
# FACT SHEET
# CLIMATE VARIABILITY AND CHANGE IN THE ZAMBEZI RIVER BASIN


Figure 1: The Zimbabwe River Basin

**Key Messages**

- *The Zambezi Basin is characterized by an unstable rainfall regime, with high variability on interannual, decadal and multi-decadal time scales.This variability can be expected to continue in the future.*
- *The basin has warmed by about 0.7°C on average between 1901 and 2014. All climate models agree that temperatures in the basin will warm by between 0.9 and 2.5°C by the 2050s depending on greenhouse gas emissions scenario.*
- *The basin has experienced some decline in rainfall particularly in the period after 1980. Most climate models agree that the basin will be drier in future with mean annual rainfall declining by as much as 3 to 12 % by the 2050s.*
- *Future runoff is sensitive to rainfall change and is projected to decline by 10 to 20 % by the 2050s.*
- *The Zambezi River Basin is vulnerable to future impacts of climate change.There are increased risks of reduced water supplies, decreased hydropower potential, drought impact on irrigation and increased extreme flood events.*

This fact sheet presents a profile of the current and projected climate conditions for the Zambezi River Basin, the related risks and state of preparedness. It includes information on temperature, precipitation and extreme climate events (floods, droughts, wet and dry spells).The fact sheet can serve as a resource to the climate risk screening of development projects and building resilience to impacts of climate change in the river basin.

## THE ZAMBEZI RIVER BASIN

The Zambezi River Basin (Figure 1) has a total drainage area of about 1.4 million km$^2$ making it the largest in Southern Africa. The Zambezi River originates in the Kalene Hills in northwest Zambia at an altitude of 1,500m and flows south and eastwards to the Indian Ocean covering a total of 2,574 km.The river has three distinct stretches: the Upper Zambezi from its source to Victoria Falls, the Middle Zambezi from Victoria Falls to Cahora Bassa Gorge, and the Lower Zambezi from Cahora Bassa to the Zambezi Delta.The basin is shared by eight riparian countries – Angola (18.2%), Botswana (1.5%), Malawi (7.5%), Mozambique (11.6%), Namibia (1.1%), Tanzania (2.2%), Zambia (41.9%) and Zimbabwe (15.9%).

Zambezi waters are essential to regional food security, hydropower production and support the basic needs of more than 40 million people – projected to reach 50 million by 2025 - whilst sustaining a rich and diverse natural environment which is critical to sustainable economic growth and poverty reduction in the region. The Zambezi River Basin currently has approximately 5,000 MW of installed hydropower generation capacity. Major hydropower dams include Kariba and Cahora Bassa Dams on the Zambezi River, Itezhi-Tezhi and Kafue Gorge Upper dams on the Kafue River, and the Kamuzu Barrage that partially regulates Lake Malawi water levels for downstream Shire River hydropower production at Nkula Falls, Tedzani, and Kapichira Stage I hydropower dams. An additional 13,000 MW of hydropower potential has been identified (World Bank 2010).

Despite a history of economically devastating droughts and floods that are predicted to become more regular in the future because of climate change, none of the Zambezi hydropower development projects, current or proposed, has seriously integrated climate change into project design or operation. To protect the critical resources in the Zambezi River Basin, stakeholders must therefore continually evaluate and report on the risks and impacts of climate change and identify appropriate adaptation and mitigation strategies by utilizing the best available science.

## OBSERVED AND PROJECTED CLIMATE TRENDS

### Current Temperature

The temperature across the river basin varies according to elevation. Mean monthly temperature for the coldest month of July is around 13°C for high elevation (1500 m) areas of northwest Zambia to 23°C in low elevation areas in Mozambique. Mean daily temperatures for October and November (the warmest months) varies from 23°C in high elevation areas of northwest Zambia to 31°C in lower parts of the Zambezi Valley.

On average, mean annual temperature has warmed by about 0.7° C in the Zambezi Basin over the period 1901 to 2014, although some areas of the basin have warmed faster than others (Figure 2). The greatest warming occurred after 1980.

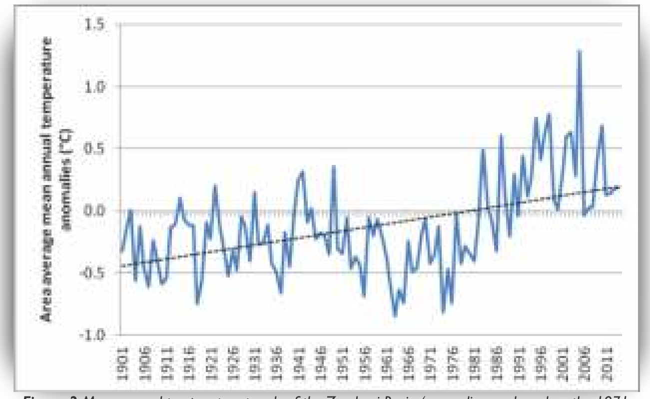


***Figure 2*** *Mean annual temperature trends of the Zambezi Basin (anomalies are based on the 1971 to 2000 reference period). (Source of data: University of East Anglia Climate Research Unit)*

### *Future temperature projections*

All climate models agree that the Zambezi River Basin will be warmer in future. Projections from five Global Climate Model (GCM) – Regional Climate Model (RCM) simulations suggest that future mean annual temperature will increase by 0.7 to 1.2°C between 2010 and 2039, 0.9 to 2.0°C between 2040 and 2069, and 1.3 to 2.7°C between 2070 to 2099 relative to the 1961 to 1990 reference period depending on emissions scenario. Twenty five Regional Climate Model simulations from the Coordinated Regional Climate Downscaling Experiment (CORDEX) for two Paris Agreement Global Warming Levels of 1.5°C and 2.0°C have also produced possible future climate changes for the Zambezi River basin. The results show a possible mean annual temperature warming of 0.5 to 1.5°C in the Zambezi Basin for the 1.5°C Global Warming Level and 1.5 to 2.5°C for the 2°C Global Warming Level above the mean for the 1971 to 2000 reference period for the moderate emissions (RCP4.5) and high emissions (RCP8.5) respectively. Lower temperature increases are more likely under a low emissions scenario and higher temperature increases are more likely under a high emissions scenario. Changes in mean annual temperature are dominated by the December-January-February (DJF) season under both Global Warming Levels.

Globally, average annual temperatures are projected to rise by 0.3 to 2.5°C by 2050, relative to the 1986 to 2005 average, but projected changes are higher for land areas. In southern Africa temperature projections range from no change to 3.5°C (winter) and 4°C (summer) warmer conditions by 2050.

### Current Precipitation

The climate of the Zambezi River Basin varies from arid in the west (Botswana and Namibia) through semi-arid and sub-humid areas in central zones and to the east. Closer to the equator, in Angola and coastal Tanzania, it is largely humid. The basin has a mean annual rainfall of 950 mm which falls mostly in the wet season from November to March. The northern parts are wetter and receive more than 1250 mm per annum, whereas the southern areas are drier receiving 500 to 750 mm per annum (Figure River Basin) has an unstable rainfall regime where annual rainfall ranges from 400 to 1000 mm with high seasonality and inter-annual variability (Figure 4). El Niño – Southern Oscillation (ENSO) events are a major inter-annual influence on rainfall. During El Niño years rainfall in most parts of the basin is subdued whereas La Niña years tend to be wetter. Three significant trends in precipitation for the Zambezi Basin are evident from historical records since 1901:

- A slight reduction in annual precipitation particularly from the 1980s,
- High inter-annual variability with more intense and widespread droughts. Some of the worst most recent droughts in the basin occurred in 1982-83; 1986-87; 1991-92; 1994-95; 2001-2002; 2004-2005; 2011-12; and 2014-15 whereas 2000; 2003; 2007 and 2008 are some of the notable recent flood years.
- An increase in heavy rainfall events in many Zambezi Basin countries (including Angola, Namibia, Mozambique, Malawi and Zambia).

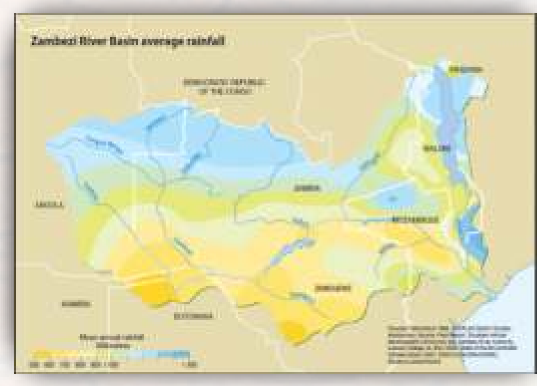


***Figure 3:*** *Long-term mean annual rainfall for the Zambezi basin (Source: Grid-Arundal)*

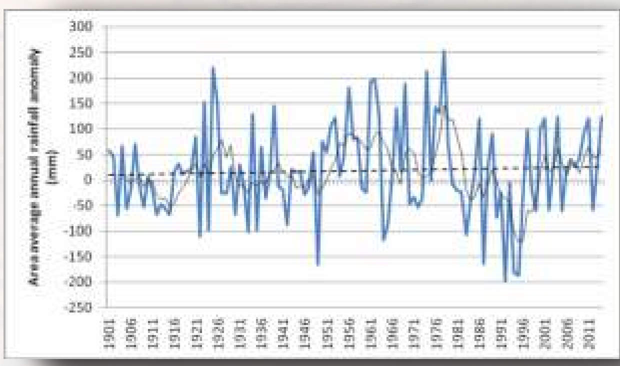


***Figure 4.*** *Rainfall variability of the Zambezi River Basin from 1901 to 2014 (anomalies are based on the 1971 to 2000 reference period). The dashed line is the linear trend line whereas the smooth curve is the five year running mean. (Source of data: University of East Anglia Climate Research Unit)*

### Future precipitation projections

Most climate models agree that there will be a general decline in precipitation in the Zambezi River Basin. Average precipitation declines from one to five percent by 2010 to 2039, three to twelve percent by 2040 to 2069 and eight to nineteen percent by 2070 to 2099. Under a 1.5°C Global Warming Level, most of the 25 GCM-RCM simulations under RCP8.5 scenario project a reduction in mean annual precipitation of up to twenty percent in smaller areas of the Zambezi River Basin. However, under a 2°C Global Warming Level (GWL), a larger fraction of the Zambezi River Basin face a robust decline in precipitation ranging from ten to twenty percent of the 1971 to 2000 mean. Annual mean changes in precipitation are dominated by the September-October –November (SON) season. In the Zambezi River Basin, variability on inter-annual, decadal and multi-decadal time scales, as experienced in the past, is expected to continue to be the dominant influence on future rainfall.

### *Extreme events*

The most severe effects of global warming will be related to the frequency of occurrence and severity of extreme events. For both 1.5 and 2.0°C GWLs, the maximum number of consecutive dry days is projected to increase over the Zambezi River Basin with longer dry spells in the southern sections of the basin including parts of Namibia, Botswana, southern Zambia and northern Zimbabwe. On the other hand, consecutive wet days are projected to decrease. Overall, the Zambezi River Basin will experience drier and more prolonged drought periods, and more extreme floods.

### Evapotranspiration

Mean annual basin wide potential evapotranspiration is about 1600 mm and potential evaporation exceeds rainfall in each calendar month for all the thirteen sub-basins. Due to the high temperatures, the annual total evaporation ranges between 5 and 10 mm per day. As a result, about ninety two percent of the rain is lost through evapotranspiration and an average of eight percent is available as surface runoff.

In future, potential evapotranspiration is projected to increase by between four and twenty percent across the basin because of warmer temperatures.

### Runoff

The mean annual discharge at the mouth of the Zambezi as it enters the Indian Ocean is estimated at 4200 $m^3/s$ (130$km^3$/year). Runoff in the upper Zambezi is highest in the period March to May. Mean annual runoff from the basin is about $26.8 \times 10^9$ $m^3$ giving an annual average flow of 850 $m^3/s$.

Future runoff is projected to decrease by about four to twelve percent by 2020, ten to twenty percent in the 2050s and sixteen to twenty three percent by the 2080s depending on emission scenario. Increasing evapotranspiration may also further reduce runoff.

## EMERGING RISKS AND CHALLENGES

The Intergovernmental Panel on Climate Change (IPCC) has rated the Zambezi River Basin as the most vulnerable to future impacts of climate change among eleven major basins in Africa because of warmer temperatures and a decrease in rainfall.

### Water climate risks

Climate change impacts present challenges of different dimensions to the development and management of water resources. The potential threats of a variable and changing climate include alteration of rainfall patterns, stream flow, soil moisture, groundwater recharge, evapotranspiration and the frequency and severity of extreme events particularly droughts and floods. For the Zambezi Basin, a number of studies show that the following risks are likely:

- All Zambezi Riparian States will experience a significant reduction in average annual stream flow. Multiple studies estimate that the Zambezi runoff will decrease by ten to twenty percent by 2050s.
- Growing water demand coupled with potential for reduced supplies will increase risk of water stress in the semi-arid parts of the Zambezi River Basin.

### Hydropower climate risks

Based on predictions from a number of climate models of a hotter and drier Zambezi River Basin, climate change has the potential to affect hydropower operations in the basin in at least six important ways:

- Decreased basin runoff (14 to 26 percent by 2100), more frequent and prolonged drought conditions will result in reduced reservoir inflows and overall hydropower output.
- Increased extreme flooding events, due to higher rainfall intensity and more frequent cyclones will increase the risk of worse flood impacts from uncontrolled releases, and risks to dam safety.
- A delayed onset of the rainy season could result in less predictable power production and more uncertainty and complications in using reservoirs for flood management.
- Increased surface-water evaporation could reduce power production.
- Increased sediment load to reservoirs, resulting from higher rainfall intensity and corresponding erosion, will lead to a decrease in reservoir capacity and greater difficulty in managing floods. The bigger reservoirs including Lake Malawi, Kariba and Cahora Bassa will be the least affected by the sedimentation challenge because of the large reservoir volume.
- As a result of reduced rainfall, increased evaporation losses in reservoirs and reduced runoff, some studies project decreased hydropower production potential in the Zambezi by about nine to 12 percent in the 2020s, 18 to 20 percent in 2050s and 28 to 31 percent in the 2080s depending on emission scenario.

### Agriculture climate risks

Over 100 irrigation projects covering an area of about 366,000 hectares are at different levels of planning or development in the basin, whereas about fifteen percent of the land is under rainfed crop production. A drier future climate means more risk related to drought impact. Higher temperatures and reduced rainfall are projected to increase demand for irrigation water and reduce rainfed crop yields by upto 50% for some countries by the 2050s.

## ADDRESSING THE CHALLENGES

Future climate projections are not certain. Addressing future imbalances between water supply and demand in the Zambezi River Basin will require diligent planning and collaboration that applies various ideas and strategies at the local, country, regional and basin-wide scale bearing in mind uncertainties in future climate projections.

Current responses include:

- **Coordination**: specific examples of coordination in the Zambezi River Basin include the establishment of the Zambezi Watercourse Commission (ZAMCOM) and the Zambezi River Authority (ZRA); The Zambezi Integrated Water Resources Management Strategy (ZAMSTRAT); the SADC revised protocol on shared watercourses of 2001, are a result of such regional coordination efforts.

- Zambezi River Basin states have implemented **drought and flood disaster risk reduction** and management programmes, early warning systems, action plans for climate change resilience and research in drought tolerant crop varieties.

**Zambezi Water Resources Information System Enhancement 3**: Hydro-meteorological Database and Decision Support System (ZAMWIS- DSS)". This initiative started in 2017 and aims to support cooperative management and development of the water resources of the Zambezi watercourse in a sustainable and climate-resilient manner through systematic data and information sharing and exchange.

**The Strategic Plan for the Zambezi Watercourse** – this is ZAMCOM's core project which seeks to develop a strategic plan that is comprised of a general planning tool and process for the identification, categorization and prioritization of projects and programmes for the efficient management and sustainable development of the Zambezi Watercourse.

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| ***Ensemble*** | *A collection of a minimum of three model simulation characterizing a climate prediction or projectic [IPCC AR5]* |
| ***Representative Concentration Pathway (RCP)*** | *Scenarios that include tin series of emissions a concentrations of the f suite of greenhouse gas and aerosols and chemica active gases, as well as la use/land cover. RCPs usua refer to the portion of t concentration pathw extending up to 2100, f which Integrated Assessme Models produc corresponding emissi scenarios. [IPCC AR5]* |
| ***RCP4.5*** | *Generally, moderate emissio One of two intermediate stabilization pathways in wh radiative forcing is stabilized approximately 4.5 W m⁻² after 2100. [IPCC AR5]* |
| ***RCP8.5*** | *Generally, high emissions. O high pathway for wh radiative forcing reaches >8 W m⁻² by 2100 and continue to rise for some amount of time. This scenario is ofte categorized as "business usual" with respect to GH emissions[IPCC AR5.]* |

**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.


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