



Climate Risk Profile for East Africa

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Regional Overview

Eastern Africa stands out as one of the most vulnerable regions in Africa to the impacts of climate change and variability, particularly concerning hydroclimate extremes such as floods and droughts¹. Compared to the change in temperature, the variability in precipitation during the agricultural seasons affects the region². Due to the high variability in seasonal rainfall, East Africa is becoming one of the most food-insecure regions of Africa and always in need of humanitarian assistance³, especially the Greater Horn of Africa (GHA) countries.

Agriculture is the dominant sector in most countries of Eastern Africa, with most of the farmers (~80%) being smallholders. Most of the population (>80%) depends on agriculture for livelihood. The agriculture sector contributes significantly to the region's GDP (up to 40%)⁴. Agriculture in the region is mainly

rained, with three main agricultural seasons: March to May (MAM), July to September (JAS), and October to December (OND). The livestock sector significantly contributes food and income (up to 70% cash income at a farmer level) for millions of East Africans, the region's GDP (20-30%), and foreign currency earnings⁵. These major regional sectors are and will be highly vulnerable to present and future climate change. They emphasize the need for sound adaptation and sustainable resource management strategies to minimize the impacts of enhancing food security in East Africa.

This profile provides information about the current and future changes in climate in Eastern Africa, including potential impacts on water, agriculture and livestock sectors, and the ecosystem. Specific countries included are Ethiopia, Kenya, Uganda and Tanzania. The profile starts with general information and provides detailed information on changes and variability in historical and future climate, climate risk by sector,

and general policy recommendations. We use high-resolution and validated climate datasets for the historical climate. For the future climate, we use the region's selected and validated Global Climate Models (GCMs). To assess the impact of future climate, the GCMs data is statistically downscaled using a novel statistical downscaling model for two future scenarios: Shared Socioeconomic Pathways (SSPs).

These scenarios encompass medium challenges for mitigation and adaptation (SSP245 or SSP2-4.5) and a fossil-fueled development trajectory (SSP585, or SSP5-8.5), posing high challenges for mitigation and low challenges for adapting to climate change. We use hydrological and river system models to assess future changes in hydrology and hydrological extremes such as droughts (e.g., duration and severity) and floods (e.g., frequency). Due to the region's vulnerability to climate change and the need to develop local-scale climate change adaptation measures, we provide high-resolution maps that allow the identification of hotspot areas. Fig. 1 shows the map and digital elevation of Eastern Africa.

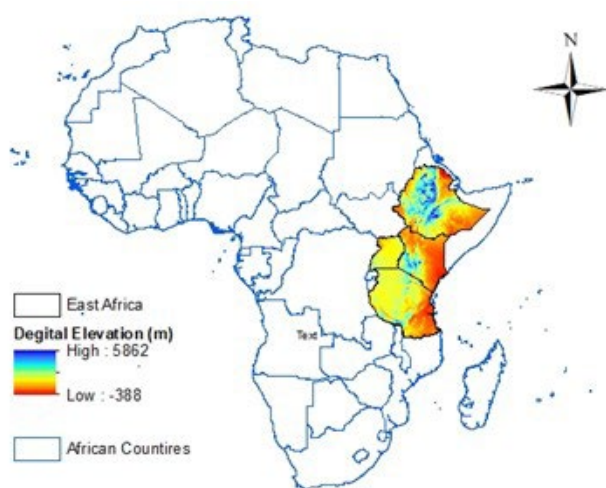


Figure 1. Map and digital elevation (m) of East Africa

Regional Climate

The climate in Eastern Africa is highly variable and ranges from arid in the east to humid climate in the west. The topography is diverse and complex; the Rift Valley lakes, monsoon systems, and convergence zones⁶ highly influence the climate. Climate variability in this region is partly influenced by local factors such as land surface heterogeneity and diverse topography, as well as their linkages with global climate-forcing mechanisms⁷. The annual precipitation for these countries ranges from less than 100 mm (e.g., lowlands of Kenya and Ethiopia) to about 2500 mm (e.g., highlands of Ethiopia). The annual average maximum temperature ranges from about 25 °C (e.g., highlands of Ethiopia and Kenya) to about 40 °C (e.g., lowlands

of Ethiopia), while the minimum temperature ranges from about 5 °C to about 25 °C. Potential evapotranspiration of the region ranges from about 1500 mm to more than 2000 mm at an annual scale. The monthly climatology of precipitation, depicting the wet and dry months, is illustrated in Fig. 2. The MAM is a critical rainy season for most countries in Eastern Africa. For instance, in south-central and south-eastern Ethiopia, it is called the Belg season, which is the primary rainy season. In northeastern and central-eastern Ethiopia, the pastoral and agro-pastoral livelihoods depend on this season's rainfall. It is a very important season in most of Kenya, Uganda, and Tanzania for agricultural activities. Of the four countries, the north-western part of Ethiopia has the JAS season as its main agricultural season, unlike the other countries.

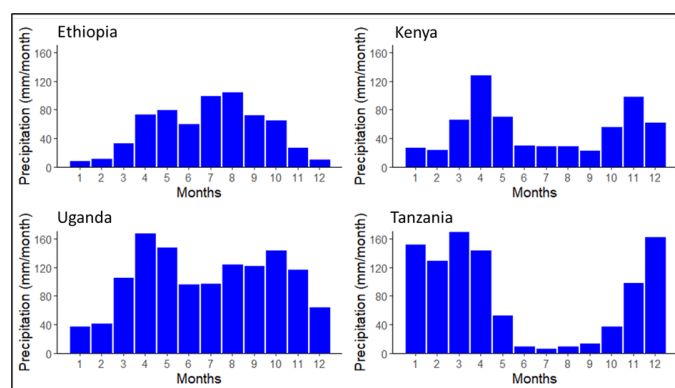


Figure 2. Climatological average precipitation (mm/month) for EA countries (1981-2019).

Historical Climate Variability and Trends

Climate Variability

East Africa is highly vulnerable to climate variability and extreme events. The variability in climate, particularly seasonal rainfall variability, is causing a significant impact on sectors such as agriculture and water. Compared to temperature, the variability in rainfall is causing a significant impact on the region's food security. Most people in East Africa depend on rainfed agriculture for their livelihoods, which is easily impacted by a shift and variability in rainfall during the agricultural seasons (e.g., MAM and OND). The variability in temperature is very low and shows an increasing trend, particularly after the 1990s⁸.

The maximum and minimum temperatures in Ethiopia, Kenya, and Tanzania have been observed to deviate above (by up to 0.7°C) and below (by up to -0.6°C) the long-term average (1979-2016), both before and after 1998. However, there is no significant change in precipitation, except in a few places (see next section), but rather high variability during the

rainy seasons. During the March-May (MAM, also called the long rainy season), the variability in rainfall is up to 150 mm above and below the long-term average (1981-2019, Fig 3). Compared to Ethiopia, Kenya and Uganda, the variability in precipitation during MAM is very low in Tanzania (Fig. 3). The variability in rainfall during MAM is influenced by large-scale climate variables such as El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole Mode Index (IOD)^{9,10}. In addition to seasonal variability, the impact of ENSO and IOD is also significant in decadal climate variability in East Africa^{10,11}.

Similarly, during OND, the variability is very high (up to \pm 200 mm) and a significant cause of extreme events (e.g., floods and droughts). The July-September (JAS) months are another critical season in Ethiopia's highlands and northern parts, showing high variability. The variability during the JAS is significantly correlated (correlation = -0.56) with ENSO⁸.

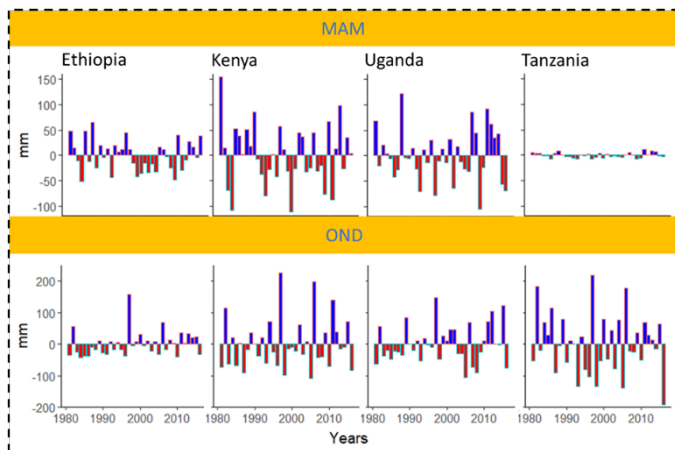


Figure 3. Seasonal precipitation variability (deviations from the long-term average) during 1981-2019 for MAM and OND seasons

Climate Trends

Seasonal Changes in Precipitation during 1981 – 2019

MAM (March-April-May)

- Rainfall during the long rainy season shows an increasing trend (up to 1.2 mm/year) in Western Ethiopia and a decreasing trend in Eastern Ethiopia (up to 0.6mm/year)
- Rainfall is increasing and decreasing in Western and Eastern Kenya, respectively.
- Eastern and Western Uganda are showing an increasing and decreasing trend in precipitation, respectively.

OND (October-November-December)

- A large part of Ethiopia and Kenya show an increasing trend.
- Uganda (except the western region) and Tanzania (except the southeast part) show an increasing trend during OND.

JAS (July-August-September)

- Rainfall in the northern part of Ethiopia is showing an increasing trend.
- This is an important agricultural season only in some parts of Ethiopia.

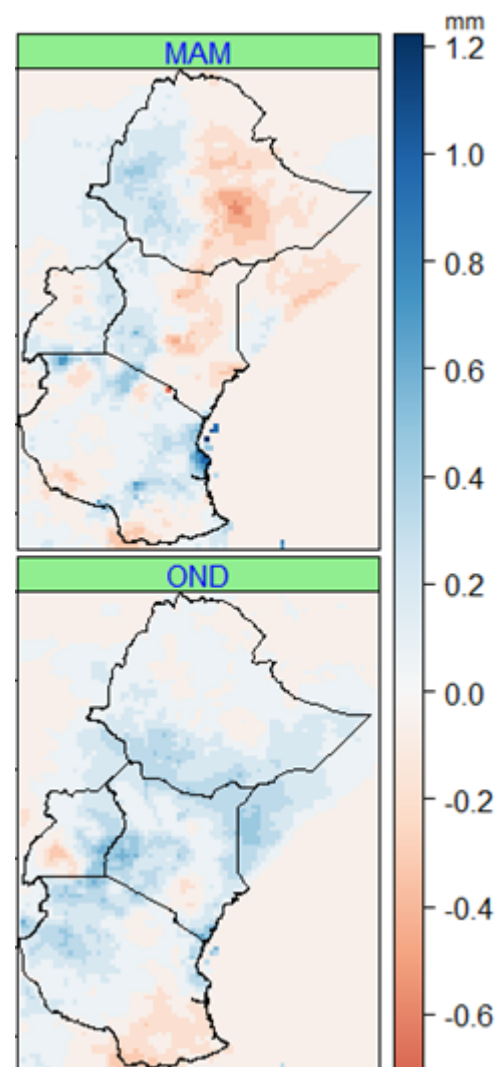


Figure 4. Seasonal trend in precipitation (mm/year) during 1981-2019 for MAM and OND

Annual Change in Precipitation and Average Temperature

Ethiopia

- An increasing trend in annual precipitation in northern and Western parts of Ethiopia.
- The central eastern part of Ethiopia shows a decreasing trend.
- The average annual and maximum temperature shows an increasing trend.
- Minimum temperature decreases in the highlands but increases in the southern part.

Kenya

- The Western part of Kenya shows an increasing trend in annual precipitation.
- A decreasing trend in large part in Eastern Kenya (up to 5 mm/year).
- Increasing trend in annual average and maximum and minimum temperature.

Uganda

- There is an increasing trend in annual precipitation, except in parts of the western region.
- The increasing trend is significant in terms of average and maximum temperature.

Tanzania

- Annual precipitation in the western and northeastern areas shows an increasing trend.
- An increasing trend in annual average and maximum and minimum temperature.

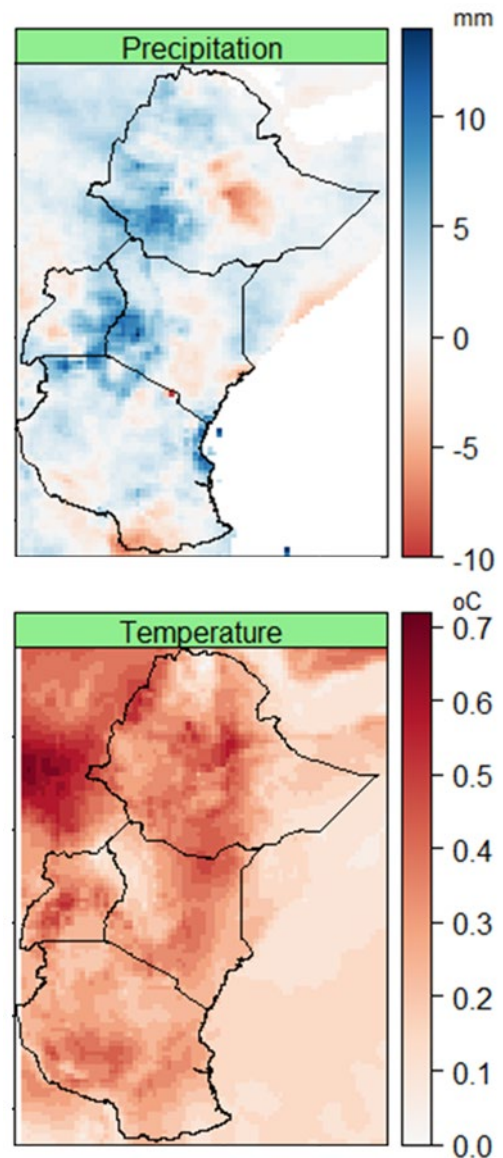


Figure 5. Annual trends in precipitation (mm/year) and average temperature (°C/decade) during 1981-2019

Future Climate Projections

Seasonal Projection

The future climate in East Africa shows an increase in precipitation during the long rainy season in Ethiopia and a decrease in different parts of Kenya and Tanzania Under SSP245 throughout the 21st century (Fig. 6). The precipitation during MAM in Uganda will increase in the 2050s (2041-2070) and 2080s (2071-2100) under SSP245 and SSP585 by more than 50 mm compared to the historical period (1981-2010).

On the other hand, a large part of the region, particularly Kenya, Uganda, and Tanzania, will receive higher rainfall (+10 to +200 mm) in the future than in the historical period. However, the north-western part of Ethiopia will receive lower precipitation amounts in the 2050s (SSP245 and SSP585) and 2080s

(SSP245). During JAS, the precipitation in the north-eastern part of Ethiopia and western Tanzania is projected to increase by up to 60% compared to the historical period. Similar to the observed increase in temperature during the historical period, it is projected to increase in the future. The projected increase in temperature leads to an increase in evapotranspiration in the region. The evapotranspiration is projected to increase by up to 15% during MAM, JAS and OND. The increase in evapotranspiration is higher during MAM and JAS compared to OND. The increase in evapotranspiration leads to more deficit in water availability in the region, affecting agriculture and other sectors. The projected water deficit (precipitation – evapotranspiration) will be higher (up to -500 mm) during MAM and OND in Ethiopia, Kenya, and Tanzania and will lower (+200 mm) in Uganda. Western Ethiopia will still have surplus water, which is higher in magnitude than in the historical period during JAS.

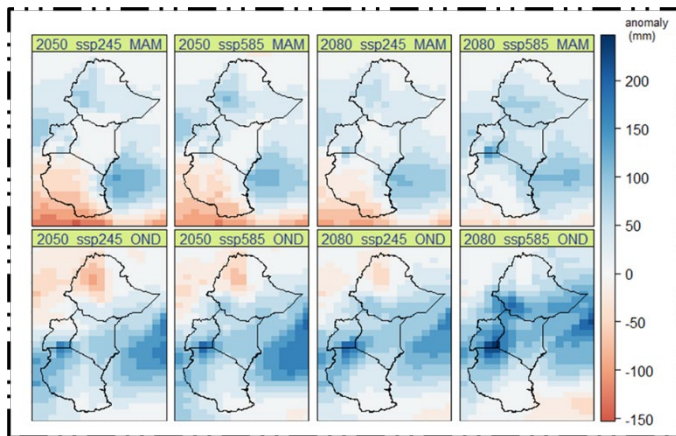


Figure 6. Annual trends in precipitation (mm/year) and average temperature (°C/decade) during 1981-2019

Annual Average

Annual precipitation and the average temperature are projected to increase in the future under SSP245 and SSP585 (Fig. 7). In Ethiopia, Kenya, and Uganda, the annual precipitation is projected to be higher than the historical period after 2030 and the projection is higher under SSP585 compared to SSP245 (Fig. 7). In Tanzania, there is high variability (+150 and -50 mm) with an increasing tendency towards the end of the 21 century. Unlike the projected increase and high variability in precipitation, the average temperature will be higher than in the historical period (up to +4°C) in Ethiopia, Kenya, Uganda, and Tanzania in the future under the SSPs. The difference between SSP245 and SSP585 is clear after 2050 and is related to the expected increase in greenhouse gas concentration after 2050s¹².

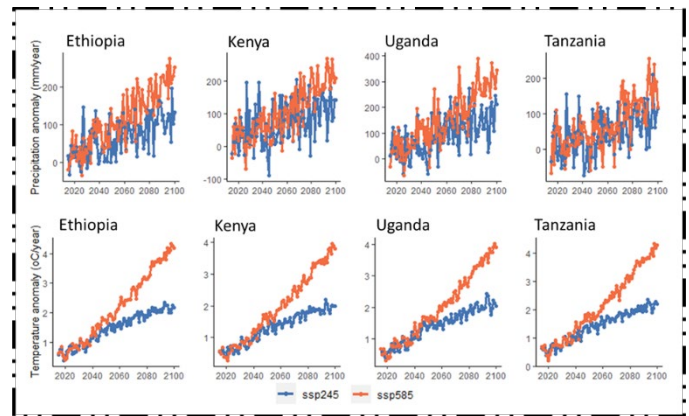


Figure 7. Annual trends in precipitation (mm/year) and average temperature (°C/decade) during 1981-2019

Future Climate Extremes

Climate extremes, particularly temperature extremes, are projected to increase in the future. The projected increase in temperature extremes (e.g., warm nights and days) aligns with the observed increasing trend during the historical period¹³ and global warming. Unlike the temperature extremes, historical and future precipitation extremes did not show a significant change but showed high variability, leading to floods and droughts. For example, the maximum 5-day precipitation is projected to be higher (up to 7 mm) than in the historical period in Ethiopia, Kenya, Uganda, and Tanzania.

In addition, there is an increase in the number of wet days (up to 25%), particularly during MAM in Ethiopia and Kenya. However, in Ethiopia, wet days will decrease (up to -30%) during OND in the 2050s. Heavy precipitation days will increase in all countries except Tanzania by up to 25% compared to the historical period. In addition, dry days will increase in the future, particularly higher (up to 80%) in dryland areas of the region (e.g., Afar and Somalia). The region will face more wet and dry days, increasing droughts and flood frequencies.

Climate Risks by Sector

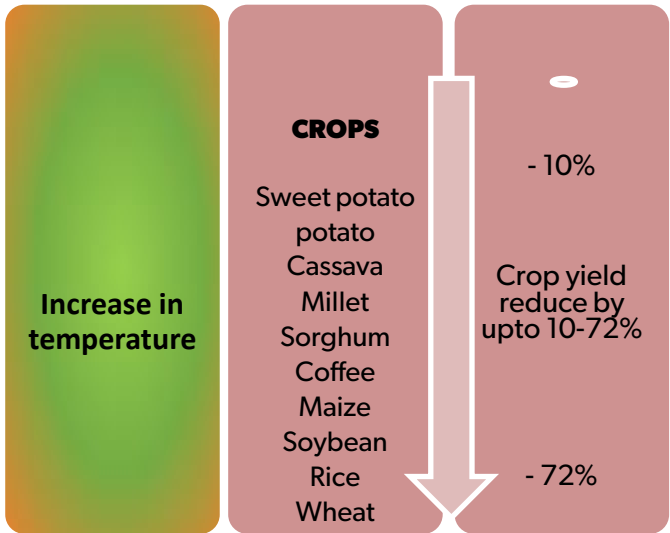
Future climate projection is not in favor of East Africa. More extreme floods and droughts are projected, negatively impacting the most important sectors.

Under climate change, the demand for water, energy and food is projected to increase in the future. In East Africa, climate change and poor management of environmental resources (e.g., water, soil and waste) will increase the demand for food, water and energy.

Unlike the developed world, the impact of climate change on agriculture, water and energy sectors is expected to be higher due to limited adaptive capacity, technologies and information on short and long-term changes in climate and climate extremes.

Agriculture and Livestock

Agricultural production will be severely affected by climate change¹⁴. Agriculture and livestock are the major economic sectors in East Africa. More than 80% of the population in the region depends on these sectors for their livelihoods and significantly contribute to the region's economy. The projected increase in seasonal precipitation over East Africa will benefit agriculture. However, the region's maximum and minimum temperatures are projected to increase, increasing



potential evapotranspiration. Potential evapotranspiration is projected to increase in this region, which is more than the projected precipitation amount, leading to a water deficit for crops and livestock. The projected increase in temperature, precipitation and extreme events will affect the region's agricultural production and food security. For example, the low rainfall during MAM in 2011, for example, caused a significant impact on the agriculture sector, leading to food insecurity for millions of people.

On the other hand, excess rains in 2015 affected crop and livestock productivity, with more than half a million people affected and more than 250 people killed. As extreme events become more frequent in the future, crops will be destroyed by floods and other agricultural activities will be disrupted. Droughts, on the other hand, will exacerbate the poverty level and will increase famine and malnutrition. With the projected increase in climate extremes, the region needs to implement adequate and sustainable adaptive measures

and strategies by introducing new technologies and diversifying crops, for example.

Key points

- A moderate increase in average temperature will help crops to grow faster. However, the projected increase in extremes such as floods, drought and heat waves will affect the growth of crops and reduce productivity.
- Higher CO2 affects crop production and will be significantly higher after 2050 due to the expected rise in CO2.
- Weeds, fungi and pests grow well under a warmer and wetter climate, affecting agricultural livelihoods and food availability.
- Soil erosion and land degradation are expected to increase due to increased climate extremes, affecting agricultural productivity.
- An increase in temperature will increase water and heat stress for crops and affect the productivity of the most important crops in the region.

Crops

Global warming is becoming a major challenge in the region and globally for food security. The increase in temperature is projected to reduce crop productivity by more than 10%.¹⁴

Even the most climate-resilient crops, such as sorghum and millet, will reduce their yields (<20%) in the 21st century as the temperature increases¹⁵. However, the projected increase in evapotranspiration and extreme events (e.g., heatwaves, floods and droughts) and variability in precipitation and river flows might exacerbate the overall reduction in crop yields. Taking the impact of climate by country, maize production in the highlands of Ethiopia is projected to increase by an average of 5%, while in Kenya and Tanzania, maize production will decrease by 2.5%¹⁶. In some parts of Ethiopia, particularly in parts of Oromia, the productivity of the major crops (teff, maize and sorghum) is expected to increase with the optimum increase in temperature (SSP245 or RCP245 and less).

By 2023:

- Ethiopia will face significant shocks in coffee production.
- Coffee production will be reduced by more than 25%.
- Wheat production will be reduced by more than 10% compared to recent years.
- Reduction in coffee and wheat production by 2030 will lead to a decrease in GDP by approximately 3%¹⁷.

Climate change adaptation at the farm level will substantially reduce the negative impacts on crop yield.

Livestock

Climate change has already affected livestock production, mainly through heat stress affecting animal productivity and mortality, and through its effects on species distribution, grassland and livestock diseases. The impact of climate change on livestock production in East Africa and globally is becoming significant. Climate change is not a future threat in East Africa, as it already affects the region. Climate change affects livestock directly through an increase in temperature (heat stress), which causes animal mortality and a decline in productivity.

The IPCC 2022 report highlights the increased heat stress and rising risks to livestock globally. Increasing temperature or the number of warm and very warm days will reduce milk production and affect animal health. In East Africa, the maximum (x) and minimum (n) temperature days for maximum (TX) and minimum (TN) temperature days show an increasing trend during the last three decades.

- Extreme heat stress risk will increase for all livestock species globally.
- The impact of heat stress increases with an increase in temperature.
- A projected increase in heat stress might reduce milk production by up to 17%.
- 2°C of warming will lead to a reduction in the number of livestock by >7% by 2050, leading to an economic loss of >\$10 billion (IPCC-2021).
- Livestock production will decrease due to heat stress and the availability and quality of feeds.

- Livestock parasites and diseases might increase under climate change, affecting livestock.
- Increasing heat stress increases the risks to livestock
- Temperature extremes are increasing in East Africa and are projected to increase in the future^{13,18}.
- By mid-century, >10 of the land used for livestock production will be unsuitable.
- In tropical areas, the reduction in dairy and beef production caused a significant economic loss of >\$9 and \$31 billion per year, respectively (IPCC-2021).

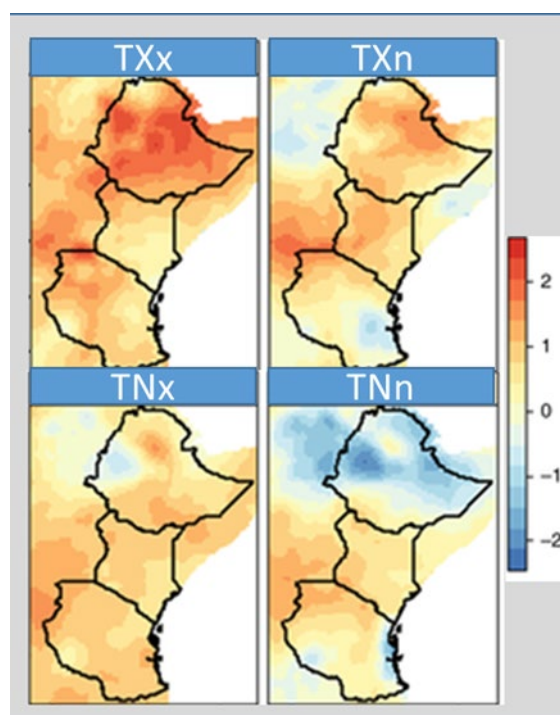


Figure 8. Historical change in maximum (x) and minimum (n) of maximum (TX) and minimum (TN) temperature (adapted from Gebrechorkos et al. 2018)

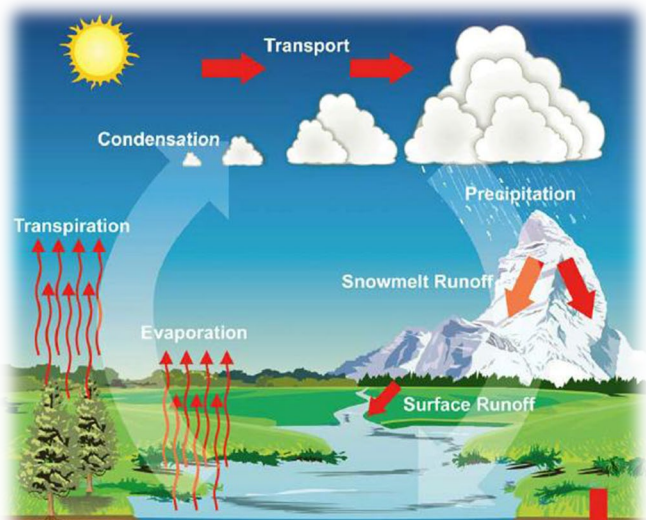
Water Resources

Climate change, particularly variability and decline in the amount of precipitation, is affecting water resources and availability (access) for people in East Africa. The projected increase in temperature is expected to elevate evaporation rates, which in turn can lead to more frequent, intense, and heavy rainfall events, as well as droughts in the future. These changes will significantly impact the dynamics of the water cycle.

Consequently, there will be increased pressure on domestic water supplies and food production due to the

occurrence of floods and droughts, which can disrupt water supply structures and agricultural systems. Higher temperatures and evaporation increase the water demand, which is a scarce resource in the region. Overall, the region will continue to face water shortages for domestic agricultural use and other sectors.

Global warming will likely speed up the water cycle by increasing the evaporation rate.



Climate change is causing more severe droughts and floods, which are expected to be more frequent in the future.

- Based on the downscaled GCMs and hydrological model outputs, the future monthly river flow will increase in most parts of the region (see Fig. 9).
- Except in Rufiji Basin (Tanzania) and Wabi Shebele (Ethiopia), the average annual river flow will be higher than in the historical period.
- The arid parts of Ethiopia and Kenya and large parts of Tanzania will be drier in the future.
- The decrease in Tanzania is mainly during the MAM and JAS months.
- Hydrological drought and floods will increase in the future under SSP245 and SSP585.
- Drought durations will increase (prolonged by up to 50%) in large parts of Ethiopia, Kenya, and Tanzania, but they will decrease in Uganda.
- The volume of water deficit during droughts will be higher in Ethiopia and Kenya.
- Floods will increase (decrease) in Ethiopia, Kenya and Uganda (Tanzania) by up to 50% in the 2050s and 2080s.

- The frequency of floods will increase in the 2050s and 2080s by about 25%.

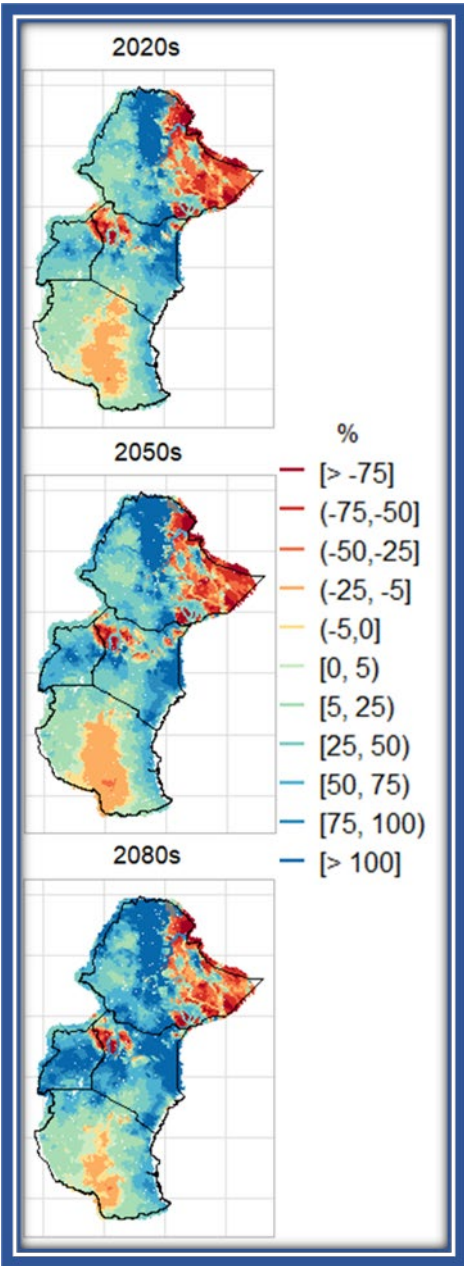


Figure 9. Historical change in maximum (x) and minimum (n) of maximum (TX) and minimum (TN) temperature (adapted from Gebrechorkos et al. 2018)

Ecosystems

In East Africa, the natural environment provides ecosystem services and supports the economy and livelihood of the people by providing clean water, food (e.g., fish), medicine, recreation, jobs, wildlife habitat and building materials. The ecosystem also protects against hydroclimate extremes such as floods, heat waves, wildfires, and droughts. As the climate changes, ecosystems' extent, distribution, and composition will be impacted. When the ecosystem is

affected by climate change, the economic values and services provided will be diminished. For example, climate change reduces the ability of ecosystems to regulate water flows and improve water quality. In addition, the change in ecosystems leads to the migration and loss of many important species.

The change and variability in climate can alter the terrestrial and freshwater ecosystems. In addition, coastal habitats are in danger due to the increased and projected increase in hydroclimate extremes. The major stressors of the ecosystem include an increase in temperature, an increase in frequency and amount of heavy rainfall events, a decrease/shift in seasonal rainfall, an increase in consecutive dry days (or dry spell days), and soil erosion and other environmental stressors (e.g., pollution, over harvestings) will impact the ecosystem and the service they provide.

“Ecosystems are rapidly changing in response to climate change and other global change drivers, not only in response to temperature changes but also associated changes in precipitation, atmospheric carbon dioxide concentration, water balance, ocean chemistry, and the frequency and magnitude of extreme events. Ecosystems vary in sensitivity and response to climate change because of complex interactions among organisms, disturbance and other stressors”¹⁹.

The change in natural ecosystems threatens biodiversity and contributes to the region's food insecurity by reducing food production. According to the National Climate Assessment, five strategies are defined to help the ecosystem adapt to climate change, and these include habitat manipulation, conserving population with higher diversity, replanting species better suited to the projected climate, offsite conservation (e.g., seed banking), and managed relocation or assisted migration.

Energy

Climate change puts energy security at risk. In East Africa, the demand for energy is rising due to the economic, population, and urban growth. Hydropower is the most important source of energy in most of the region. Climate change and variability mainly increase temperature, precipitation variability, and extreme hydroclimate frequency, affecting energy production. Climate change will likely increase the energy demand for cooling during the summer seasons. On the other hand, climate change will affect the water available for energy production. In addition, the efficiency of energy production reduces during a warmer climate as more water is used for cooling. Climate

change directly affects energy production, fuel supply, and the resilience of current and future energy infrastructure. Extreme events such as droughts and heatwaves put existing energy generation under stress.

- A large amount of water is required for cooling during a warmer climate.
- Sever and frequent heatwaves increase the demand for water for electricity.
- Floods affect the way hydropower operates to reduce downstream flooding.
- The projected increase in temperature, evaporation, and droughts will increase energy production to provide water for agriculture and domestic use.

Regional, National and Local Scale Climate Change Adaptation Strategies

Climate change and variability are arguably some of the most critical challenges East African countries face today. Due to its limited adaptation capacities and well-written and documented adaptation strategies, East Africa is one of the most vulnerable regions to climate change. The limited knowledge and scarcity of regional climate change adaptation strategies in East Africa are further impacting the region's economy and well-being.

Climate change adaptation is a complex process because the severity of the impacts of the change varies from place to place depending on the topography, degree of socioeconomic development, adaptive capacity, response mechanisms, and technologies. Therefore, a multi-sector governance approach involving a wide range of stakeholders, representing individual citizens, non-governmental and governmental sectors, regional decision-makers and country-level decision-makers, must be engaged in developing adaptation strategies.

According to UNFCCC, “climate change adaptation is a critical component of the long-term global response to climate change to protect people, livelihoods and ecosystems,” and the implementation depends on the active and sustained engagement of stakeholders. Adaptation is a process by which strategies are developed and implemented to reduce and manage the impacts at different levels (see Fig. 10 for details).

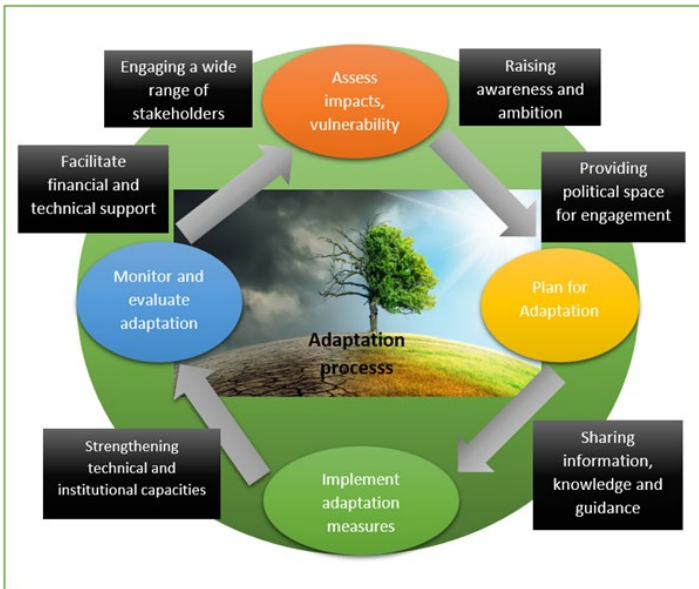


Fig. 10. Climate change adaptation process adapted from UN-FCCC

In East Africa, considering the current disasters, for example, the “Borena Zone drought in 2023” in Ethiopia, which killed more than 2.3 million livestock and left millions of households in danger, and the projected increase in extreme events (e.g., droughts, floods and heatwaves), the region urgently requires the development of site-specific adaptation measures and sound forecasting and monitoring tools to minimize the impacts.

Various site-specific adaptation measures are required to mitigate the effects of the projected change in extreme events. These are required to combat water shortages and reduce land degradation to enhance the quality and availability of water for agriculture, energy, and other sectors. In agricultural-intensive areas, adaptation strategies can focus on crops (e.g., crop selection, mixed cropping, soil conservation, and afforestation) and livestock (e.g., breeding strategies and management systems), labor migration, and income diversification. Further, agroforestry, integrated systems agriculture, sustainable forestry, and rehabilitation of degraded pastures are recommended as the most sustainable and effective measures to adapt to climate change and enhance the productivity of agricultural lands.



Fig. 11. Drought in Borena Zone in 2023 (©Silvy Bolliger)

Overall, unlike the existing adaptation strategies available in the region, an integrated approach involving all sectors (e.g., water, energy and agriculture) and basins’ scale users is urgently required to manage the future impacts of climate change. In addition, regional capacity development and awareness about the climate and future water availability are required to manage the limited resources available in the region sustainably. Finally, considering the future variability in precipitation, a government-supported transformation from rain-fed to irrigated agriculture would benefit the region's food security.

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