Regional Climate Messages for East Africa

CARIAA
Collaborative Adaptation Research Initiative in Africa and Asia

ASSAR
Adaptation at Scale in Semi-Arid Regions

About ASSAR Working Papers

This series is based on work funded by Canada's International Development Research Centre (IDRC) and the UK's Department for International Development (DFID) through the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA). CARIAA aims to build the resilience of vulnerable populations and their livelihoods in three climate change hot spots in Africa and Asia. The program supports collaborative research to inform adaptation policy and practice.

Titles in this series are intended to share initial findings and lessons from research and background studies commissioned by the program. Papers are intended to foster exchange and dialogue within science and policy circles concerned with climate change adaptation in vulnerability hotspots. As an interim output of the CARIAA program, they have not undergone an external review process. Opinions stated are those of the author(s) and do not necessarily reflect the policies or opinions of IDRC, DFID, or partners. Feedback is welcomed as a means to strengthen these works: some may later be revised for peer-reviewed publication.

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Funded by:

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International Development Research Centre
Centre de recherches pour le développement international

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Regional Climate Messages for East Africa

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This document should be cited as: Daron, JD (2014) "Regional Climate Messages: East Africa". Scientific report from the CARIAA Adaptation at Scale in Semi-Arid Regions (ASSAR) Project, December 2014.

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SUMMARY MESSAGES

The climate across East Africa varies from arid to tropical monsoon conditions.

It is mainly influenced by large scale seasonal atmospheric patterns as well as the warm waters of the Indian Ocean. Temperatures are high throughout the year across much of the region with cooler temperatures in the highland regions of Ethiopia, Kenya and Tanzania. Northern regions receive the majority of rainfall in the June to August period, southern regions receive the majority of rainfall in the December to February period, and equatorial regions experience two rainfall seasons with peaks in October and April.

Temperature and rainfall vary on annual, decadal and multi-decadal timescales.

Over the past half century there has been substantial multi-decadal variability in rainfall. Parts of central Ethiopia were unusually wet in the 1970s and unusually dry in the 1980s and 1990s, while other parts of East Africa experienced the opposite pattern.

Temperatures across the region have increased by 1.5 to 2°C on average over the past 50 years.

The greatest increases are found in central regions, particularly in South Sudan where increases in the March to August period have exceeded 3°C.

Future projections of temperature change show significant increases across the region.

The largest increases in temperature are projected for central and northern regions. Projected increases in average annual temperatures range from no change to 4°C by 2050, though model projections are subject to substantial uncertainties. Relatively high/low increases are more likely under a higher/lower greenhouse gas emissions scenario.

Rainfall trends over the past 50 years are less evident than for temperature, and there are large variations in the direction and magnitude of changes across the region.

In some locations, and for some seasons, an increase in rainfall is observed while a decrease in rainfall is observed elsewhere. In general, trends are weak.

Future projections of rainfall change show both potential increases and decreases.

Projections of rainfall vary considerably. There is a tendency for models to project wetting across the region in the October to March period but at present there is insufficient evidence to support statements suggesting a likely shift to drier or wetter conditions in the future at most locations.

The impacts of future climate change on different sectors are complicated by the spread of model projections and the complexity of natural and societal systems.

The impacts of climate change on water resources are unclear but the likely increase in evaporation expected to occur with increasing temperatures may place additional stress on vulnerable systems. In the absence of clear trends in past or future rainfall, hydrological discharge trends are likely to remain primarily driven by changes to local water use and land use changes. For agriculture, there is a high degree of diversity of outcomes (including some favourable outcomes) across climate scenarios, sectors, and regions.

CHAPTER 1

Historical Climate

Historical Climate

This report provides a general overview of the regional climate in East Africa. A follow-up report that provides a specific focus on the climate of the semi-arid regions of East Africa is currently under development.

1.1 General overview

The climate across East Africa varies from arid conditions in the east to more humid conditions in the west. A semi-arid transect is found in the Sahel region in central and southern Sudan, as well as a north-south transect running through central Ethiopia, Kenya and Tanzania and pockets of arid and semi-arid conditions are found elsewhere, such as northeast Kenya. Other climatic zones are also present, including tropical rainforest conditions in the Lake Victoria region of southern Uganda. The primary factors affecting the climates experienced in East Africa include altitude, the proximity of the warm Indian Ocean, the migration of the Inter-Tropical Convergence Zone (ITCZ) and the location of dominant atmospheric high and low pressure systems.

The equator passes through Uganda, Kenya and southern Somalia. Therefore the northern parts of the region receives the majority of its rain during the boreal summer months (June to August) while the southern parts of the region receives the majority of its rain during the austral summer months (December to February). Regions closer to the equator typically have two rainy seasons with peaks in rainfall in or around April and October. These peaks are particularly pronounced in the more arid regions.

The highest temperatures are experienced in the drier regions towards the north and east. Particularly high temperatures are found in Eritrea and Djibouti where average summer temperatures exceed 30°C. The lowest temperatures are found in the high altitude regions of Ethiopia, Kenya and Tanzania, located in on the edges of the East African Rift Valley.

1.2 Seasonal and annual variability

Throughout the year, the timing and magnitude of the summer rains is dictated, largely, by the seasonal migration of the ITCZ. This large-scale atmospheric feature represents an area of intense convective activity associated with low pressure. The ITCZ is found near the equator during late March and late September (the equinoxes), moving north during the northern hemisphere summer and moving south during the southern hemisphere summer, bringing rains to the regions as it migrates. However, each year the amount of summer rainfall experienced varies as the ITCZ interacts with other dominant global and regional atmospheric patterns.

The best studied, and one of the most important, of these patterns is the El Niño Southern Oscillation (ENSO) – a cyclical variation in the surface temperature of the tropical eastern Pacific Ocean. When the ocean surface in this region is warmer than average an El Niño event occurs and when the ocean surface is cooler than average a La Niña event occurs. The timing between ENSO events varies but typically an El Niño or La Niña occurs once every few years. El Niño is associated with higher than normal rainfall in East Africa from October to

December while La Niña is associated with drier than normal conditions. However, these associations vary at finer scales and they are not always apparent. The mechanisms that link ENSO and the East African climate are still not fully understood.

Another very important influencing factor controlling East African climate variability on annual to decadal timescales is the natural variability in the Indian Ocean. Similar to ENSO, the Indian Ocean Dipole (IOD) is an oscillation of sea surface temperatures in the Indian Ocean. Over a thirty year period the IOD is positive (higher sea surface temperatures in the western Indian Ocean) and negative (higher sea surface temperatures in the eastern Indian Ocean) approximately four times each and such events tend to last for about six months. Like ENSO, the association with IOD event and the East African climate are still not perfectly understood. However, there is evidence that a positive phase of the IOD is associated with stronger rainfall in East Africa. IOD events are not completely independent from ENSO events but the science of how these large scales oscillations interact, and their combined impact on the East African climate, is still a subject of intense research.

Year-to-year variability in the weather is a result of variability in these large scale processes and variability in regional and local scale processes, such as variability in the prevailing winds and feedbacks between the atmosphere and land surface.

Figure 1.1

December to February (DJF) and June to August (JJA) mean, maximum and minimum temperatures at each grid cell over the period 1963 to 2012; adjacent grid cells may display warmest/coolest temperatures from different years. Data taken from the CRU TS3.22 dataset - see technical reference document.

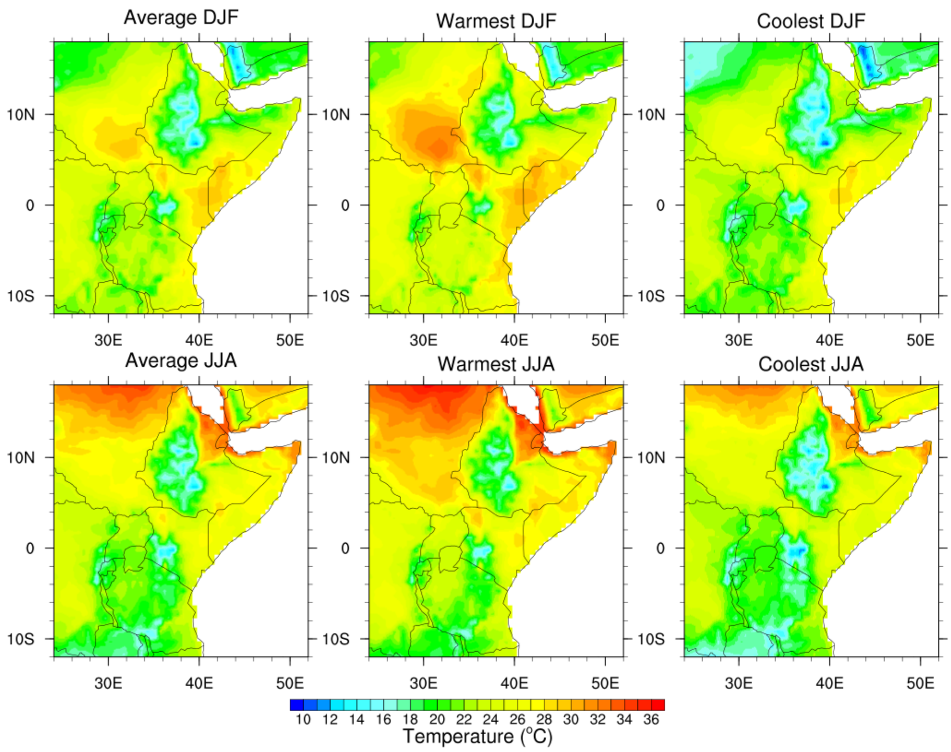


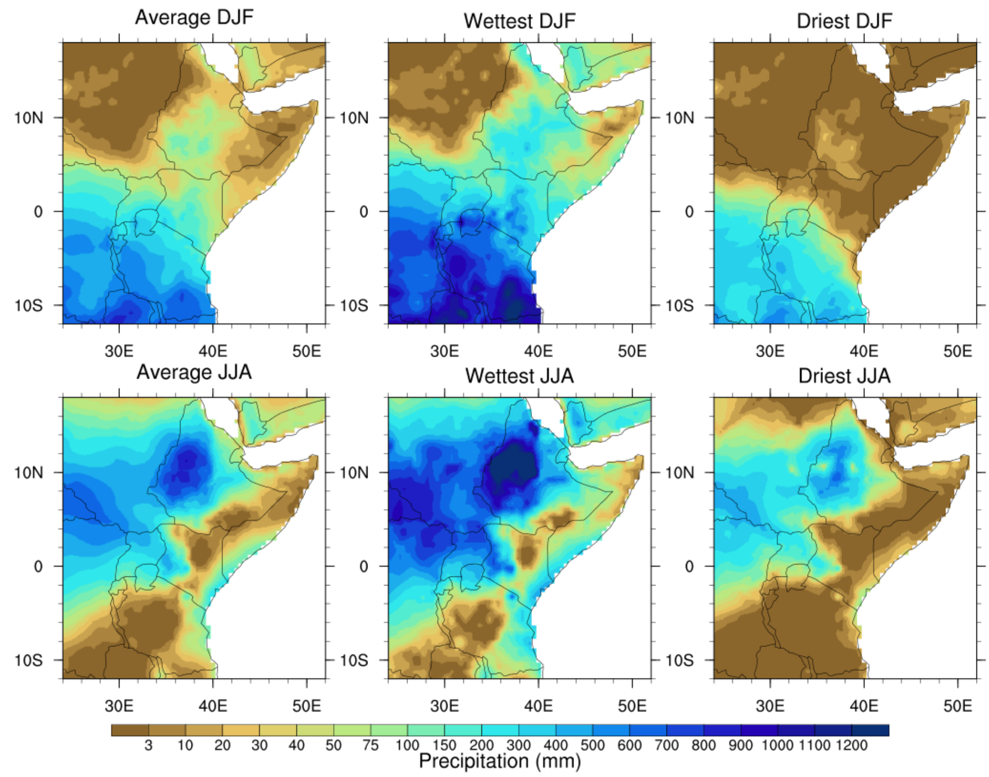
Figure 1.1 shows the average December to February (DJF) and June to August (JJA) temperatures across the region (left column), as well as the warmest (middle column) and coolest (right column) years over the 50 year period from 1963 to 2012 for a particular

location; the year of the warmest season in one grid cell may differ for an adjacent grid cell. The figure shows that the temperatures in some parts of the region, including parts of Kenya, Ethiopia and Somalia, do not vary much throughout the year. High JJA temperatures are experienced in the north of the region, with particularly high temperatures in Eritrea and northern Sudan. The coolest temperatures occur in the high altitude regions of Ethiopia, Kenya, Tanzania and the eastern Democratic Republic of the Congo (DRC). The greatest differences between the average DJF and JJA temperatures in the warmest and coolest years are found in the far north and south of the region, with a large difference also found in South Sudan in DJF.

Rainfall is more variable than temperature, both in space and time. Figure 1.2 shows the average DJF and JJA rainfall as well as the wettest and driest years at each grid cell. In DJF there is a clear north-south split with southern regions receiving many hundreds of millimeters of rainfall and northern regions receiving very little rainfall. In JJA the situation is largely reversed as the northern regions receive much higher rainfall than in the south, though the coastal regions of Tanzania, Kenya and southern Somalia continue to receive some rainfall (approximately 100mm). Other places also experience rainfall in both seasons, particularly in the west and, to a lesser extent, in the highlands of Ethiopia. The difference between the wettest and driest years is substantial in many locations. For example, in Ethiopia much of the country receives above 100mm of rainfall during DJF in the wettest year with little to no rainfall in the same period in the driest year.

Figure 1.2

December to February (DJF) and June to August (JJA) mean, maximum and minimum total rainfall at each grid cell over the period 1963 to 2012; adjacent grid cells may display wettest/driest conditions from different years. Data taken from the CRU TS3.22 dataset – see technical reference document.



1.3 Decadal and longer term variability

The climate of East Africa also varies on much longer time scales. Decadal and longer term variability in the climate system results from natural processes both internal and external to the climate system. On decadal, multi-decadal and centennial time scales, major modes of variability are found in the Pacific, Atlantic, Indian and Southern Oceans, and they can have substantial influences on global and regional atmospheric circulation patterns. These large scale modes of natural variability mean that one decade can be warmer or cooler, and drier or wetter than the previous decade without any changes in the external influences on the climate system. However, factors such as solar cycles, volcanic eruptions, biosphere processes, and more recently human emissions of greenhouse gases (GHGs) and aerosols (particulates in the atmosphere), exert external forcings on the climate system that can also cause variability and change on long time scales.

Figure 1.3 shows the difference between the mean decadal (ten year) temperature and the mean temperature over the 1963 to 2012 period at each grid cell. We can clearly detect a warming signal as all locations in East Africa were warmer, on average, in the 2000s than in the 1970s. Indeed the 2000s were particularly warm in the central and north-western parts of the region with much of South Sudan over 2°C warmer on average in the 2000s than the 1970s. However, it is also apparent that in some locations more recent decades have been cooler than preceding decades; for example, parts of eastern Kenya and southwest Somalia were warmer in the 1970s than in the 1980s and 1990s.

Figure 1.3

Difference between decadal mean temperatures and 1963 to 2012 mean temperatures at each grid cell. Data taken from the CRU TS3.22 dataset – see technical reference document.

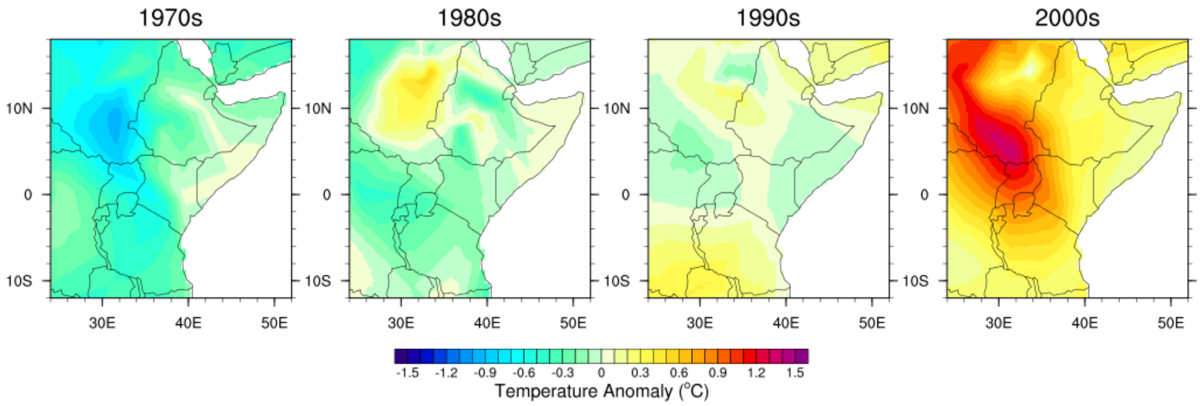
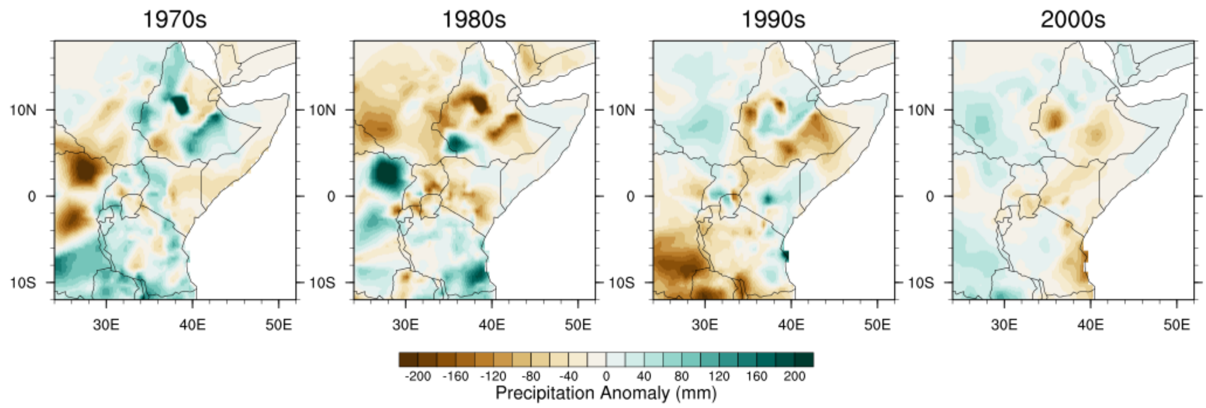


Figure 1.4 shows the difference between the mean annual rainfall total for each decade and the mean annual rainfall total over the 1963 to 2012 period at each grid cell, illustrating considerable variability in rainfall on multi-decadal time scales. There is a marked contrast between the observed rainfall in the some decades compared to the preceding decades for many locations. For example, there are two regions in Ethiopia where much higher than average rainfall was observed in the 1970s and much lower than average rainfall was observed in the 1980s and 1990s. A similar contrast can be seen in the northeastern DRC where the 1970s were much drier than average while the 1980s were much wetter. Such dramatic differences on these decadal timescales must be taken into account when examining future projections of rainfall in these regions.

Figure 1.4

Difference between decadal mean annual rainfall totals and 1963 to 2012 mean annual rainfall totals for each grid cell. Data taken from the CRU TS3.22 dataset – see technical reference document.



On much longer time scales, the climate can vary dramatically due to external influences on the climate system. Over time scales of thousands of years, it is well established that the glacial-interglacial cycle is primarily driven by variations in the orbit, tilt and precession of the Earth and the resultant impact on incoming solar radiation.

1.4 Climate trends

To determine whether or not, and by how much, the climate has changed in the recent past, trends in temperature and rainfall are calculated from the available observed data. Figures 1.5 and 1.6 show the seasonally averaged spatial and temporal changes in temperature over East Africa during the period 1963 to 2012. Despite annual and decadal variability, across all seasons and locations temperatures have increased over this period. Temperature increases were generally higher (approximately 1.8 to 3.8°C) in the central and northwestern part of the region, particularly in Uganda, Sudan and South Sudan, and lower (approximately 0.4 to 1.2°C) along the eastern coastal regions of Somalia and Kenya. Whilst there has been an increase in temperatures in all seasons, the highest increases are found in the MAM period, with the exception of the south of the region.

Figure 1.5

The change in temperature between 1963 and 2012 at each grid cell, according to a linear trend, for the four seasons: DJF, MAM, JJA and SON. Data taken from the CRU TS3.22 dataset – see technical reference document.

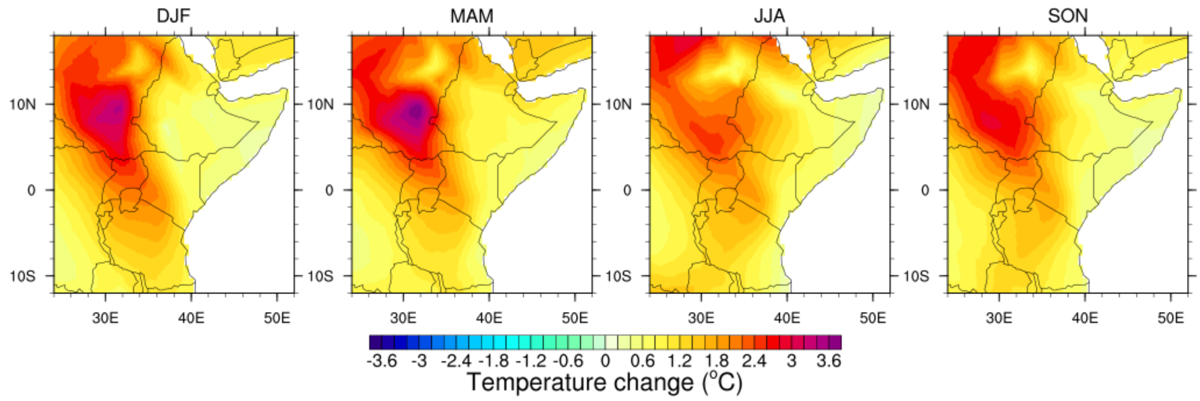
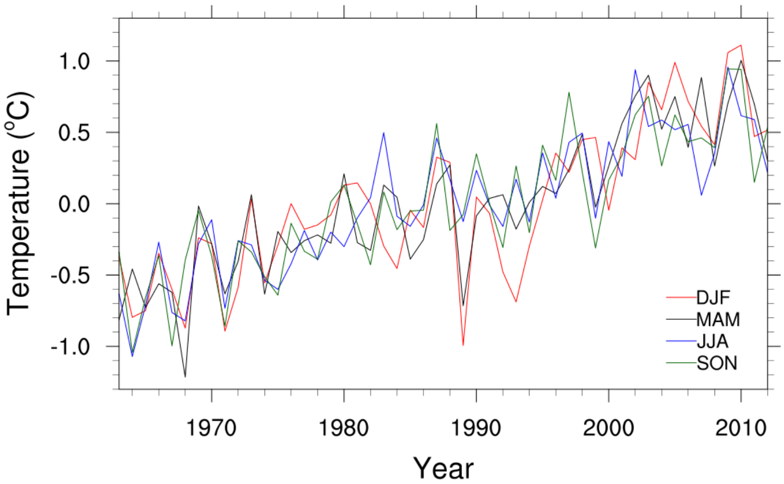


Figure 1.6

Time series of the land area averaged seasonal temperature changes between 1963 and 2012, corresponding to figure 5. Data taken from the CRU TS3.22 dataset – see technical reference document.



Figures 1.7 shows how the total rainfall has changed for each season from 1963 to 2012. The most notable change appears to have occurred in the MAM (March to May) season where large parts of the region, specifically Tanzania, Kenya and southeast Ethiopia, have seen decreases in rainfall exceeding 100mm. These changes are particularly pertinent in the drier regions where absolute rainfall totals are lower. In contrast, some highland regions of Ethiopia show drying in the JJA (summer) season with increases in South Sudan and southern Sudan. The patterns of change are not consistent everywhere and rainfall in East Africa, as described in prior sections, is highly variable so any signals of systematic change are typically weak.

Observations of rainfall are subject to substantial uncertainty – see technical reference document. Therefore the evidence presented here must be treated cautiously and the conclusions must be interrogated in the context of additional regional and local scale information and observed datasets. In particular, linear trends in rainfall are not entirely reliable as an indicator of change, especially in semi-arid regions where year to year variability is very high. Figure 1.8 shows the variation in annual rainfall at two locations in eastern Sudan and northeast Kenya. The year to year variability is very high, with some years receiving over three times more rainfall than others. Both stations are located on the edge of arid to semi-arid boundaries, and the evidence supports a general observation that drier locations are associated with higher year-to-year rainfall variability.

Figure 1.7

The change in rainfall between 1963 and 2012 at each grid cell, according to a linear trend, for the four seasons: DJF, MAM, JJA and SON. Data taken from the CRU TS3.22 dataset – see technical reference document.

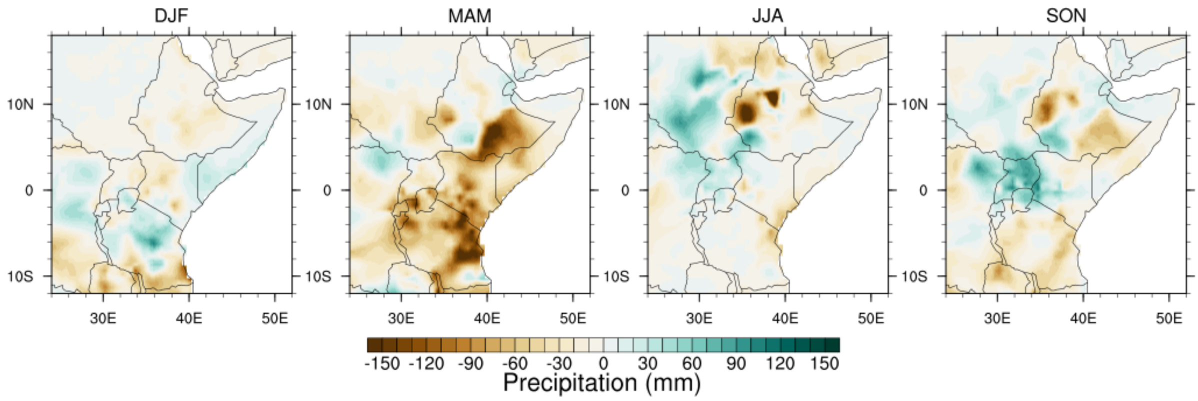
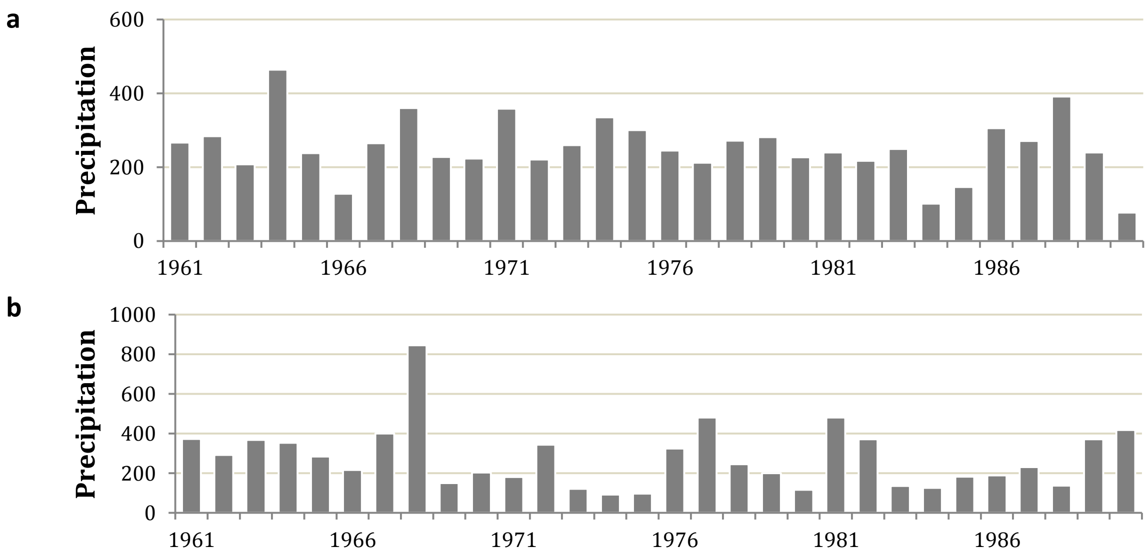


Figure 1.8

Station observed annual rainfall (mm) at: a) Kassala, eastern Sudan, and b) Mandera, northeast Kenya. Data extracted from the CSAG Climate Information Platform; 1961 to 1990 represents the longest period of concurrent, uninterrupted observations.



In relating any observed climate trend to underlying changes in the climate, we must first account for the different time scales of climatic variability. In East Africa, the climate is subject to decadal and longer term climate variability (see section 1.3). Moreover, even if we detect a significant trend, that we are confident is not merely a result of long time scale variability, we must first rule out other external drivers before we can attribute such changes to increasing GHG concentrations – see technical reference document for more explanation.

1.5 Trends in extreme rainfall and temperature

To better understand the impacts of historical climate variability and future climate change on communities and ecosystems, it is often more relevant to focus on the less frequent but more severe weather and climate events that influence exposure and vulnerability to climate.

A report by Climate Development Knowledge Network (CDKN 2012) summarizes the findings of the Intergovernmental Panel on Climate Change (IPCC) special report on managing extreme events (SREX, IPCC 2012). Changes to temperature and precipitation extremes in East Africa observed since the 1950s, with the period 1961-1990 used as a baseline, are reported (see Box 3.1 in Chapter 3 of SREX for more information):

- Spatially varying trends in most areas for minimum temperatures – *medium confidence*
- Increases in warm nights in Southern tip (decrease in cold nights) – *medium confidence*
- Spatially varying trends in dryness – *low confidence*

Because of sparse and unreliable observations across much of East Africa, and given statistical issues associated with deriving trends in extremes for short sampling periods, none of the findings are stated with high confidence. The low confidence associated with trends in dryness is consistent with the findings for mean annual rainfall where the variability over the last 50 years confounds any trends. Furthermore, the report states that there is insufficient evidence to say anything meaningful about trends in heatwaves or heavy precipitation events. This makes any analysis of the impacts of climate change on extreme weather, and the resultant consequences for society, very difficult.

CHAPTER 2

Future Climate Projections

Future Climate Projections

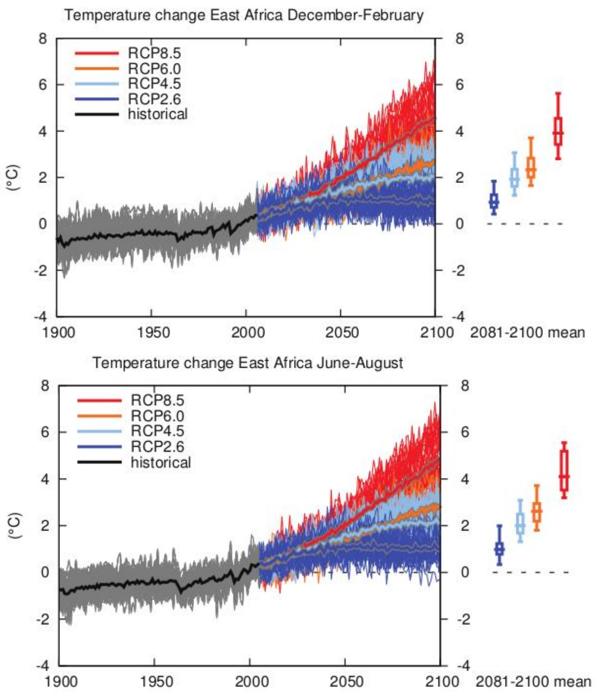
2.1 Key results in the IPCC AR5

Climate change projections span a range of possible future climates. This range results from substantial uncertainty in key climate processes as well as different future GHG emissions scenarios. The projections shown in this section are taken from the available output of the latest generation of Global Climate Model (GCM) experiments. It is possible that the "true" uncertainty range is wider than the range of model projections. Further information on the issues associated with climate prediction is provided in the supporting reference document.

The IPCC fifth assessment report (AR5) provides a synthesis of the output from approximately 40 GCMs developed at institutions across the world. The model simulations were conducted as part of the fifth phase of the Coupled Model Intercomparison Project (CMIP5)[1] to generate a set of climate projections for the coming century. This section presents some of the model results relevant for East Africa.

Figure 2.1

Time series of temperature change relative to 1986–2005 averaged over land grid points in East Africa in December to February (left) and June to August (right). Thin lines denote one model simulation and thick lines are the multi-model mean. On the right the 5th, 25th, 50th, 75th and 95th percentiles of the distribution of 20-year mean changes are given for 2081–2100 for the four RCP scenarios. Source: IPCC (2013).

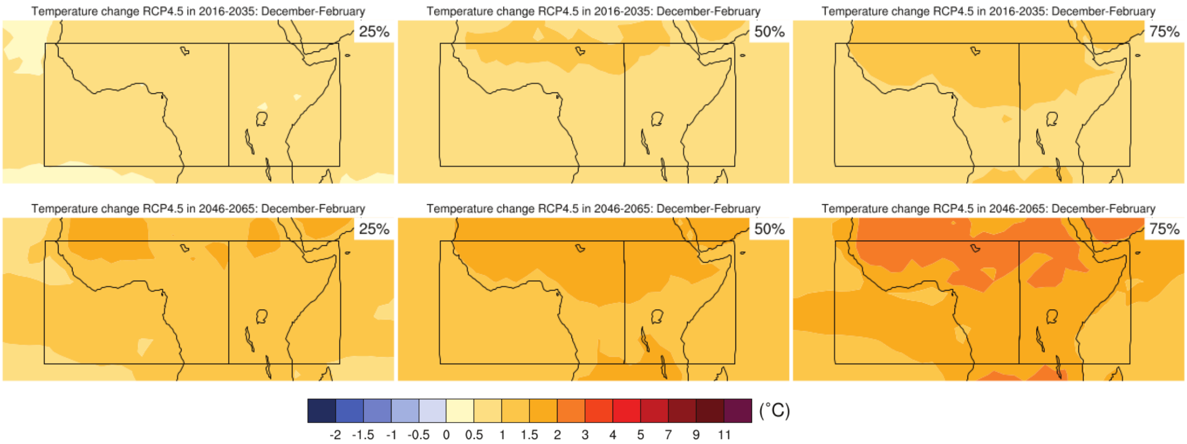


[1] http://cmip-pcmdi.llnl.gov/cmip5/

Globally, average annual temperatures are projected to rise by 0.3 to 2.5°C by 2050, relative to the 1985 to 2005 average, but projected changes are higher for land areas. Figure 2.1 shows that in East Africa temperature projections range from approximately no change to 4°C warmer conditions in both DJF and JJA seasons by 2050. Lower temperature increases are more likely under a low emissions scenario and higher temperature increases are more likely under a high emissions scenario.

Figure 2.2

Maps of temperature change in East Africa in December to February for 2016–2035 and 2046–2065 with respect to 1986–2005 according to the RCP4.5 scenario. The left column show the 25th percentile (i.e. a quarter of models are below these values), the middle column shows the median and the right columns shows the 75th percentile (i.e. a quarter of models are above these values). Source: IPCC (2013).

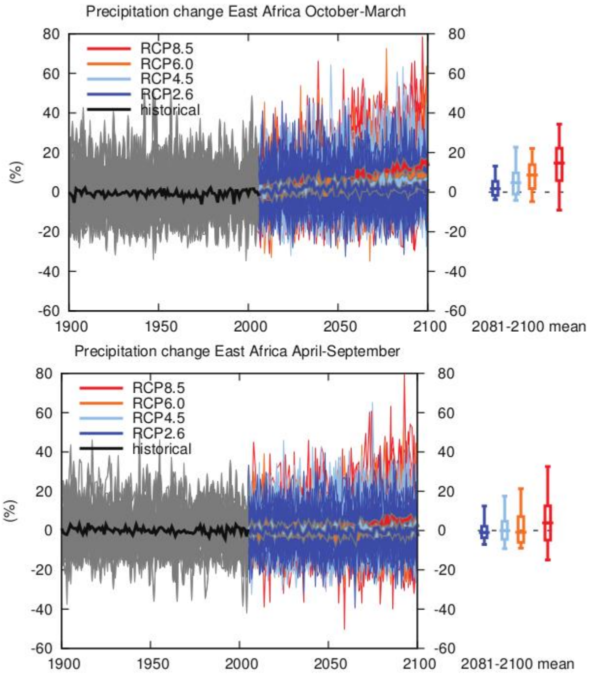


Projected changes in temperature vary spatially. Figure 2.2 shows that, for the RCP4.5 emissions scenario, northern regions of East Africa are projected to warm more than other regions, continuing the observed trends (section 1.4). By mid-century half of all model simulations project a warming in the DJF season of between 1°C and 3°C for northern regions of East Africa and between 1°C and 2°C elsewhere. In the JJA season (not shown), the pattern is similar but the south of the region also shows high levels of warming. Beyond increases in average temperatures, the IPCC report states “it is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales as global mean temperatures increase”.

Future projections of rainfall change are subject to substantial uncertainties and model simulations disagree on the likely direction and magnitude of change. In East Africa, variability on interannual, decadal and multi-decadal time scales, as experienced in the past, is expected to continue to be the dominant influence on future rainfall. However, towards the end of the 21st century there is a tendency of models to predict a shift to slightly wetter conditions on average over East Africa, especially for the high RCP8.5 emissions scenario, whilst some models project drier average conditions. Figure 2.4 shows that the wetting is likely to be greater in October to March, with some models predicting an average increase across the region of up to 35% under the RCP8.5 emissions scenario. However, for the next few decades up to 2050 any signal across the model ensemble remains either weak or non-existent.

Figure 2.4

Time series of precipitation change relative to 1986–2005 averaged over land grid points in East Africa in October to March (left) and April to September (right). Source: IPCC (2013).



2.2 CORDEX Projections

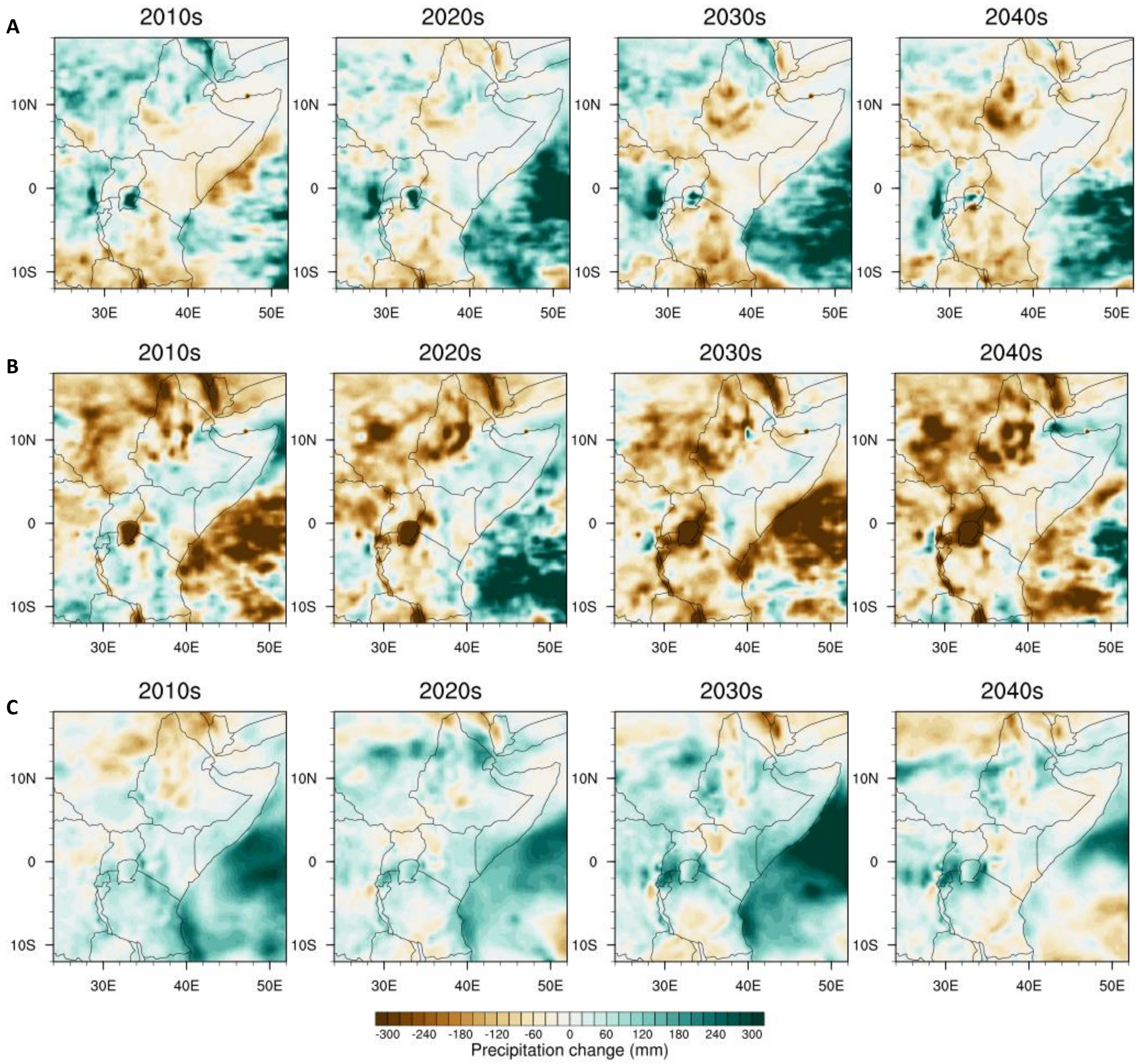
The Coordinated Regional Downscaling Experiment (CORDEX) uses the latest generation of regional climate models (RCMs) to provide 50 km resolution projections of climate change up to the year 2100 for regions across the world. The models are driven by GCMs used in the IPCC AR5 report. Here, some example CORDEX model projections are presented showing possible future regional climate change scenarios for East Africa. It should be noted that all projections shown are for the same GHG forcing scenario, RCP8.5; this scenario is often categorized as "business as usual" with respect to GHG emissions.

Regional climate projections are subject to significant uncertainties (Hawkins and Sutton 2009). The output of a single model simulation should be treated with caution and even an ensemble of regional model projections cannot be expected to provide reliable quantitative "predictions" (Daron et al 2014). Rather, the projections show plausible scenarios of future change. Further explanation of the issues in projecting the future climate at regional scales is provided in the supporting technical reference document.

The model projections shown in figure 2.5 are taken from combinations of two GCMs (HadGem2 and ICHEC) and two RCMs (KNMI and CCLM4), all driven by the RCP8.5 scenario. A more rigorous exploration of future climate scenarios would involve analyzing many more GCM-RCM combinations that are being made available in the CORDEX project. However, for demonstrative purposes it is useful to look at some of the available data to examine the nature of future climate output. Figure 2.5 shows model projections of future rainfall change for four decades. The average annual rainfall change for a particular decade is calculated by subtracting the decadal average from the average annual rainfall over the period 1950 to 2000 in the model.

Figure 2.5

Difference between decadal mean annual rainfall totals and the 1950 to 2000 mean annual rainfall totals, at each grid cell, for three CORDEX models under the RCP8.5 scenario: A = HadGem2-CCLM4; B = ICHEC-CCLM4; and C = ICHEC-KNMI.

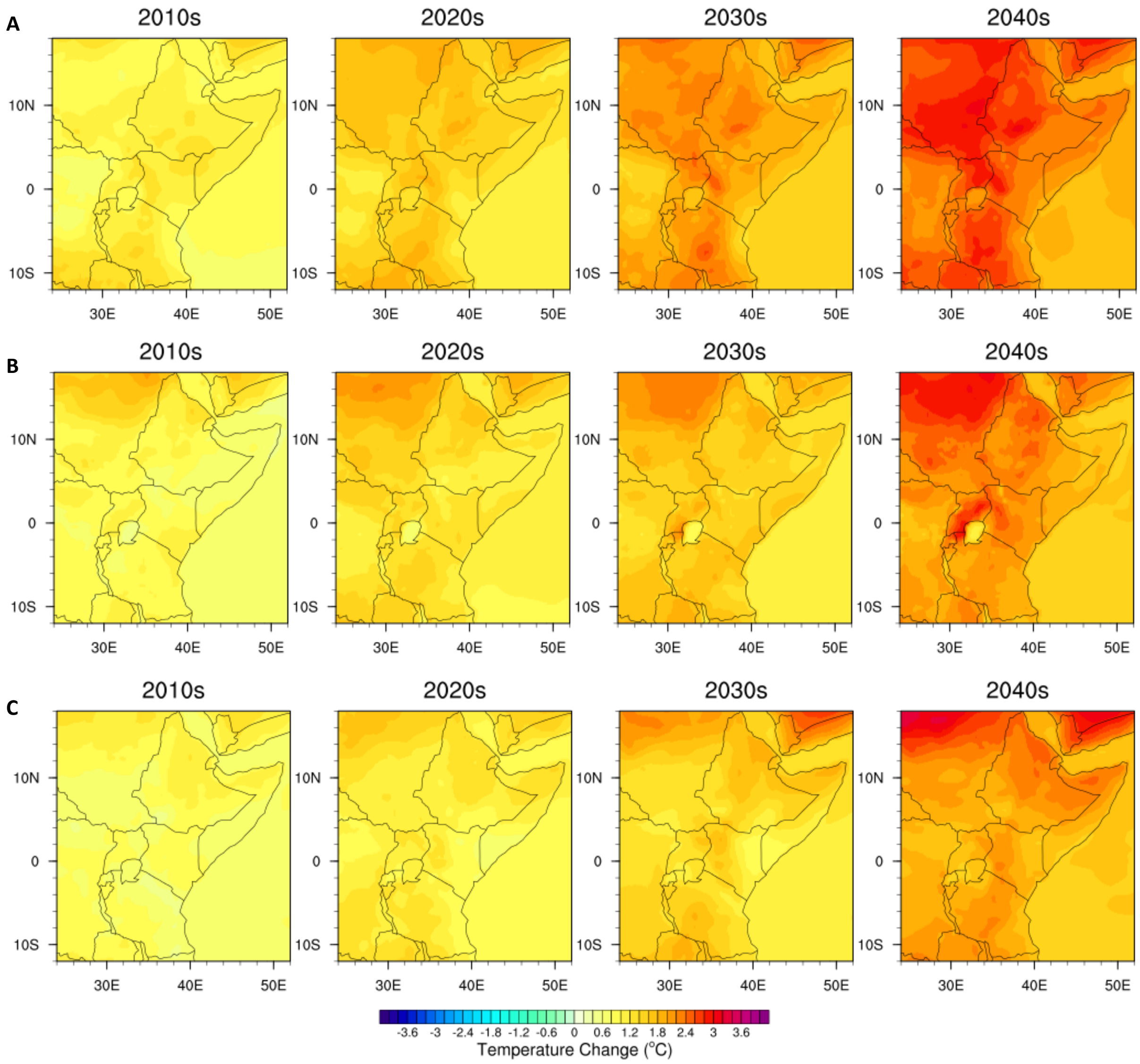


The model projections shown in figure 2.5 indicate very different responses of the regional climate for the selected future GHG forcing scenario. In fact there are very few locations that show a consistent pattern of drying or wetting across the three simulations. Even for the same RCM, some locations show contrasting directions of change; in the Lake Victoria region model A projects wetting while model B projects strong drying, demonstrating the influence of the driving GCM. For most locations, the changes are no more dramatic for decades further into the future than for nearer decades, suggesting that decadal and multi-decadal variability are still likely to dominate any changes. However, there are some exceptions; model A projects that the highland regions of Ethiopia will get drier as the decades progress.

Whilst there is no consensus on the direction of change in rainfall for the future, even amongst a small selection of three model simulations, there is much better agreement that temperatures are likely to increase. Figure 2.6 shows decadal changes in temperature for the same set of GCM-RCM combinations under the RCP8.5 scenario. In all model simulations, temperatures across the region are projected to rise. Model A projects the greatest magnitude increase by the 2040s with central regions of Tanzania, eastern Uganda, western Kenya, western Ethiopia and South Sudan expected to have an increase in average annual temperatures of up to, and in some locations exceeding, 3°C. The changes are less dramatic in model B and C with most regions expected to warm by less than 2.5°C by the 2040s, with higher warming in northern Ethiopia and Sudan (and Uganda for model B). In general there is less warming along coastal regions and in the DRC, which corroborates with the CMIP5 GCM projections and the observed warming in the last 50 years (see section 1.4).

Figure 2.6

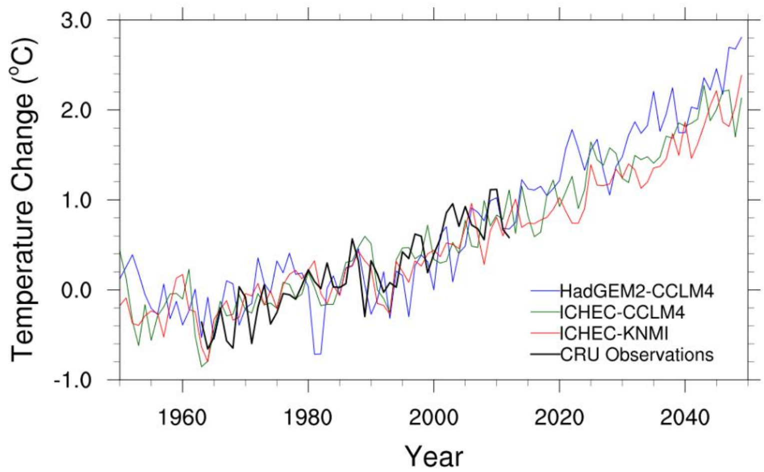
Difference between decadal mean temperatures and the 1950 to 2000 mean temperatures, at each grid cell, for three CORDEX models under the RCP8.5 scenario: A = HadGem2-CCLM4; B = ICHEC-CCLM4; and C = ICHEC-KNMI.



Unlike rainfall, changes to temperature on the decadal time scale appear to be dominated by a systematic warming signal as opposed to multi-decadal variability. This can also be seen clearly when aggregating temperature changes over the region and analysing the time series' of model projections. Figure 2.7 shows the change in annual average temperature for the three model simulations, as well as the observed changes from the CRU dataset. All model simulations appear to capture the emergence of a warming trend over the past 50 years and this trend is projected to continue into the future. By 2050, there is some uncertainty in the projected temperature change – even from a very small sample of simulations all driven with the same GHG forcing scenario – with the three simulations projecting a 2.1°C to 2.7°C warming by 2050. The divergence of models would likely be much larger if additional simulations and forcing scenarios were included.

Figure 2.7

Time series of the change in East Africa annual average temperatures from the three CORDEX models analysed (see key). The model changes are relative to the average of the models in the respective domains from 1963 to 2000, while the CRU TS3.22 observational data (from 1963 to 2012) are relative to the observed 1963 to 2000 average.



CHAPTER 3

Literature Review: Key Findings

Literature Review: Key Findings

3.1 Historical climate and impacts

A number of studies have investigated the impacts of past climate change on ecosystems and societal systems in East Africa. Water resources in East Africa are critical for the success of many economic sectors. Koutsouris et al (2010) uses a statistical analysis of hydro-climatic data for the period 1968–1995 for the Lake Victoria region of Kenya. They find that there are no significant trends in precipitation or evapotranspiration at the local or national scale, implying that any observed local and regional hydrological discharge trends are primarily driven by local and regional water use and land use changes. Despite a lack of long-term trends, decadal and multi-decadal variability still pose challenges to the management of water resources. Schreck and Semazzi (2004) show that ENSO is the most important factor affecting rainfall variability over eastern Africa. They find that El Nino events are associated with above-normal rainfall amounts during the short rains throughout the entire region, except for Sudan

Using the output of 18 GCMs from the Programme for Climate Model Diagnosis and Intercomparison, Conway and Schipper (2011) focus on changes to the climate and its impacts in Ethiopia. They find that warming has occurred across much of Ethiopia, particularly since the 1970s, at a rate broadly consistent with wider African and global trends. They refer to the work of Woldeamlak and Conway (2007) which reviewed the recent literature and showed that observed trends in past rainfall are non-uniform and highly sensitive to which region and period of time is used in the analysis. Based on an understanding of the past climate in the country, Conway and Schipper (2011) use economic analysis to highlight sensitivities, and evidence of a possible one-year lagged effect, of the country’s economy to large-scale drought. They note that while the adverse effects are clear in major drought years, the relationship is weak in other drought years.

Kassie et al (2013) also explored the impacts of changing rainfall in Ethiopia noting that during the period 1977–2007 total rainfall decreased but not significantly. The study finds that despite a lack of significant rainfall trends, substantial inter-annual variability in the length of the growing season, ranging from 76 to 239 days, implies a challenge to rain-fed agriculture. In addition, Kassie et al (2013) utilise the Crop Water Requirement Satisfaction Index (WRSI) to show that the warming trend in the Central Rift Valley of Ethiopia impacts crop production by raising the evaporative demand, particularly in regions where rainfall is already scarce.

In a study exploring bird biodiversity in the savannah regions of Tanzania, Beale et al (2013) find that local patterns of species colonisation can be explained by both climate change and conservation efforts to maintain a network of protected areas. They note that the overall picture for Tanzanian savannah birds suggests that local extinctions are not (yet) associated with climate deterioration, but rather with land degradation outside protected areas. In Kenya, Kissling et al (2010) note that current patterns of bird species richness peak in the southwestern parts of Kenya where precipitation and topographic heterogeneity are highest.

A USGS (2011) study documented recent observed changes to the climate in Sudan stating that the summer rains in western and southern Sudan have declined by 10–20% since the mid-1970s. The study notes that areas with changing climate are coincident with zones of substantial conflict, suggesting some degree of association, but that the contribution of climate change to these conflicts is not currently well understood.

3.2 Future climate and impacts

Future projections of climate in East Africa are uncertain and model projections provide contrasting evidence with regards to future impacts in the region. A range of crop models, hydrological models and other impacts models are used to determine the impact of climate change on agriculture, water resources, biodiversity and other key sectors in the region, but most studies require climate model projections that span a wide range of possible futures.

A study by Burke et al (2006) uses a single GCM (HadCM3) and shows that globally the model projects an increase in the area affected by droughts in the future. Using the same GCM, Abdo et al (2009) examine changes to rainfall in the Blue Nile region of Ethiopia and find that the mean monthly rainfall shows a decreasing trend at the beginning of the rainy season (May and June) and an increasing trend towards the end of the rainy season (September and October). They use the projections to drive the HBV semi-distributed rainfall-runoff model and find that runoff in the Gilgel Abay catchment in Lake Tana basin, Ethiopia, is projected to decrease by 10% by the 2080s. However, a more recent study by Dile et al (2013) also examines runoff in the Gilgel Abay catchment using the same GCM, but they use a river basin model, the Soil Water Assessment Tool (SWAT), and find that climate change will ultimately result in an annual increase in flow volume for the Gilgel Abay River. This is based on a model projection of a decrease in rainfall of up to 30% in the near decades, but an increase in rainfall of 30% in the latter half of the century. A related study by Block and Strzepek (2010), again using the same GCM, combines the output of a crop model and hydrological model to investigate the impact of climate change on hydropower and irrigation development on the Blue Nile in Ethiopia. They state that climate change scenarios indicate potential for small benefit-cost increases, but also reflect the potential for noteworthy decreases, relative to the historical climate conditions.

According to some modelling studies, there is a tendency for models to project higher rainfall in East Africa. Shongwe et al (2011) draws on 12 GCMs, weighted according to the statistical method of Tebaldi et al (2005), and finds that although the rate of change is still uncertain, almost all results point to a wetter climate with more intense wet seasons and less severe droughts. Tumbo et al (2010) use self-organising maps to downscale GCM data for Tanzania and find an increase in future rainfall amounts, a decrease in dry spells, as well as an earlier start and later end date of the rainy seasons implying longer rainy seasons. Other studies find that there is no consensus regarding the direction of future rainfall change in the region. Recently, Otieno and Anyah (2013) analysed the output of six models from the latest generation of Earth System Models (ESMs) run with RCP4.5 and RCP8.5 forcings. They find significant variation among models in projected precipitation anomalies, with some models projecting an average increase as others project a decrease in precipitation during different seasons. Ahmed et al (2011) focus on changes to precipitation volatility (variability) and state that models disagree for the coming decades with regards to increasing or decreasing rainfall volatility.

Based on analysis of satellite records, and utilising SWAT, Mango et al (2011) assess water resources in the upper Mara River Basin, Kenya. They show that any further conversion of forests to agriculture and grassland in the basin headwaters is likely to reduce dry season flows and increase peak flows, leading to greater water scarcity at critical times of the year and exacerbating erosion on hill-slopes. Setegn et al (2011) also use SWAT driven by an ensemble of 18 GCMs to examine changes to rainfall and temperature, and their impacts on streamflow in the Lake Tana Basin, Ethiopia. While projections show statistically significant increases in median temperature (interquartile ranges for 2070–2100 are 2.0°C–4.4°C in the wet season and 2.2°C–4.9°C in the dry season), they find no consensus about the sign of the precipitation change in the region (interquartile ranges for 2070–2100 are −13% to +12% in the wet season and −14% to +16% in the dry season). Nevertheless, the authors state that streamflow changes, which follow the sign but are larger in magnitude that the rainfall changes, could still be significant. A hydrological modelling study of the Upper Nile Basin in Uganda (Kingston and Taylor 2010) shows that projected change in mean annual precipitation from multiple GCMs over the Mitano basin varies from a 23% increase (NCAR model) to a 23% decrease (CSIRO model) by the late 21st century. Their study shows that annual river discharge first increases, then declines with rising global mean air temperature.

Using a crop model and economic model, Arndt et al (2011) show that food security in Tanzania appears likely to deteriorate as a consequence of climate change. Their analysis points to a high degree of diversity of outcomes (including some favorable outcomes) across climate scenarios, sectors, and regions. In Ethiopia, Evangelista et al (2013) conducted a crop modeling study using the output of three GCMs and find that all models show similar decreasing spatial trends in cereal production. Their results show that barley is predicted to have the greatest reductions (net losses in land area ranging from 28 to 62 %) while sorghum had the least change (net loss of 21 % to a net gain of 14 %).

To investigate the possible (re)emergence of Tsetse and African Trypanosomiasis in Kenya under increasing temperatures, Messina et al (2012) use the Tsetse Ecological Distribution (TED) model and a projection from a single GCM (CCSM3). They find that there is a probable expansion of tsetse into the Kenyan Highlands, which could directly threaten the core of the agricultural dairy industry and expose a large population of people to the risk of African Trypanosomiasis.

CHAPTER 4

References

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