achievable. In order to ensure such developments are equitable and sustainable, they will also need as far as possible to empower communities to adapt rather than increasing dependence.

In addition to highlighting once again the need for the global community to achieve urgent and deep cuts in greenhouse gas emissions in order to slow and ultimately reverse the slide into climate change impacts, this report identifies a number of other recommendations more specific to the ability of the African continent to prepare for and respond to committed change. These include:

- improving the scope, structure and resolution of climate models, supported by investment in monitoring capabilities, in order to record and project trends and events reliably at local and regional scales. Particular account needs to be taken of increases in variability and the frequency of extremes which may be the clearest signatures of impending abrupt and possibly irreversible changes;

- developing action plans in the face of considerable uncertainties on the basis that temperatures are expected to continue to rise in most regions of the continent and that rainfall patterns will become increasingly variable, unreliable and locally intense. This needs to take account of the fact that neither issues relating to human activity and development nor those relating to the response of natural systems to climate change can be considered in isolation;

- ensuring that efforts are focused where natural, social and agricultural systems are already under the most severe strain, building institutional support to develop solutions and assist adaptation. This must take special account of the particular needs of girls and women and ensuring that, as a result, communities become more, not less, empowered and able to meet their vital needs and those of future generations.

Introduction

Broadly speaking, weather is the mix of events (temperature, rainfall, humidity, wind) that happen daily in a given place on the planet, while climate is the average pattern of such weather events over many years.[1] It is now becoming ever clearer that global temperatures have risen and that they continue to do so, and that this is driving changes in climate and hence, in the weather events experienced at a regional level.

The Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (AR4) from 2007 is the most recent holistic scientific assessment. This made it clear that atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased in the atmosphere since 1750. The overall net effect of these increases in greenhouse gases has been one of warming over the globe as a whole, with the rate of increase thought to be unprecedented in the last 10,000 years. Global air and sea temperatures have risen, snow and ice have melted, and sea levels have risen as a result.[2] In turn, long term changes in climate have been observed in some areas including changes in rainfall/snowfall, heatwaves (leading to both droughts and flooding), changed wind patterns and more intense tropical storms. The frequency of such extreme events is predicted to increase in the future.[3] The IPCC AR4 concluded that in order to try and avoid the worst impacts of climate change it would be necessary to reach peak emissions by 2015.

Although the greenhouse gases responsible for climate change are uniformly distributed in the atmosphere, this does not mean that impacts will be uniform across the globe. The global climate varies regionally as a result of differences in input of energy from the sun which ultimately drives earth's climate processes. The atmosphere, the land and the sea surfaces react individually to this input, but also interact with each other and with the physical features of the region. Added to this is the possibility that some feedbackmechanisms may be provoked in regions distant from those in which climate processes are actually being forced. The picture is further confounded by the possibility that atmospheric and ocean circulation patterns may themselves be changed.[4] The amount of warming the world is likely to experience is the subject of much debate. 2°C was agreed by the Copenhagen Accord of 2009 as a temperature below which the most dangerous impacts of climate change could be avoided. Although it has been argued that even this limit is too high, the failure to adopt effective regulation of greenhouse gas emissions has raised the prospect that global temperatures could rise by 3°C-4°C during the 21st century.[5]

Although the continent of Africa is treated as a single region by the IPCC in its reports,[4] in reality it has a huge landmass extending from latitude 35°N across the equator to 35°S. The UN Statistics Division lists 58 countries (some of which are offshore islands) and subdivides these into the regions of Eastern Africa (19), Middle Africa (9), Northern Africa (8), Southern Africa (5) and Western Africa (17)[6]. Commonly, however, the term "sub-Saharan Africa" is used to denote all African countries except the Sudan and those of Northern Africa. The Sahel is the name given to the transitional country extending from the southern border of the Sahara desert to the tropical forests bordering maritime coasts.[7]

The population of the African continent is around 15% of the global total, 63% of whom subsist on less than $2US per day. Population is distributed as follows: The countries of Eastern Africa are home to 31.9% of the population, 12.4% live in Middle Africa, 20% in Northern Africa, 5.5% in Southern Africa and 29.7% in Western Africa. 18% of the population in Northern Africa live below the notional poverty line of $2US per day. In the other regions between 45% and 75% subsist on this amount or less.[8] The dependence of the regional economies on agriculture is high. It accounts for much of the economic activity, supporting 60% of employment and generating 50% of the GDP in some countries.[10] Agriculture, however can be precarious due to the variability of the climate. High temperatures, droughts and floods all contribute to potential food insecurity.

The climate of Africa ranges from the moist tropical equatorial systems through seasonally arid tropical and sub-tropical (Mediterranean) climates. These varied climates are characterised by degrees of variability over annual, decadal and multi-decadal timeframes, particularly in terms of rainfall.[9] The climate overall is subject to three major, globally significant drivers: the Inter Tropical Convergence Zone (ITCZ), the El-Niño-Southern Oscillation (ENSO) and the West African Monsoon. The interactions between these, and the influences likely to be brought to bear on them by climate change, are not well understood.[10]

Knowledge and observations are key to an understanding of African weather and climate. Not only is coverage of Africa well below the minimum recommended by the World Meteorological Organisation (WMO)[11], but the continent has one of the lowest data reporting records globally as evidenced in maps produced by the WMO. This suggests that substantial areas, in Central Africa particularly, are essentially un-monitored.[12 11] A further consequence of the poor coverage is that data are not available for ground-truthing of weather satellite observations. All these factors tend to conspire against the formulation of robust, evidence based recommendations to address climate change across the African regions.

Whatever the ultimate rise in global temperature, climate change impacts on Africa remain clouded by uncertainty. Some key drivers of African climate are poorly understood,[4] while the science base necessary to develop an understanding of climate processes in Africa remains poorly developed.[13 11] Nonetheless, it is certain that climate change impacts will occur, and they are expected by many scientists to be severe, not only because of the direct negative effects, but because of the high reliance on agriculture coupled with a limited scope for adaptive strategies to be devised and implemented.[14 11]

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The Major Climatic Drivers

The Intertropical Convergence Zone (ITCZ) appears on satellite images as a band of clouds, often thunderstorms which encircle the globe near the equator. These clouds are formed by air convection driven by solar heating together with the converging trade winds. As this air rises it cools and leads to intense rainfall on an almost daily basis. The ITCZ moves seasonally over land as a result of the tilt of the earths axis and the changing solar zenith. It moves north in the northern summer and south in the northern winter.[15] This drives the seasonality of rainfall in Africa and the ITCZ is largely responsible for rainfall occurring between latitudes of approximately 23.5° N and S.[16] The distance that the ITCZ moves seasonally is governed in part by differences in land and sea temperatures, and it moves a greater distance southwards in the central to eastern areas of the continent. As the ITCZ crosses areas twice, it gives rise to two wet periods. The degree of latitudinal movement also varies from year to year explaining some of the inter-annual variation in rainfall.[17]

The West African Monsoon (WAM) is another important climate driver in Africa. The heating of the land causes air above the Sahara to rise, drawing warm moist air in from the sea 1000km to the south. This south westerly airflow then generates rainfall over parts of West Africa from April to June. In mid-July, the rainfall maximum moves suddenly northwards following the movement of the ITCZ. This movement is related to easterly atmospheric waves, which in turn are associated with the ITCZ. The precise relationships are not well characterised.[17 18 19 20]

The third major global driver of African climate is the El-Niño Southern Oscillation (ENSO), a phenomenon which takes place every three to seven years. Although centred in the Pacific, it nonetheless influences not only African Climate but climate all over the world. It involves a close coupling of the ocean and atmosphere. Usually, the coupled system leads to extensive rainfall over the western Pacific with the east staying relatively dry. When this pattern is reversed during an El-Niño event, more rain falls in the east and droughts occur in SE Asia and Australia. The term "La-Niña" describes an extreme version of the baseline situation with very dry conditions in the eastern Pacific. During an El-Niño year it is usually wetter in Eastern Africa and drier in the south with a dry Sahel. East African floods resulted from the very strong 1997 /98 El-Niño event while the 1998 La-Niña period which lasted until 2000 was associated with serious floods in the Sudan and Sahel, and also in Mozambique.[21] In Ethiopia, rainfall appears to be suppressed during the El-Niño phase of an ENSO event and increases during the cold La-Niña phase, but there are also other drivers involved, including monsoon flows.[22] A La-Niña event was also associated with the 2007 flood in sub-Saharan Africa together with unusually high tropical Atlantic temperatures and changes in the West African Monsoon flow. Although the precise interactions of these potential drivers are uncertain, overall this event illustrates the potential complexity of the forcing factors which could possibly be involved.[23]

The predictability of the climate drivers and understanding of the way in which they are likely to interact, is poor. Even with ENSO, considered the most predictable of the short term fluctuations in global climate systems, there is significant room for improvements in understanding and predicting it.[24] In addition, while the influences of ENSO on African climate are known, other significant forcings may exist such as the sea surface temperatures in the Atlantic[25] - this factor has been linked to persistent droughts in West Africa in the historical record.[26] It has also been suggested that precipitation in tropical east Africa is more closely linked to sea surface temperatures in the Indian Ocean than to the ITCZ or ENSO.[27] Moreover climate models do not function well in teasing out the relationships between these factors. As an example, according to one study, eight of eighteen models used by the IPCC in AR4 fail to incorporate the West African Monsoon as a driver of climate in the region.[19] Nonetheless, given the geographical extent of Africa, the range and diversity of climatic conditions and the complexity of the climatic drivers, the impacts of climate change in Africa are also likely to be diverse and complex.

© Greenpeace / Jennifer Heslop. Self-help project to support Rusinga Island, Kenya 2000.

Projected and Observed Temperature and Rainfall Changes in Africa

Despite the considerable data gaps, projections of how temperatures are likely to rise in Africa, and the impact of this warming on rainfall patterns in the coming decades, have been made using mathematical climate models.[4] It is thought very likely that the continent as a whole will experience higher temperature rises than the global average. This is true of all seasons, and the drier subtropical regions will warm more than the tropical areas. Overall, it is possible that both Northern and Southern Africa will warm by more than 4°C and suffer a 15% reduction in rainfall over the coming century.[17] The likelihood of decreased rainfall in Mediterranean Africa and the Northern Sahara is high, with decreases predicted to become more acute towards the Mediterranean coastline. A likely decrease in rainfall in Southern Africa is also predicted. Increased rainfall in East Africa could lead to the spread of vector borne diseases although there may be some benefits to agriculture. Rainfall may also increase in central Africa. Critically, however, future rainfall patterns in the Sahel and Southern Sahara remain somewhat uncertain together with areas of West Africa.[28] The overall changes, however, are broadly captured in Chapter 11 of the 2007 IPCC 4th Assessment Report[4] (see, in particular, Figure 11.2).

In general terms, therefore, Africa will become warmer and drier, but with the added possibility of tropical cyclones becoming more intense and an overall greater variation in climate with more extreme weather events being recorded. In addition to these climate changes, sea levels are projected to rise by around half a metre by the end of the 21st century. This could have serious impacts on deltaic regions (e.g the Nile) and low lying coastal regions such as those in West Africa.

The broad brush predictions mask the details of what may happen at more local levels. Many of the models in use do not have sufficient resolution to predict these local effects, and "empirical downscaling" of models has been used to try and predict impacts more precisely. The use of such techniques depends upon having a good database of observations. As noted earlier, this is not the case over much of the African continent. Even in areas where the model projections suggest a relatively unchanged average rainfall, this may mask substantial changes in the actual pattern of rainfall and in its extremes. It is possible that rainfall could become concentrated into fewer, but heavier events.[29] There are some indications of increasing variance in the observations of rainfall across the global tropics as a whole, suggesting that extremes of wet and dry may be becoming more commonplace and that this may be an emerging "signature" of climate change.[30]

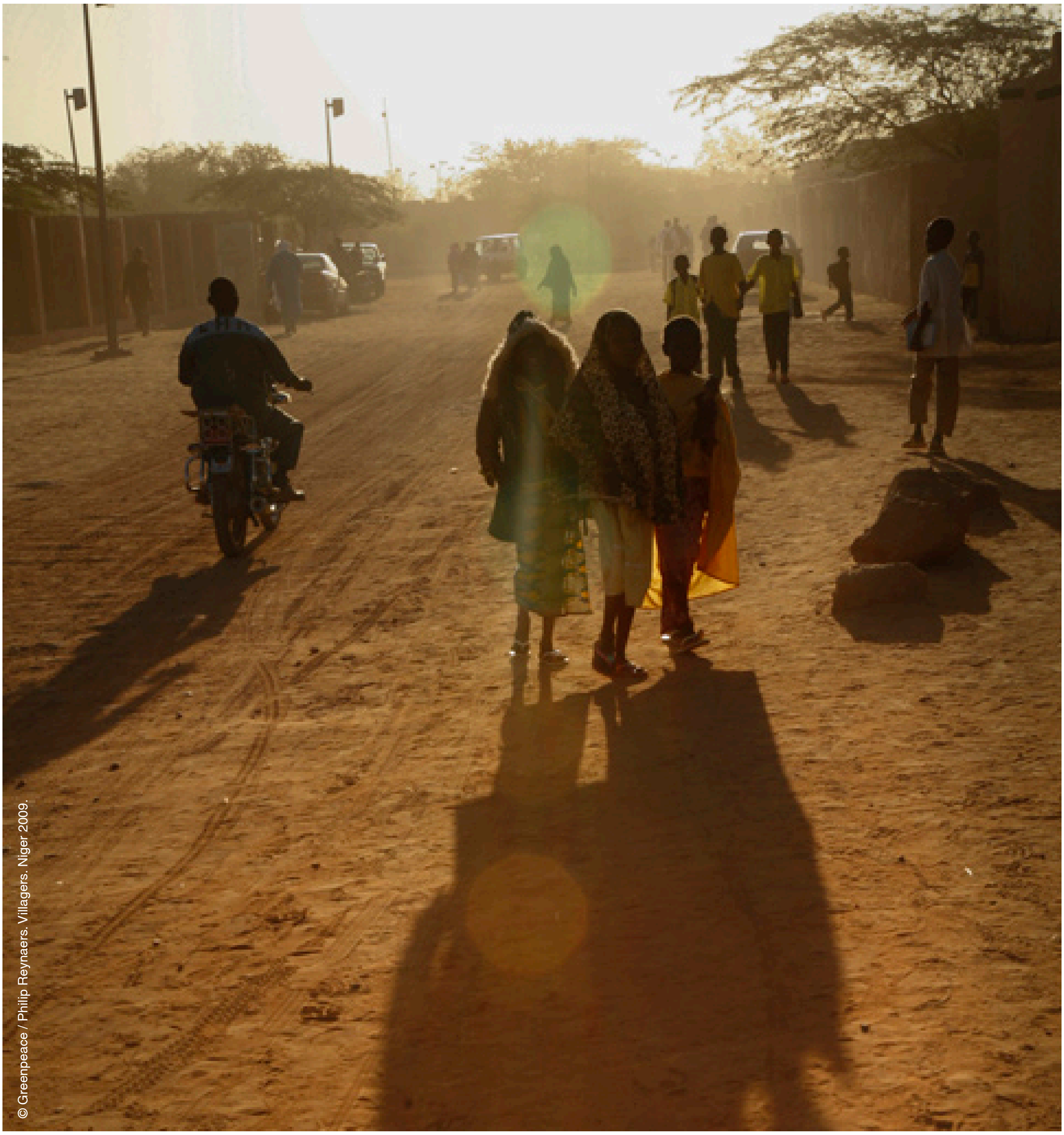
The data that do exist specific to Africa suggest that warming has corresponded with that recorded in the global datasets of around 0.5°C per century. There is some evidence that the continent may be warming faster than the global average. The greatest warming has occurred between approximately 1910-1930 and again after around 1970.[9] The IPCC AR4 suggests that accelerated warming has been occurring since the 1960s but that warming trends are not uniform, with a rise of 0.29°C every ten years recorded in African tropical forests and 0.1°C-0.3°C in South Africa.[31] In some coastal and lakeside locations in Eastern Africa a trend of decreasing temperatures has been observed. The number of warm spells has increased over southern and western Africa with a decrease in the number of very cold days.

A complicated picture emerges in relation to rainfall which as noted earlier is subject to considerable variability in both time and spatially. It appears, however, that in West Africa rainfall declined by 20%-40% between 1931-1960 and 1968-1990, with lower declines in the tropical forest regions. Over the last 30 years, however, a 10% increase has been observed along the coast of Guinea.[31] No long term trend has so far been noted for southern Africa although in some areas there has been a significant increase in heavy rainfall events. There is some evidence too of changes in seasonality and extreme weather. In eastern Africa, increasing rainfall over the northern sector has been accompanied by a decrease over the southern sector. Evidence has also emerged of later starts to the wet season over Africa as a whole despite the confounding effect of interannual variation. Starting in 1978 and taking observations through to 2002 it was found that the wet season began on average some 9-21 days later (depending on the definitions used) over the 25 year period, with some locations showing a delay of 4 days per year.[32] Overall, it has been estimated on the basis of predicted changes in precipitation and a resultant decrease in perennial drainage flows, that access to surface water resources could be seriously impacted over c. 25% of the continent as a whole.[33]

The Sahel countries also present a complex picture considered as a group. Modeled projections have reached differing conclusions about whether rainfall will increase or decrease and what sub-regional changes may evolve as a result.[4 31 54 40] Increased soil temperatures may increase evaporation of water from soils, increasing the impacts of lessened rainfall and negating any beneficial impacts of precipitation increases.

Attempts to analyse the projected impacts of climate change in Africa can, therefore, result in a broadly generalized overview lacking specificity. Accordingly, any predictions need to be carefully qualified and the inherent uncertainties made explicit. More focused overviews have been made on a sub-regional basis and these can serve to illustrate the more specific potential temperature and rainfall impacts facing African countries. The UNDP has produced a number of country profiles for Africa based upon available data and projections. These are designed to make existing data more readily available and accessible and to facilitate the dissemination of data. This is particularly important in the many areas of Africa where scientific and technical infrastructure related to climate change are not well developed.[34]

Mali, Kenya and South Africa represent examples of countries with different climatological characteristics and are likely to face differing spectra of impacts under progressive climate change. The following information has been mostly distilled from the UNDP reports.



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a) Projected and observed temperature and rainfall impacts in Mali

Mali is a West African country, north of the equator between 10°N and 25°N which straddles the Sahel. The northern part of the country extends into the Sahara desert while the south is wetter and more tropical. The movement of the ITCZ strongly influences rainfall which averages 300mm per month between June-October. Little rain falls from November to March and in the wet season rainfall falls markedly with increasing distances northwards in the country. The northern most regions of the country are desert with very low annual rainfall. The average rainfall figures also conceal a substantial inter-annual variability caused in turn by the varied movement of the ITCZ from year to year across the latitudes. Seasonal temperature variations are large and greatest in the north although annual mean temperatures are consistent at 27°C-30°C.

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Recent trends in climate have been observed, the best characterized of which is an increase in mean annual temperature of 0.7°C since 1960. The rate of increase has been most pronounced in the hot season from April to June at with an average rise of 0.25°C each decade, but with no evidence of such a trend in the very dry months between January-March. There have been more hot nights between 1960-2003 (average 55 annually) except between December-February. There has also been a decrease in cold summer days and in cold nights across all seasons except winter which falls in December to February.

In relation to rainfall, identification of the long term trends is confounded by the normally high inter-annual and inter decadal variability. The 1960s were characterised by high rainfall while the early 80s were dry in Mali and other Sahelian countries. This was followed by an increase in rainfall and relatively wet periods through the late 90s onwards. Overall, the annual five day rainfall maxima have decreased since 1960, with the largest decreases observed in the wet season from June-August. Global Climate Model (GCM) predictions indicate that mean annual temperature will increase by 1.2°C-3.6°C by the 2060s and up to 5.9°C by the last decade of the 21st century consistently across Mali with a significant increase in the frequency of hot days and nights.

The available projections generally suggest that rainfall will decrease although there is uncertainty in the figures. Both north and south of the country will be affected by decreases, with the largest decreases in total rainfall occurring in the southwest of the country in the wet season. Heavy rainfall events are projected to increase in the south but decrease in the north with a less certain trend towards more intense events. This generally translates to Mali becoming drier overall and with rain in the south of the country being delivered in fewer days of higher rainfall, and more evenly (but very reduced) in the north.

Beyond these broad observations (in themselves subject to considerable uncertainties), any projections for Mali are held hostage to the huge uncertainties that are associated with the drivers of climate change and the wide variation in the output of climate models.

b) Projected and observed temperature and rainfall impacts in Kenya

Spanning the equator between 6°S & 6°N latitude in Eastern Africa, Kenya's climate is tropical but modified by the topography which ranges between coastal plains and highlands. Annual mean temperatures in the high areas (15°C) are cooler than the coast (29°C) with an overall seasonal fall of around 2°C in the coolest months between June and September.

Rainfall is largely driven by movement of the ITCZ which causes the "short" rains between October-December as it moves southwards and the "long" rains between March and May, two distinct rainy seasons. Local rainfall varies between 50 and 300mm per month. The timing and intensity of the rainfall varies significantly between years. The rains are influenced by Indian Ocean temperatures and by ENSO events.

Over the period since 1960, an overall temperature rise of 1.0°C has been recorded (average 0.21°C) per decade, with the highest average rise recorded for the hot months of March-May. Significantly increased frequencies of hot days (March-May) with much larger increases in the occurrence of hot nights (September-November) has been noted over the period 1960-2003. In addition the frequency of cold nights annually has decreased in all seasons.

By contrast, rainfall figures appear not to show any particular trends since 1960, although there are indications that the proportion of rain falling in heavy events may be increasing daily, but other calculations show no consistent trends.

In terms of future trends, estimates of a temperature increase of 1.0°C-2.8°C by the 2060s and for 1.3°C-4.5°C by the 2090s have been made, with increases in the frequency of hot days and nights and considerable decreases in the number of cold nights. Even though no trends in rainfall in Kenya have been unequivocally observed as yet, projections suggest that rainfall is likely to increase by up to 48% with the largest increases taking place in October-December but with proportional increases greatest in January and February. A greater proportion of rainfall is likely to fall in more intense events, with both 1 day and 5 day rainfall maxima increasing significantly.[36]

The likely impact of ENSO events, particularly upon interannual variability of rainfall in Kenya can be very high. The future frequency and intensity of ENSO events remains highly uncertain[4] and this introduces a key element of uncertainty into climate projections for the country.

© Greenpeace / Jennifer Heslop. Masaii herdsman with cattle. Kenya 2005.

c) Projected and observed temperature and rainfall impacts in South Africa

South Africa is subtropical (22°-34°S) and its climate is mostly influenced by the Indian and Atlantic Oceans coupled with its varied topography. This is reflected in temperatures which range from below freezing at higher altitudes in winter to 32°C in more low lying areas in summer. As a result of warm ocean currents moving southwards along the eastern coast and cold water moving northwards along western coastlines, a temperature differential of around 5°C exists between east and west at any given latitude. Convective rainfall driven by moist air from the Indian Ocean occurs in summer (November-March) in the east while in the southwest rain falls mainly in winter (May-August). There is a strong difference in the quantities falling in the west and east of the country. The northwest has less than 200mm annually while the east may receive more than 500mm. Rain-fed agriculture is bounded approximately by the limits of the 200mm rainfall zone. Rainfall is influenced by ENSO events and other unusual sea surface temperature conditions in the Indian and South Atlantic oceans.[37]

Mean annual temperature averaged over the whole of South Africa has increased by around 0.6°C between 1960 and 2006 at an average rate of 0.14°C per decade, with observed daily temperatures trending towards greater extremes. Over March-May, the average number of hot days per year has increased significantly as have hot nights. At the same time mean rainfall has decreased by 1.5mm per month each decade since 1960, with the greatest decreases recorded for the months March-April. No trends have been identified in extreme rainfall over this period.

Mean annual temperatures are projected to increase by between 1.1°C and 2.4°C by the 2060s and by 1.6°C-4.3°C by the end of the 21st century, with a marked increase in the number of hot days over the whole year, but particularly between December to February. Decreases are projected in the number of cold nights. A small decrease in annual rainfall is projected but with wide variation across the country. Extreme rainfall events are projected to show only small changes. These projections, however, are circumscribed by considerable uncertainties attached to the future occurrence of ENSO events. Downscaling has suggested that summer rainfall could increase in the South African interior and in the east in summer, and decrease in the west.[38] Even so, the role of temperature related soil drying as an offset to any increased rainfall could act negatively upon agriculture.

Finally, the coarse resolution of the climate models used to make the projections are unable to accurately simulate processes at a level allowing projection of impacts at a regional or sub-regional level. Given the climatic heterogeneity found in South Africa these resolution difficulties are of considerable importance. For example, it has been suggested that both the arid interior and wetter north eastern regions of the country could experience increased evapo-transpiration and more frequent flood events, while the south west could experience earlier winter weather front activity and increased rainfall over high areas.[39] Together with temperature related impacts this could translate into a multiplicity of changes in agricultural production, biodiversity, water resources and human health across the country as a whole.

© Greenpeace / Shayne Robinson. Kusile Power Station in the Delmas municipal area. South Africa 2011.

Extreme Weather Events

The IPCC has recently published the Summary for Policy Makers of a Special Report on the subject of extreme weather events. The main body of the report is due for full publication in early 2012.[40] The IPCC notes that a changing climate (driven by a 2°C-4°C temperature rise) will lead to changes in the frequency, intensity, spatial extent, and duration of extreme weather and climate events. Some such events may prove to be unprecedented in their intensity. This report is the first major overview of the subject to be published since the IPCC AR4 and can be used to gauge to what degree the science of climate change has evolved specifically in relation to Africa over this period.

The report points out that not all extreme weather causes extreme impacts (or disasters) and not all disasters are caused by extreme weather. Extreme impacts can be the result of a single extreme event, successive extreme or non-extreme events, including non-climatic events (for example, wildfire, followed by heavy rain leading to landslides and soil erosion), or simply the persistence of conditions, such as those that lead to drought. Nonetheless, the changes projected in the report, in the context of increasing vulnerability, will lead to increased stress on human and natural systems and a propensity for serious adverse effects in many places around the world.

With the above *caveat* in mind the study notes that, on a global level, it is likely that there have been statistically significant increases in the number of heavy precipitation events in more regions than there have been statistically significant decreases. There are strong regional and subregional variations in the trends. It is likely that there has been an increase in extreme coastal high water. Heavy precipitation or the proportion of total rainfall from heavy falls will increase in the 21st century over many areas of the globe and heavy rainfalls associated with tropical cyclones are likely to increase with continued warming induced by enhanced greenhouse gas concentrations.

The report also notes that it is very likely that there has been an overall decrease in the number of cold days and nights, and an overall increase in the number of warm days and nights, on the global scale, i.e., for most land areas with sufficient data. It is likely that these changes have also occurred at the continental scale in North America, Europe, and Australia. There is medium confidence of a warming trend in temperature extremes in much of Asia. Confidence in observed trends in temperature extremes in Africa and South America generally varies from low to medium depending on the region. Globally, in many (but not all) regions with sufficient data there is medium confidence that the length or number of warm spells, including heat waves, has increased since the middle of the 20th century. In the future, the report finds that it is virtually certain that increases in the frequency and magnitude of warm daily temperature extremes and decreases in cold extremes will occur through the 21st century on the global scale. It is very likely that the length, frequency and/or intensity of warm spells, including heat waves, will continue to increase over most land areas.

Finally, mean tropical cyclone maximum wind speed is likely to increase, although increases may not occur in all ocean basins and it is very likely that mean sea level rise will contribute to upward trends in extreme sea levels in the future. There is high confidence that locations currently experiencing adverse impacts such as coastal erosion and inundation will continue to do so in the future due to increasing sea levels, all other contributing factors being equal.

Specifically in relation to Africa, relatively few projections are made for the continent. Confidence in the evidence for emerging trends in possible extremes of e.g. temperature is currently not high, and this is partially to do with poor data coverage. There is medium confidence that West Africa has experienced more intense and longer drought phases although projections are hampered by the equivocal output from the climate models used. In southern Africa, the report points to the possibility of intensified droughts, and while observation of trends in heavy precipitation is hampered by poor data, it is thought likely that heavy events will increase in East Africa.

Overall, therefore, in relation to Africa, the report points to a number of potential risks, but it is acknowledged that the confidence in projections is eroded by equivocal model outputs and poor data quality. It is clear that few advances have been made in resolving the key uncertainties for Africa since the IPCC AR4 was published in 2007.

Potential Impacts of Climate Change on Agriculture in Africa

Climate change is expected to particularly impact on the agricultural smallholder operations which predominate in Africa. Like physical factors affected by climate change, effects upon agriculture are likely to vary across the continent, but are set to be most pronounced in areas where temperature and water availability are already major constraining factors. The drylands (excluding deserts) of Africa comprise around 43% of the land surface and support a rapidly growing population of around 325 million people.[41] 12 of the 20 most disadvantaged countries in the world are in these dry areas of Africa.[43] Among the population, women often play a dominant role in growing and marketing crops and in supporting their families.[42]

Broadly, in the semi-arid regions of Africa the small cropping operations (with animals) interface with more arid regions where crop production is highly marginal or simply not possible. In these more arid regions pastoral activities predominate and rely on the natural rangelands to graze livestock. For the pastoralists, an integral part of the "coping" strategy in times of drought are their linkages with the less vulnerable semi-arid areas.[43] Nomadic/transhumant pastoralists have long been a feature of African agriculture.[44] This flexible strategy for using the land is mirrored in similar flexible strategies employed by cultivators to cope with the uncertain and high risk environments in which both communities live. Both are likely to be seriously impacted by climate change and both have limited scope for adaptation given the current socio-economic conditions. It is unclear whether the supportive inter-linkages between the pastoralists and cultivators will survive extensive climate change particularly given ongoing changes in land rights in various of the key countries. These changes tend to favour cultivators.[42 43]

Most models forecast reductions in the length of the growing period and although of different magnitude across the continent, these are projected to be most severe in the more arid regions. A varied increase in the percentage of failed seasons is likely in most areas of the continent.[45] Even under steady conditions, agriculture in Africa would need to change. The current model of agricultural production would need to evolve to meet demands from a growing population and one that is becoming progressively more urbanized. African agriculture is perceived as one which "struggles to meet the challenges of a changing global society"[46] and hence one in which climate change impacts are likely to be severe and, therefore, of major concern. Africa is highly dependent upon rain fed agricultural production, (around 90% of cereal production in sub-Saharan Africa is rain fed[42]), and according to one recent global analysis has the highest increase in risks of drought over the period to 2100 which would result in significant crop yield reductions.[47]

The Sahel region is considered particularly vulnerable to climate change as a result of its geographic location to the south of the Sahara Desert and the high dependence on rainfed cropping and livestock. Three major discrete drought episodes were recorded in the 20th century, the most recent of which was an extended period of declining rainfall, punctuated with drought years, which spanned the 1970s through to the 1980s, ending in 1988.[7] In addition to causing around an estimated 100,000 deaths (probably a highly conservative figure) the prolonged dry period provoked unprecedented mass migrations and accelerated the process of urbanization. It was reported that significant tracts of land had become desert. Since the return of "normal" rains, remote sensing studies have shown that the Sahel has "greened".[48] Based on coarse resolution satellite imaging, it is not clear from the study whether the previous vegetation types have returned, or have been superceded by different types. In any case The IPCC AR4 cautions against taking this as initial evidence that the Sahel will become wetter as a result of climate change[4].

The IPCC AR4 suggests that areas of arid and semi-arid land in Africa could expand by 5-8% (60-90 million hectares)[31] and that there will be a reduction in the amount of suitable rain–fed land for cereal production by the end of the current century. Some studies cited by the IPCC have predicted that wheat production could disappear from Africa altogether by the 2080s. In any case, an increase in ENSO events could result in significant reductions in maize production while changes in rainfall patterns could impact on the maize growing season in the southern African maize belt.[49]

Against these negative impacts, it is thought that some areas of Ethiopia and Mozambique could experience longer growing seasons and increases in agricultural production, but even with such an increase, coupled with adaptation measures, cereal production in 40% of Sub-Saharan Africa could be severely reduced. In line with predictions of changes in rainfall, the most severely affected lands are likely to be those where water stresses are already an important driver of agriculture.[50]

The extensive Saharan and Southern African sand dune systems which cover 30% of the continent are currently inactive and not moving. They are used for both pastoralism and agriculture and could become reactivated as an impact of climate change. For example modeling has shown all dune areas in southern Africa will have become highly dynamic from northern South Africa through Angola and Zambia by 2099.[51]

If global temperature rise exceeds 4°C, then evidence from downscaled climate models suggests that most of

Africa below the equator will experience at least a 20% reduction in growing season length. There is, however, a marked variability in the output from the models used, with considerable uncertainties as to how this may unfold in West Africa and in parts of Southern Africa. In east Africa length of growing season could increase slightly. Overall, a 5°C global rise could cause rain fed agriculture in southern Africa below latitude 15°S to fail one year in every two.[52] When the yields of representative crops (Maize, beans, and forage grass) are estimated for central, east, west and southern sub Saharan- Africa, then consistent declines in maize yield per hectare of 13-23%, and in bean yields of 47-87% are reported. Pasture grass is least affected with yields changing by between +11% and -6% in the different regions. All estimates assume that consistent planting patterns are maintained. In east and southern Africa it is estimated that under these conditions some 35% of current crop growing land could become unfit for purpose because cultivation would become too risky.

Significant areas of more marginal lands are likely to be forced out of production even under scenarios less extreme than a 4°C temperature rise. Many African crops including wheat, maize, groundnut and soybean are already grown close to the limits of their temperature or water stress tolerances.[17] Low or unusually timed rainfall can severely impact the yield of crops, while unusually high but short duration temperature events can also decrease yields. It has been estimated that a 2°C-3°C rise in temperature relative to the long term mean could result in a reduction in yield of millet between 20 and 40%.[53]

There is also the possibility that crops could respond differently in different areas of their current growing range. A modeling exercise carried out for maize in three different areas in South Africa suggested that under the influence of raised temperature, changed rainfall and elevated CO_2, maize crops would show a potentially complex and variable response in terms of yields, with overall nitrogen loss from the soils in all cases. At a 3°C rise, projected yields began to decline in all the areas modeled.[54]

Climate change is also likely to result in significant changes to Central and West African forest cover with studies predicting both increases and declines. According to one study, by the end of the 21st century, even in the absence of anthropogenic deforestation, modeling has predicted that tropical forests will be much less extensive, with a lower leaf area index and an increased presence of deciduous as opposed to evergreen forest trees.[55] In addition, this will give rise to other impacts such as reduced runoff and reduced net primary productivity. The limit between savanna and forest is projected to move southwards together with the boundary between savanna and grassland. This in turn could lead to increased wildfires. At the same time, pressure on forests is likely to increase as a result of increasing marginality of cultivation and pastoral agriculture in regions to the north.[56] The IPPC AR4 projects a variety of changes in African forests overall, with some gains and some losses, although the precise nature of the changes due to climate change is likely to be contingent upon changes in land-use, another highly important factor, until around 2050.[57] A recent modelling study of global humid tropical forests suggested a robust projection of increase in such forests in the Congo basin, although the tension between climate change impacts and other anthropogenic factors may undermine the reality of this projection in the real world.[58]

The uncertainties in the model outputs and the sometimes equivocal predictions for agriculture in Africa where both positive and negative impacts are possible, are compounded by the limited perspectives encompassed by the models. They fail to take account of many of the non-climatic impacts that may take place. The consensus, however, is that all African agriculture is potentially vulnerable to climate change and that responses in the form of policies and adaptation strategies need to be informed from a widened scientific and technical base.[45]

The Social and Economic Implications of African Climate Change

Studies of potential climate change impacts upon African societies and their economies have focused largely on the dryland areas (principally the Sahel and areas of southern Africa). These are the areas where it is thought that the major impacts of climate change upon agriculture will be felt. Sixteen of Africa's least developed nations have the majority of their agricultural lands in semi-arid regions and produce a diverse array of crop commodities. These include some that are grown in wetter areas of the countries concerned, and some that are grown under irrigation. Maize, sorghum and millet are the most important cereals in the least developed countries. Maize is the most important cereal crop for the continent as a whole (including for export purposes), 95% of which is grown on holdings of less than 10 hectares, with yields ranging between around 0.8 tonnes per hectare in western Africa countries (used mostly as a subsistence crop), to 10 tonnes per hectare in suitable growing areas in southern Africa. In southern Africa, considerable expansion of maize cropping has taken place in those countries with water resources to support it. Millet and sorghum predominate as staples in the Western Sahelian countries and Sudan, 75% of this as a subsistence crops consumed directly by the households producing them.[59] After cereals the second most important crop group by value is oilseeds, some of which are traded on international markets. In addition to the staple cereal crops, the drylands produce fruits, nuts, pulses, vegetables poultry and livestock, sometimes on commercial scales.

As noted earlier, livestock production as a pastoral activity is important in many dryland areas. Beef, sheep and goat herding, with mobile grazing of the stock on open rangelands, is the most common practice within the African production system. There are around 50 million pastoralists (some of whom also grow crops) in sub-Saharan Africa, 40% of whom are already malnourished.[49] The Sahel and south-eastern African pastoral systems are essentially an adaptive strategy to these high risk/low rainfall areas. These areas would otherwise remain unexploited. Sheep and goats provide almost 40% of the meat produced in the drylands of the least developed nations and are reared because they respond well in harsh conditions. All livestock species reared in drylands have been selected more for hardiness than for milk or meat production. It is estimated that between 25 and 55% of African pastoralists live below the extreme poverty line, a position which appears to be getting worse.[58 1]


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The Sahelian environment is a harsh environment in which to live and work. Some areas have a rapidly growing population which is acting as a major environmental stressor in its own right. In the West Sahel it has been suggested that the increase in rainfall projected in some models might not produce unambiguous benefits while a substantial increase in drought severity and frequency would "most likely exacerbate and accelerate the current 'downward spiral' of underdevelopment, poverty and environmental degradation".[60] Human coping strategies could lead to additional pressure on resources and increased land degradation and desertification. There is an urgent need, therefore, for uncertainties in the models to be resolved in order that adaptation and response systems can be put in place, insofar as this is possible.

Overall, many of the climate change scenarios projected for the future involve marked changes to the hydroclimatic regime in Africa, most of which are likely to result in increased variability and intensity of rainfall. Concomitantly, this increases the risks of participating in what are already quite marginal agricultural enterprises by increasing the possibility of droughts or floods. Overall, the situation has been described as one in which "the cumulative effects of drought and other traps lead to a poverty trap of highly vulnerable low productivity subsistence level agriculture".[61] Even in areas where climate impacts are projected to be less severe (such as in East Africa where an increase in rainfall is predicted by many models), there are few grounds for complacency. The details predicted by the modeling may well prove to be incorrect or inaccurate. Food security is a significant problem even in the absence of drought. The possibility of migration of large numbers of people and livestock into less impacted areas, thereby causing issues of over-exploitation is a very real one in East Africa and elsewhere. This happened in 1997 in Tanzania.[62] Overall, therefore, climate change in Africa threatens human security in the broadest possible sense of the term.[63]

Models have projected that growing season failures are likely to increase in all cropping systems in Africa in the years to 2050, except in hyper arid range lands and in irrigated systems. In some cases these changes are marked. The major zones affected are widely spread through east, west and southern Africa and it has been suggested that one possible adaptive strategy is a transition from cultivation to livestock keeping.[64] In addition to the migration (transhumance) involved in dryland livestock rearing, it is possible that climate change could provoke migration as an adaptive response in itself, depending upon the degree of exposure to climate change. Migration is historically well established as a human adaptive response to inimical conditions and includes known examples from Africa.[65 66] The likely benefits of migrating to urban environments are questionable given that around 43% of urban dwellers in Africa live in poverty and this rises to 50% in some of the countries considered most at risk from climate change.[67]

Migration, in common with other adaptive strategies, is likely to have disproportionate impacts upon women under many of the climate change scenarios projected for Africa. Although men are responsible for decision making and planning, and women have little authority, they nonetheless play a key role in producing food and livestock and gathering fuel, animal feed and water. They also play a significant role in diversification initiatives. In short, as lands become degraded, women tend to assume more work and more responsibilities. This is often a result of the men migrating to urban areas leaving the women behind. While this may lead to women taking more responsibility, perhaps also securing changes in control of resources and land rights, any apparent improvements are set against a background of an increased workload.[41] In the pastoral communities, selling of animals is mainly a male preserve, and the involvement of women in inter alia selling of milk, firewood/charcoal or the brewing of alcohol are lower status and less rewarding activities, and in the latter two cases are generally illegal. The specific impacts upon women need to be taken into account when formulating adaptation strategies to climate change in Africa.[68]

The question of future human and animal health in Africa is also a germane one under projected climate change. Much of the debate on this issue has focused around malaria transmission and the results have been somewhat equivocal to date.[66] Nonetheless, there are grounds for concern that both malaria and dengue fever, both transmitted by mosquitoes, may expand their range (including higher grounds) into areas which are projected to become warmer and more humid such as East and Central Africa.[17] The same may apply to Rift Valley fever, a viral livestock disease also transmitted by a mosquito vector.[69] Any such changes are likely to have profound socio-economic consequences.[66] Increasingly dense urban populations coupled with poverty is highly likely to increase the incidence and prevalence of non-vector transmitted diseases.

A number of adaptive responses to projected climate change can be made. These, however, are all held potentially hostage to uncertainties and indeterminacies attached to the variables involved in the physical basis of climate change and the way in which these will drive climate change itself. In turn, this causes huge uncertainties in projections of impacts upon agricultural and pastoral systems alike. When changes do become manifest, it is entirely possible that they will fall outside the experiential realm which informs current adaptive behaviours.[51] Hence, proposed changes in crop management, in the development of new seed varieties, or in the evolution of pastoral agriculture (perhaps switching from cattle to sheep and goats) will require a considerable degree of institutional support on a continent arguably the least well resourced to provide it and where climate change could rapidly foreclose many of the development options currently seen as realistic and achievable.[70]

Conclusions and Recommendations

Taken together, the indicators and trends synthesised above paint a picture of the potential for widespread and locally or regionally severe impacts of climate change across the African continent. This, however, is against a backround of substantial complexity and uncertainty arising from the combination of limits to knowledge and model resolution and the natural variability in climatic drivers and their impacts. A number of more specific **conclusions** can be drawn:

1. At a continental level, climate in Africa is influenced by a number of key factors and their interaction, including the extent and seasonal movement of the Inter Tropical Convergence Zone, the strength of the West African Monsoon and periodic influences from the El Nino Southern Oscillation. At a more regional level, sea surface temperatures in the Atlantic and Indian Oceans are also important. However, many climate models have so far failed to take account of one or more of these key drivers, and understanding of their interactions and possible future trends remains limited.

2. The resolution and therefore power of model projections have been further constrained by relatively poor availability of monitoring data across many parts of Africa, making reliable ground-truthing of models difficult if not impossible and potentially "missing" important local and regional variations in sensitivities and projected impacts.

3. Despite these limitations and inherent uncertainties, much of the available research nonetheless indicates that Africa as a whole is likely on average to become warmer and drier in coming decades, and can expect rates of temperature increase somewhat greater than the global average. Where available, temperature records already suggest warming trends in parts of West, East and Southern Africa in recent decades, lending support to such projections. Changes in rainfall appear more complex and harder to predict, though there are indications that countries may well experience higher variability in rainfall with an increase in short-term, intense rainfall and other extreme weather events. For a continent which relies more than any other on rain-fed agriculture, this could be of particular significance.

4. Observations of increasing variability and severity in climatic conditions and weather events may prove to be a key indicator of underlying trends in climate dynamics. Greater extremes in both wet and dry conditions, increasingly characteristic of tropical regions globally, may provide a particular 'signature' of climate change.

5. Many African nations are already predisposed to suffer disproportionately high impacts as a result of existing socio-economic, political and environmental pressures which will inevitably limit the scope of people and the natural systems on which they depend to cope with and adapt to climate change. Those areas already under considerable temperature and water stress are likely to be worst hit and least able to adapt.

6. Many crops are already grown under conditions which are close to their limit in terms of both temperature and water availability. Although some models project increasing rainfall in some regions of Africa in coming decades, such a trend may not be universally beneficial in terms of agriculture and human health because the periodicity and severity of rainfall matters as much as total quantity. The capacity to store water affordably and without increasing risk of disease transmission is likely to remain difficult. At the same time, projected further decreases in rainfall in other regions are likely only to compound water stress for both humans and wildlife.

7. Traditional and supportive inter-relationships between pastoral communities and those involved in cultivation, which have endured and provided some level of adaptive capacity over many hundreds of years are already strained as a result of previous droughts. These may begin to breakdown altogether under additional stress of climate change and its impacts on water and grazing availability and the success of harvests. The pressures on families to migrate to urban areas may be expected to grow further, making the challenge of tackling poverty an even greater one.

8. Although all members of subsistence communities may suffer as a result of rising temperatures and increased variability in rainfall patterns, women may be expected to experience disproportionate impacts in relation to further increases in responsibility and daily workload.

9. A focus on agriculture, access to water and human health is necessary and understandable, but cannot be pursued in isolation from consideration of impacts on natural habitat and biodiversity. In the same way, model outputs which predict regional recovery of forests and greening of other areas should be interpreted with caution against a backdrop of increasing human pressures on the biosphere.

10. Any substantive adaptive shift in agricultural practice, including the development of new seed varieties and practices, will demand considerable institutional support, whether national or international, in order to be implemented effectively. In order to ensure such developments are equitable and sustainable, they will need as far as possible to empower communities to adapt rather than increasing dependence.

Based on these broad conclusions, a number of **recommendations** can be proposed:

1. An overarching binding commitment must be made by Governments globally to agree to peak global emissions by 2015 and thereafter reduce emissions by at least 80% below 1990 levels by 2050. This is in accordance with the recommendations of the IPCC. In order to achieve such a peak in emissions, governments must urgently improve their emission reduction targets and also ensure the delivery of the financial and technological support they have already promised to developing nations. Any delay in implementing this strategy will diminish the probability of keeping global average temperature rises below 2°C. By restricting temperature rise to this level, it is thought that the most dangerous impacts of climate change can be avoided, although there are scientific concerns that even this temperature rise is too high.

2. There is an urgent need to improve the scope and structure of models applied to climate change to increase their ability to identify changes at the sub-regional level their ability to project impacts in the context of Africa. Such developments will need to be supported by investment in the monitoring capabilities and networks. This is necessary in order to be able to record trends and events on a local scale and provide a means of calibrating model outputs and remote sensing data

3. In future monitoring and modelling programmes, particular attention should be paid to increases in variability in climatic and weather conditions and the frequency of extremes, as such trends may provide the first indications of more fundamental shifts in the climate system, including the proximity of potential 'tipping points' of change.

4. Despite inevitable and to some extent unavoidable uncertainties, it is vital to develop action plans now on the basis that temperatures are expected to continue to rise in most regions of the continent and that rainfall patterns will become increasingly variable, unreliable and locally intense.

5. Such plans must also recognise that issues relating to human activity and development and those relating to the response of natural systems to climate change are closely interlinked and that neither can therefore be considered in isolation when projecting and planning for climate change impacts and adaptation.

6. When initiating and underpinning adaptation in social and agricultural systems, it will be vital to target effort where such systems are already under the most severe strain, which may not necessarily be where observed and/or projected changes are most attributable to climate change.

7. When building institutional support to develop solutions and assist adaptation, it is vital that communities become more, not less, empowered and able to meet their vital needs and those of future generations. It will also be important to take special account of the problems faced by, and particular needs of, women when designing and implementing such programmes.


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GREENPEACE

RSA Office:
10A and 10B Clamart House, Clamart Road, Richmond, Johannesburg, South Africa

Postal address:
Greenpeace Africa
PostNet Suite 125
Private Bag X09, Melville
Johannesburg, 2109
South Africa

DRC Office:
Greenpeace Environnemental Organisation 8, avenue lodja, Q. “Socimat” Commune de la Gombe, Kinshasa,
République Démocratique du Congo

Senegal Office:
2, Avenue Hassan II, 6eme etage, Dakar, Senegal

iafrica@greenpeace.org
www.greenpeaceafrica.org

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