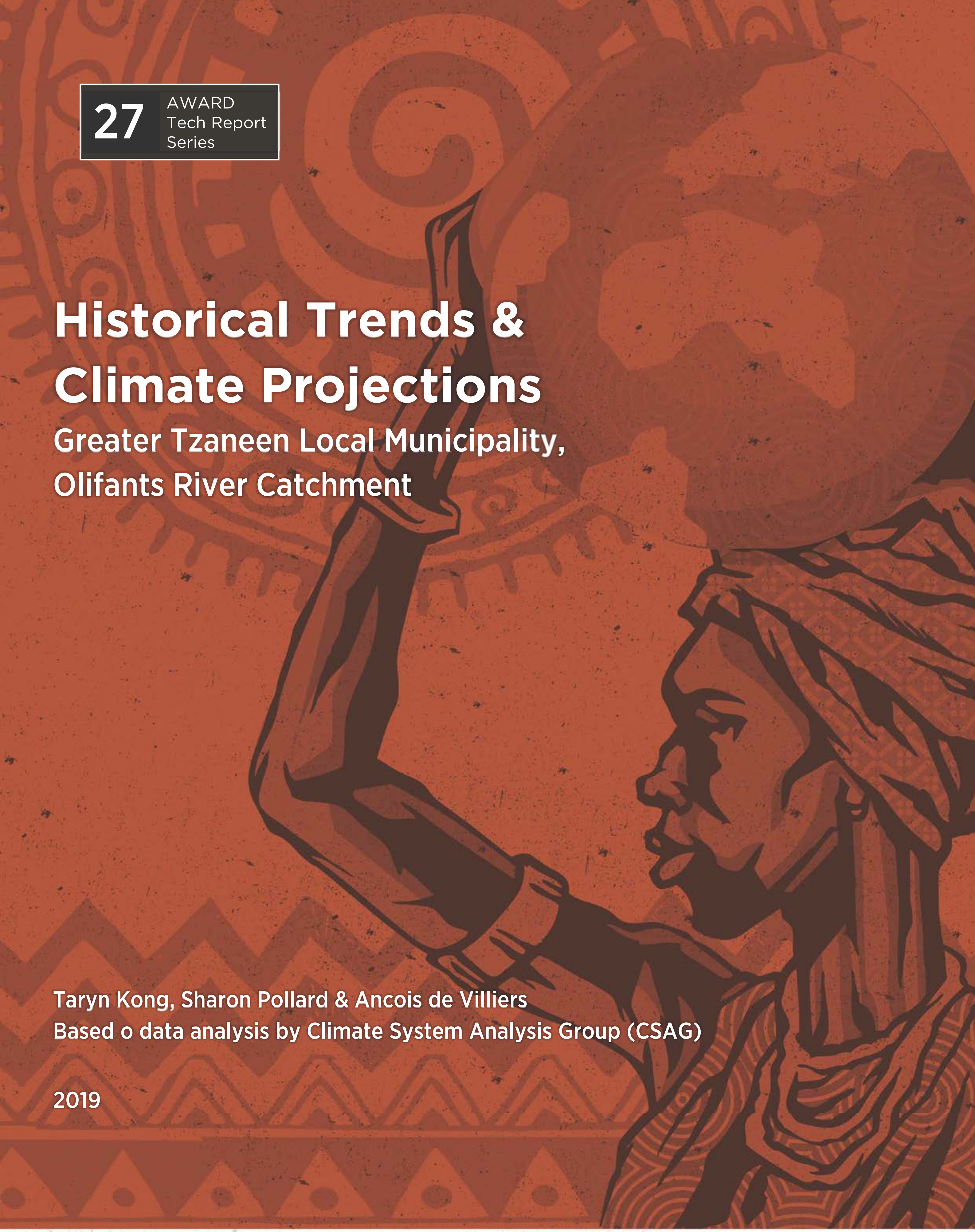

27 AWARD
Tech Report
Series

Historical Trends & Climate Projections

Greater Tzaneen Local Municipality, Olifants River Catchment

Taryn Kong, Sharon Pollard & Ancois de Villiers
Based o data analysis by Climate System Analysis Group (CSAG)

2019

USAID: RESILIENCE IN THE LIMPOPO BASIN PROGRAM (RESILIM) - OLIFANTS

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Based on data analysis by Climate System Analysis Group (CSAG)

The Climate System Analysis Group (CSAG) is a research group at the University of Cape Town. CSAG seeks to apply core research to meet the knowledge needs of responding to climate variability and change. The climate data in this is report comes from CSAG.

2019

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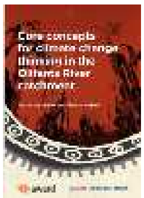
Acronyms

AWARD	Association for Water and Rural Development
CHIRPS	Climate Hazards Group InfraRed Precipitation with Stations
CRU	Climate Research Unit
CSAG	Climate System Analysis Group
GCMs	General Circulation Models
GHG	Greenhouse gas
GPCC	Global Precipitation Climatology Centre
IPCC	Intergovernmental Panel for Climate Change
RCP	Representative Concentration Pathways
SOMD	Self-Organizing Map based Downscaling
WFDEI	WATCH Forcing Data methodology applied to ERA-Interim

AWARD’s Climate Change Adaptation series

Series 1: Understanding core concepts of climate change



Core Concepts for Climate Change Thinking in the Olifants River Catchment

A basic brochure describing the difference between climate and weather, and outlining climate change and its impacts. The brochure is available in English or Sepedi.

Climate Change: Understanding Scenarios, RCPS and PPM

A technical brochure that explores greenhouse gas scenarios and helps to understand Representative Concentration Pathways (RCPs) and parts of carbon dioxide per million parts of air – or parts per million (ppm). Find out what the 400 ppm figure is and why an increase of 2°C is so important.

Series 2: Understanding climate change projections in the Olifants Catchment

How is the climate changing in the Olifants River Catchment?

Within the Olifants River Catchment, the local climate has changed and is continuing to change. Importantly, these changes are not uniform across the catchment, partly because of the diversity and complexity of the landscape as well as weather patterns. This brochure describes the 5 distinct climate regions within the catchment. It can be used to inform planning and action to address climate change by reporting on the historical changes (from 1979 to 2013) and future projections (over a period including 2020, 2040 and 2080) in rainfall and temperature patterns for each climate region.

Technical brief series on historical trends and climate projections for local municipalities

A series of technical briefs which capture historical trends and projected changes in rainfall and temperature patterns for 5 local municipalities within the Olifants River Catchment:

1) Ba-Phalaborwa, Mopani District;
2) Maruleng, Mopani District;
3) Greater Tzaneen, Mopani District;
4) Elias Motsoaledi, Sekhukhune District Municipality; and
5) Lepelle-Nkumpi, Capricorn District Municipality.

Series 3: Dialogues for action - Supporting people to think about climate change & act

Guide to using a dialogical systemic approach for climate change literacy

A short guideline on how to facilitate meaning-making dialogues about climate change, potential impacts and adaptation to support climate literacy and action.

Series 4: Supporting adaptation plans

AWARD has developed several guides and tools to supporting identifying, developing and implementing potential adaptation plans for natural resource management.

See http://award.org.za/index.php/resources/

Introduction

AWARD has produced a series of communication documents to support climate change adaptation initiatives by describing and contextualising how the climate within the Olifants River Catchment has changed and is continuing to change. These insights are based on the downscaled and localised climate analysis provided by the Climate System Analysis Group (CSAG) from the University of Cape Town (UCT) on behalf of AWARD.

To support planning at the municipal scale, this series of technical briefs capture the results of an analysis focusing on the municipal boundaries of selected local municipalities. Although not all local municipalities of the Olifants River Catchment are presented, reasonable conclusions can be drawn by considering these municipalities as localised examples of the climate regions which extend across the Olifants River Catchment (see Figure 1)[1]. We have provided technical briefs for the following local municipalities:

1) Ba-Phalaborwa, Mopani District

2) Maruleng, Mopani District

3) Greater Tzaneen, Mopani District

4) Elias Motsoaledi, Sekhukhune District Municipality

5) Lepelle-Nkumpi, Capricorn District Municipality

These municipalities were selected based on the availability of climate data, and key project sites for several of AWARD's projects for climate change adaptation under the USAID-funded Resilience in the Limpopo Basin Program (RESILIM): Olifants Catchment (RESILIM-O) program.

Box 1: What is climate change?

What is weather? Weather is the pattern of rainfall and temperature over a short period of time (i.e. just a few days, and up to a week). The weather can change from day-to-day.

What is climate? Climate is the expected pattern of rainfall and temperature over a long period of time (i.e. seasons, years, or decades).

What are climate regions? Climate regions are areas that have distinct temperature and rainfall characteristics because of natural variability in the local climate and heterogeneity of a landscape.

What is climate change? Climate change is "beyond what we would expect" in the usual patterns of temperature and rainfall over a long period of time. This is when things are "odd".

What causes climate change? Our atmosphere has a "blanket" of greenhouse gasses (GHGs) which insolates our planet from the coldness of space, very much like we use blankets to stay warm in winter. Without these GHGs, our world would be too cold to live on. However, since the industrial revolution, we have increased the concentration of these GHGs by elevating fossil fuel emissions, and degrading our forests and grasslands which help to regulate GHGs. Consequently, the GHGs blanket has "thickened", trapping more heat on the planet than normal and so disrupting our climate system.

The current technical brief presents the analysis results for **Greater Tzaneen Local Municipality**.

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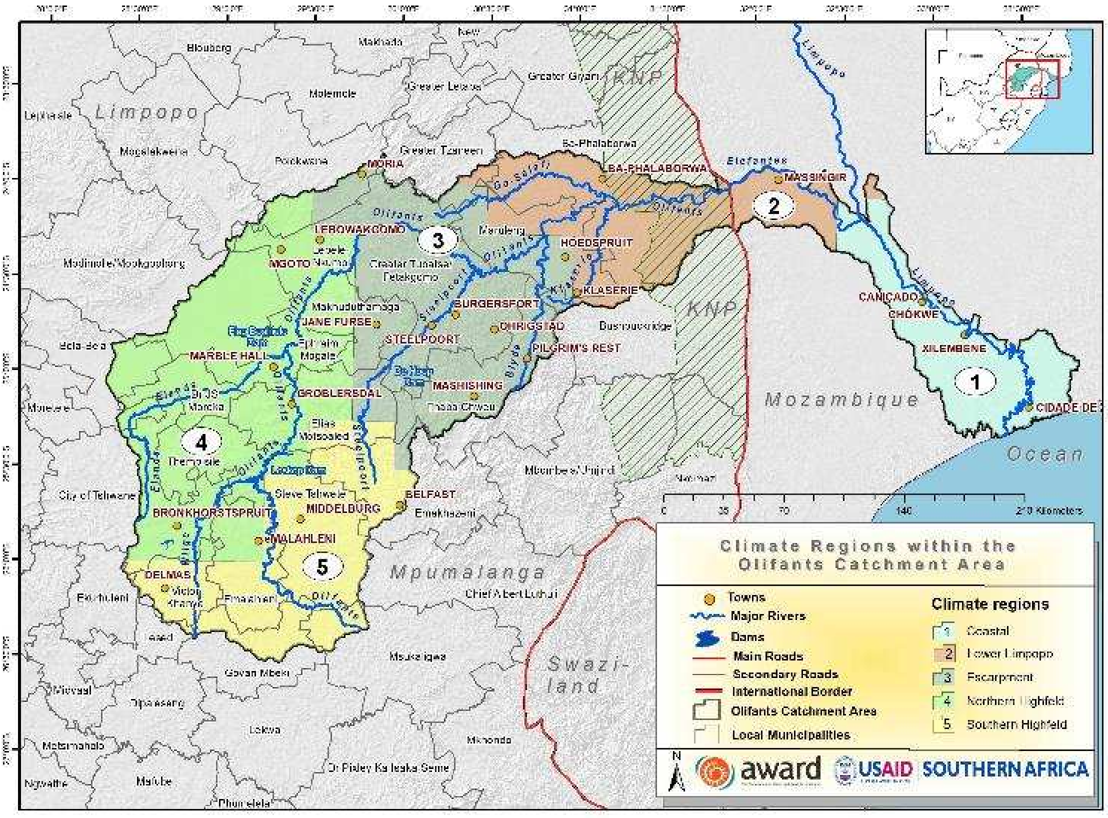
[1] *For an analysis that addresses climate change at the catchment scale which takes into consideration the heterogeneity of rainfall and temperature patterns across the landscape, see the technical report 'Historical trends & climate projections for climate regions in the Olifants River Catchment' and the associated brochure by Dr Taryn Kong, Dr Sharon Pollard and Ancois de Villiers (eds.) (2018).*



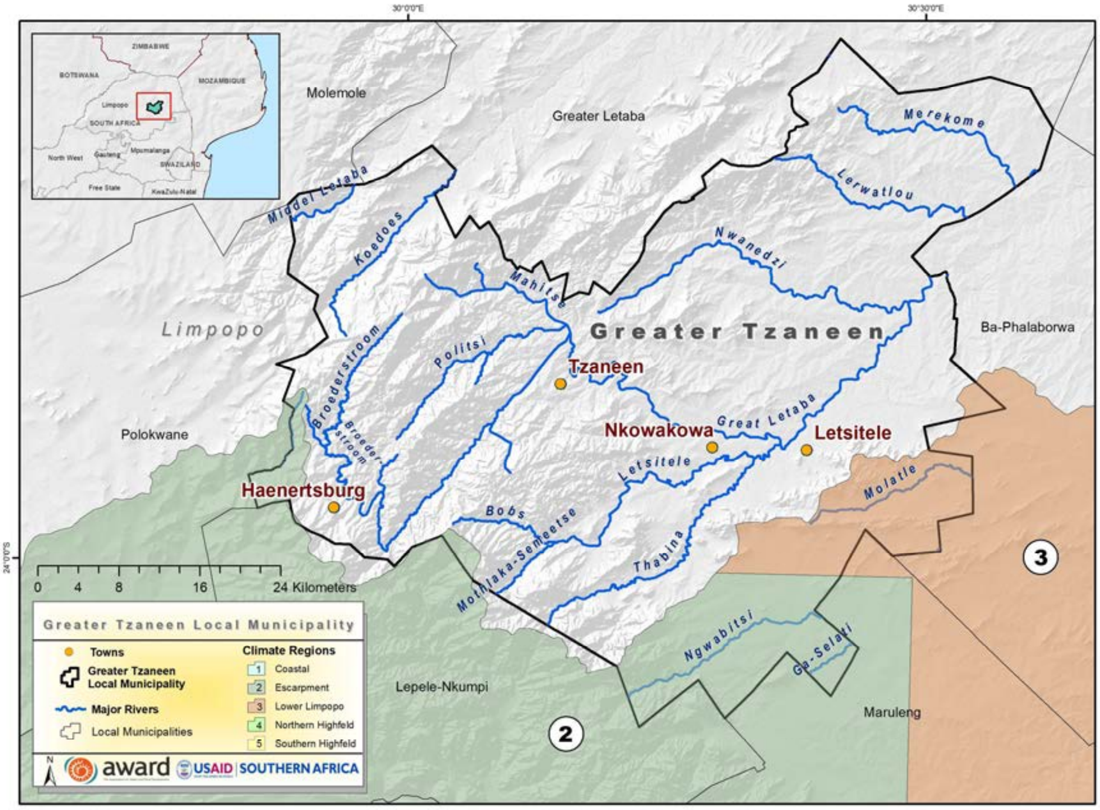


Figure 1. Top map shows the five distinct climate regions of the Olifants River Catchment. Bottom map shows the Greater Tzaneen Local Municipality in the Mopani District Municipality, Limpopo, South Africa, including two climate regions: Lower Limpopo Climate Region and Escarpment Climate Region.

The local context: Climate, hazards & vulnerabilities

Before we can consider how the climate has changed, we must review the characteristics of the current climate of the local municipality.

Current climate context

The focus of this brief's climate analysis was the Greater Tzaneen Local Municipality, Mopani District Municipality, in the Limpopo Province of South Africa (Figure 1), The municipality's current climate is characterised as hot and semi-arid with summer-rainfall (Table 1). The municipality includes two distinct climate regions:

- **The Lower Limpopo Climate Region,** which lies in the south-eastern part of the municipality. This climate region is one of the hottest in the Olifants River Catchment.
- **The Escarpment Climate Region,** which lies to the south-western part of the municipality near Haenertsburg.

TABLE 1. THE CURRENT CLIMATE CHARACTERISTICS OF THE GREATER TZANEEN LOCAL MUNICIPALITY, WITH REGARDS TO THE BOUNDARIES OF THE MUNICIPALITY, AND CLIMATE REGIONS.

Defined boundary	Mean annual temperature	Mean annual rainfall
Greater Tzaneen Local Municipality*	22°C	587mm
Lower Limpopo Climate Region	23°C	558mm
Escarpment Climate Region	18°C	818mm

Climate-related hazards

Historically, the municipality's risk profile includes the following climate-related hazards[2].

- Floods
- Droughts
- Periods of extreme heat, i.e. heat waves
- Veld fires
- Windstorms

Drivers of risk and vulnerabilities in the municipality

The climate-related hazards have implications for the social, economic and environmental drivers of risk and vulnerability currently active within the municipality. These drivers are presented in detail in Table 2. These drivers were identified and described as part of Collaborative Resilience Assessment with communities within municipality under the RESILIM-O program.

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[2] *See https://riskprofiles.greenbook.co.za/ for more details*

TABLE 2. THE AREAS OF CONCERN REGARDING RISKS AND VULNERABILITIES WERE CHOSEN FOR THEIR SIGNIFICANCE WITH RESPECT TO THE RESILIENCE OF ECOSYSTEMS AND LIVELIHOODS WITHIN THE OLIFANTS CATCHMENT.

Areas of concern		Drivers linked to risk and vulnerability
Water Quantity	🟨	**Agriculture**: Increasing demand for production puts more pressure on limited water resources.
	🟥	**Regulation**: Lack of oversight and enforcement of limitations on water use and water use licences.
	🟥	**Deforestation**: The removal of indigenous trees over a large area increased soil erosion rates, which can lead to more sediment flooding rivers and dams. This can reduce their capacity to hold water.
Water Quality	🟨	**Agriculture**: Organochemical run-off from extensive use of chemical fertilisers, pesticides and herbicides on agricultural land impacts water quality.
	🟨	**Deforestation**: The removal of indigenous trees over a large area increased soil erosion rates, which can lead to more sediment flooding rivers and dams. This can reduce water quality.
	🟨	**Inequality**: Some people living in poor rural areas do not have access to water of healthy quality.
Biodiversity	🟥	**Agriculture**: Extensive clearing of indigenous plants for more farm land to meet production demands.
	🟥	**Inequality**: High levels of inequality and poverty force people to become dependent on and overexploit natural resources.
Livelihoods	🟥	**Invasive Alien Plants:** The invasion of alien plants can replace economically valuable indigenous plants, and also limit land-use (i.e. bush encroachment of grazing land). However, some people do use these invasive alien plants to support their income, which can lead conflicting needs between people's livelihoods.
	🟥	**Land Restitution**: Changes in landownership provides both risks and opportunities land-use develop that will or will not support sustainable natural resource management.
Climate Change[2]	🟥	**Temperature**: Average temperatures have increased and are continuing to increase. Heat waves and days of extreme heat are becoming more frequent and extensive. **Impacts on water**: Under project climate changes, stream flow is expected to be reduced by between 40 - 60%[1].

High	🟥	Level of risk and vulnerability
Medium	🟨	
Low	🟩	

[1] Sawunyama, T. and Mallory, S.L.J. 2015. Impacts of climate change on runoff and yield in the Olifants River catchment. Association for Water and Rural Development (AWARD): USAID RESILIM-O Program.

[2] See the rest of this report for more details

How the climate analysis was conducted

To determine if and to what extent the climate of the municipality (a) has changed and (b) may change in the future, we need to consider both the recorded past and projected future patterns of rainfall and temperature in the area[3] (see Annex B and C).

- **Historical analysis and trends:** As a first step, we look *back* and conduct an analyses of historical trends, using observed temperature and rainfall data. This means that the data used for the analyses are actual records of temperature and rainfall in the area. The analysis determines if changes have already happened in our local climate. For the analysis, we considered records of temperature and rainfall between 1979 and 2014.

- **Future projections:** For the second step, we look *forward* and conduct an analyses of future projections based on modelling the global climate response to increasing greenhouse gas (GHG) concentrations. The models are a reconstruction of reality, and present our best current understanding of the climate system going forward from 2015 to 2040, 2060 and 2080. For this brief, we focused on the next two decades (i.e. 2015 to 2040).

The analysis of historical trends and future projections of rainfall and temperature are described in more detail below.

Historical trends

Analysis for the historical trends was based on observed data from three resources (see Annex C). Historical trends were analysed for 13 climatic variables in terms of temperature and rainfall (see Annex A). In analysing the historical trends, CSAG determine the statistical significance of any changes in these variables, i.e. how likely is it that the observed change was just by chance or can be attributed to climate change. Note that a lack of significant change does not imply that a change has not occurred, but rather that we cannot ascribe the change to some underlying process such as climate change. In terms of impacts, even non-significant trends can still be experienced as an impact and this is often corroborated by the lived experiences of communities on the ground level.

Future projections

Future climate projections are a product of modelling the global climate response to increasing greenhouse gas (GHG) concentrations. These models are called General Circulation Models (GCMs), which simulate the physical processes in the atmosphere, ocean, cryosphere and land surface. There are many GCMs developed by different climate research institutes around the world. Each GCM may simulate a different climate response for the same inputs because of the way certain processes and feedbacks are modelled. Among the scientific community, one way to manage this uncertainty is to use an ensemble of GCMs instead of an individual model. This is the approach that was followed in the analysis of the climate projections. With an ensemble, climate projections should be read as a range of outputs instead of a single number or an average.

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[3] *For a more detailed and technical summary description of the approach and methods used in the analysis, see the technical report Historical climate trends and projections for local municipalities in the Olifants River Catchment (Kong and Pollard, 2017 as derived from CSAG 2016).*

One key input for the GCM is GHG concentrations. At the time when this analysis was conducted, the Intergovernmental Panel for Climate Change (IPCC) adopted four GHG concentration trajectories, or Representative Concentration Pathways[4]. The four RCPs are RCP 2.6, RCP 4.6, RCP 6 and RCP 8.5[5]. One could think of these RCPs as different scenarios, ranging from optimistic (RCP 2.6) to pessimistic (RCP 8.5) about global efforts to change the future of GHG concentration in the atmosphere. The climate scientists at CSAG advised that the trajectory for RCP 8.5 is the most likely scenario given the current upward trend of GHG concentration in the atmosphere. For the Olifants River Catchment, CSAG performed analysis on climate projections for RCP 4.5 and RCP 8.5 (see Table 3). The RCP 8.5 as the “worst-case” scenario. The ensemble projections for the two RCPs should be understood as two separate sets of possible futures, and thus should not be combined or averaged.

TABLE 3. DESCRIPTION OF THE TWO SCENARIOS FOR FUTURE GHG CONCENTRATIONS USED IN THE ANALYSIS TO CONSIDER THE PROJECTIONS OF TEMPERATURE AND RAINFALL UNDER CLIMATE CHANGE.

	RCP 4.5 “Optimistic”	**RCP 8.5 “Worst-case”**
GHG emissions	GHG emissions are **stabilised** by mid-century and fall sharply thereafter.	Continued **increases** in GHG emissions until the end of the 21st century. i.e. no mitigation or business-as-usual.
What does this mean?	Climate change will still happen but the severity of the changes and impacts would be **abated** to an extent.	Climate change will continue to **accelerate** and the impacts will be more **severe** and **extensive** than under other scenarios.

Box 2: Downscaling GCMs

Each unit of analysis in a GCM is a three-dimensional grid over the globe. To understand this, imagine that the world is covered by three dimensional rectangular columns that stretch into the sky from the ground. The spatial scale of these grids are typically 250 to 600 km on their horizontal side. Such a spatial scale is too coarse for use at a local level, where factors contributing to the climate are at a much finer spatial scale. Therefore, these GCMs need to be downscaled, which is a process of adding spatial resolution to projections. Typically, downscaled projections have a spatial resolution of 25 km by 25 km. There are two main types of downscaling techniques: dynamical and empirical/statistical. CSAG used an empirical downscaling technique called Self-Organizing Map based Downscaling (SOMD), which is a statistic approximation of regional scale response based on global scale circulation and historical observed data. See Annex C for the list of downscaled GCMs used in their analysis.

Box 3: What GCMs are good at and not so good at

It is important to remember that models like the GCMs are reconstructions of reality, i.e. our best guess at our current level of understanding and information of how things actually are and work. At the moment, GCMs have become very sophisticated in projecting temperature into the future. However, scientists are still refining the GCMs ability to simulate patterns of rainfall, especially at the regional scale. Therefore, projections for rainfall may provide less clear results.

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[4] *See AWARD’s technical brochure Climate Change: Understanding Scenarios, RCPS and PPM*

[5] *Vuuren, Detlef P. van, Jae Edmonds, Mikiko Kainuma, Keywan Riahi, Allison Thomson, Kathy Hibbard, George C. Hurtt, et al. 2011. “The Representative Concentration Pathways: An Overview.” Climatic Change 109 (1-2): 5.*

What has changed?
What is likely to change?

This section summarises the results of the analysis regarding (a) historical climate trends, and (b) projections of future changes in the climate. The results are summarised in Table 4 and Table 5.

Temperature

The analysis indicated a strong signal of change for temperature. The annual mean of daily maximum and minimum temperatures has already significantly increased over the past decades, and are projected to continue to increase. Furthermore, the number of very hot days, although not having changed significantly over the last decades, are projected to increase under both scenarios.

Rainfall

For rainfall, the results are less clear. No statistically significant change was found for historical trends in any of the rainfall variables. Furthermore, overall, most models projected no change in rainfall patterns into the future. However, there were discrepancies amongst the models with several of these projecting increases and other decreases in the rainfall variables. Therefore, projected future rainfall patterns are uncertain.

These results are aligned with the findings of the historical and projected changes in climate for the two climate regions of the municipality (see Table 5). Furthermore, the CSIR Long-term Thematic Programme, South Africa, and the International Development Research Centre, Canada, also found strong signals for increased temperature, but less clarity in projected changes in rainfall for the region[6].

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[6] See https://riskprofiles.greenbook.co.za/, Accessed in June 2019

TABLE 4. SUMMARISED RESULTS OF THE HISTORICAL TRENDS AND FUTURE PROJECTIONS FOR THE GREATER TZANEEN LOCAL MUNICIPALITY.
THESE RESULTS WERE DERIVED FROM GRAPHS PRODUCED BY CSAG, SEE ANNEX B.

	Historical trends - the last 100 years	Future projections to 2040	
		Good scenario	Bad scenario
Temperature			
Annual mean of daily maximum	Increase of 1.1 to 1.3ºC	Increase of 0.75 to 2.1ºC	Increase of 1.1 to 2.3ºC
Annual mean of daily minimum	Increase of 1.4ºC in the last century*		
annual number of days with maximum temperatures over 36C (very hot days)	No statistically significant change	Increase of 7 to 32 days	Increase of 14 to 44 days
Seasonal mean of daily maximum temperatures	Increase, especially autumn, winter and spring	Increase pronounced in summer and autumn	Increase across all seasons
Seasonal mean of daily minimum temperatures	Increase across seasons		
Rainfall			
All climate variables related to rainfall	No statistically significant change	No change	No change

*This increase was not significant in the three most recent decades (1979 to 2014)

TABLE 5. SUMMARISED RESULTS OF THE HISTORICAL TRENDS AND FUTURE PROJECTIONS FOR THE CLIMATE REGION IN GREATER TZANEEN MUNICIPALITY.
THESE RESULTS SUPPORT THOSE PRESENTED ABOVE.

		Historical trends from 1979 to 2014	Future projections to 2040	
			Good scenario	Bad scenario
Lower Limpopo	**Temperature**			
	Mean daily max temperature	Increase of 0.25°C	Increase of 1 to 2°C	Increase of 2°C
	Annual number of days with maximum temperatures over 36C (very hot days)	No significant change	Increase of 30 to 37 days	Increase of 46 to 54 days
	Rainfall			
	All climate variables related to rainfall	No significant change	Mostly no change	Mostly no change
Escarpment	**Temperature**			
	Mean daily max temperature	Increase of 0.33°C	Increase of 2°C	Increase of 2°C
	Annual number of days with maximum temperatures over 36C (very hot days)	No significant change	Increase of 4 to 11 days	Increase of 9 to 13 days
	Rainfall			
	All climate variables related to rainfall	No significant change	Mostly no change	Mostly no change

What does this mean for planning & action?

The key message from the results of the analysis are that the municipality’s climate *has already changed and will continue to do so.*

Temperatures *have increased and will continue to increase over the next two decades. This change has cross-sectoral impacts across water resources, biodiversity, human health and food security. At the municipal scale, increased temperatures will impact the following services which impairs economic development and sustainably of livelihoods (see below and*

Figure 2). This will require a collaborative approach to address these impacts and adapt to a new climate context.

- **Increased temperatures intensify the stress on our water resources by reducing availability and quality, while increasing demand**: Increased temperatures increase the evaporation rate, in rivers, wetlands, estuaries and dams, as well as in the soil used for agricultural. Perversely, this then increases the demand for water use for human consumption, agriculture and industries, while also reducing the water quality in our water resources because of the dilution effect (i.e. less water means higher concentrations of pollutants and harmful organisms).

- **Increased temperatures can disrupt the operations of wastewater treatment works (WWTWs):** The functioning of WWTWs is delicate balance of biochemical reactions. Increased temperatures can disrupt these reactions, e.g. making them react faster than expected which makes it more difficult to manage the required balance. Furthermore, the lack of available water (as discussed previously) also impairs the functioning of WWTWs – a certain volume of water needs to be flowing through the system to work effectively at treating sewage. These disruptions could lead to WWTWs not functioning properly, resulting in spillage of untreated wastewater into river systems and the greater environment, threatening human health and damaging natural resources.

- **Increased temperatures threaten food security**: As mentioned, increased temperatures reduce the availability of good quality water for agriculture. Furthermore, high temperatures can damage crops directly and increase the spread of pests. Indeed, some crops, like maize, may become uneconomical to produce in the municipality under projected future temperatures. The potential reduction of crop pollinators such as bees, is alarming given the projected dramatic changes in extent and range. The health and production of livestock is also impaired, because of heat-exhaustion, lack of water and the spread of diseases.

- **Increased temperatures impact human health**: Increased temperatures can directly impact human health and our ability to work because of heat exhaustion, sun stroke, and dehydration. Furthermore, some diseases, like malaria, are expected to spread and intensify.

- **Other impacts** to consider include the increased risk of fire, changes in vegetation types (i.e. grasslands replaced by bush-encroachment which reduces grazing), and decreased biodiversity.

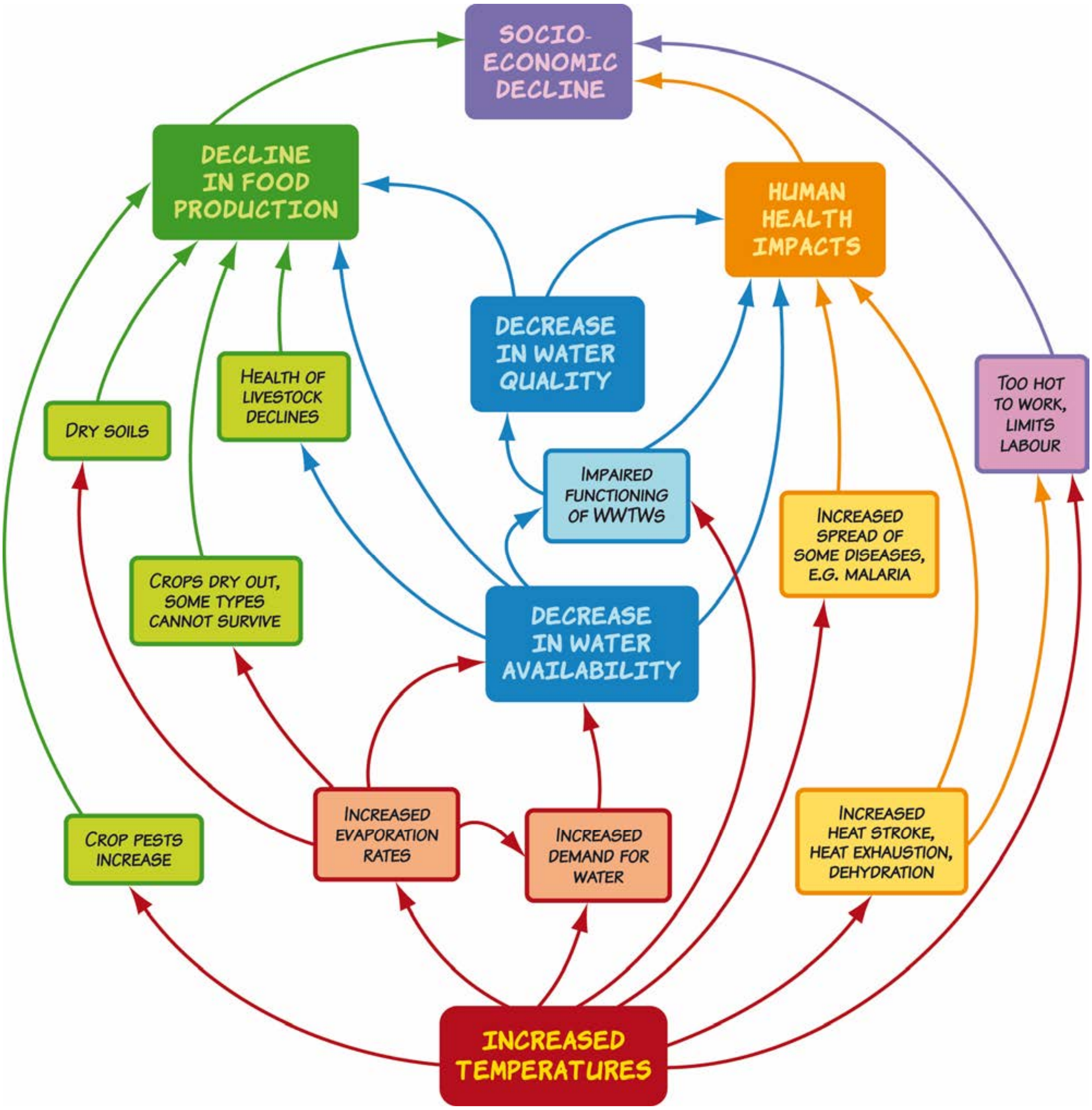

Figure 2. Concept map illustrating the systemic impacts on increased temperatures on key aspects of water security, food security and human health.

Regarding **rainfall**, changes in rainfall patterns were inconclusive. However, this does not mean that we can continue with “business as usual” since increased temperatures are highly likely and changes in rainfall patterns (incl. amount, intensity) may still occur. Therefore, we highly recommended the precautionary approach, i.e. planning for a drier future so that we are prepared if the worst is to happen.

The uncertainty of our rainfall, along with the impacts of the increased temperatures, exacerbate established day-to-day challenges for providing basic services and supporting livelihoods. These also increase the vulnerability of our communities to extreme weather events such as droughts and floods.

Transitioning to a new climate will require us to adapt our practices for natural resource management in the Olifants River Catchment to align with the new context and to remain resilient in a time of uncertainty.

Annex A: Climate variables analysed

1. Seasonal mean of daily maximum temperatures
2. Seasonal mean of daily minimum temperatures
3. Maximum dry spell per year: A dry spell is a period of at least 15 consecutive days with less than 1 mm of rainfall/day.
4. Annual number of days with maximum temperatures over 36ºC
5. Annual mean of daily maximum temperatures
6. Annual mean of daily minimum temperatures
7. Number of rain days per season
8. Mean daily rainfall in a season
9. Mean daily rainfall in a year
10. Total seasonal rainfall
11. Total annual rainfall
12. Number of rain day >20 mm: Number of day with rainfall greater than 20 mm per day.
13. Maximum duration of period with rainfall < 1 mm/day: Maximum count of consecutive dry days in a year

Annex B: Future climate projections

The following graphs capture the results of the future climate projections which were part of the climate analysis conducted by CSAG on behalf of AWARD.

How to interpret the graphs

These graphs capture and compare the projected changes in select climate variables under the good scenario (i.e. RCP 4.5) and under the bad scenario (i.e. RCP8.5). Note that the y-axis of these graphs extend beyond 2040. However, our interpretation of the analysis only pertains up to 2040, i.e. the next 20 years from the present.

In the figures that follow, each line represents the downscaled projection by a GCM. The shaded areas surrounding the projected values (i.e. the plume shape in the figure) are estimates of uncertainty resulting from natural variability. The significance of the projected changes (i.e. when the changes exceed the bounds of what we have experienced in the past) are highlighted by a change in colour from blue to reddish orange. This allows for some estimation of when in the future we are likely to be operating under a climate that is distinctly different from the climate we currently experience.

Projections for temperature

Note that the x-axis indicating temperature in degree Celsius (ºC), is slightly different between the two scenarios. This is because the bad scenario is projected to have notably higher temperature increases than the good scenario.

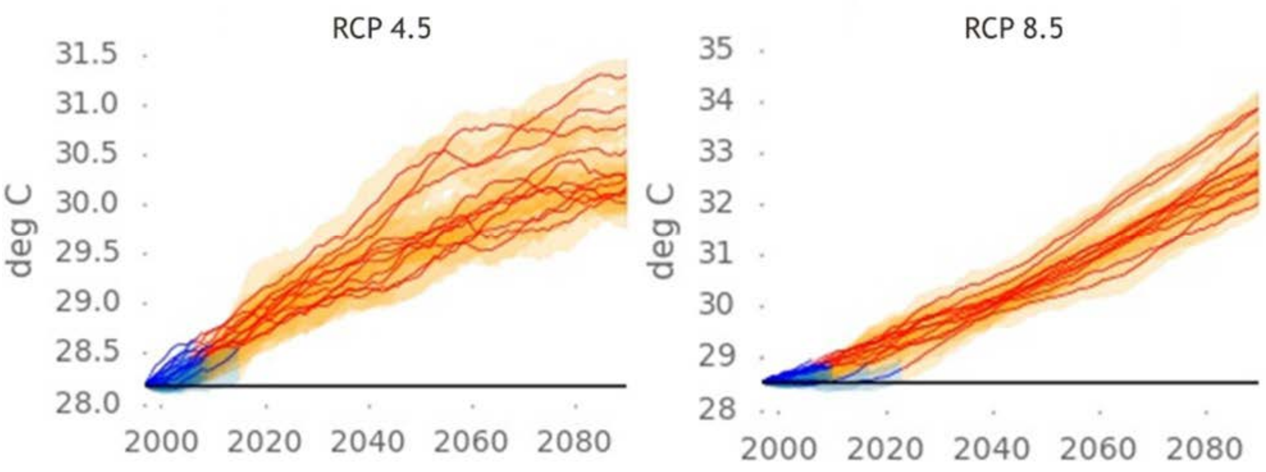

Figure 3. Downscaled projection of average daily maximum temperature under good scenario (RCP 4.5, to the left) and under the bad scenario (RCP8.5, to the right).

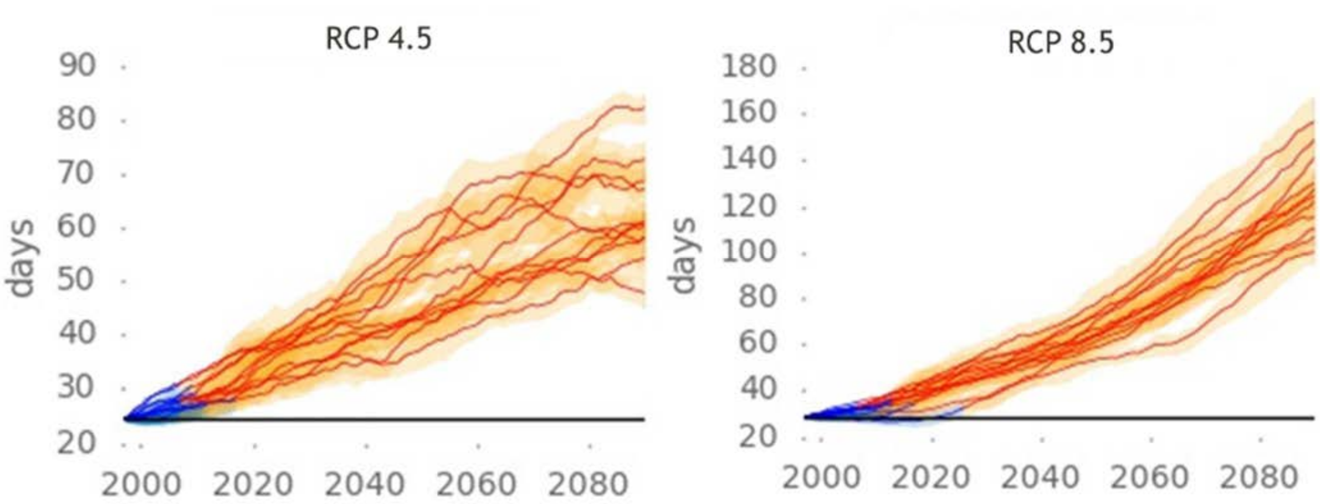

Figure 4. Downscaled projection of number of days with temperature over 36°C under good scenario (RCP 4.5, to the left) and under the bad scenario (RCP8.5, to the right).

Projections for rainfall

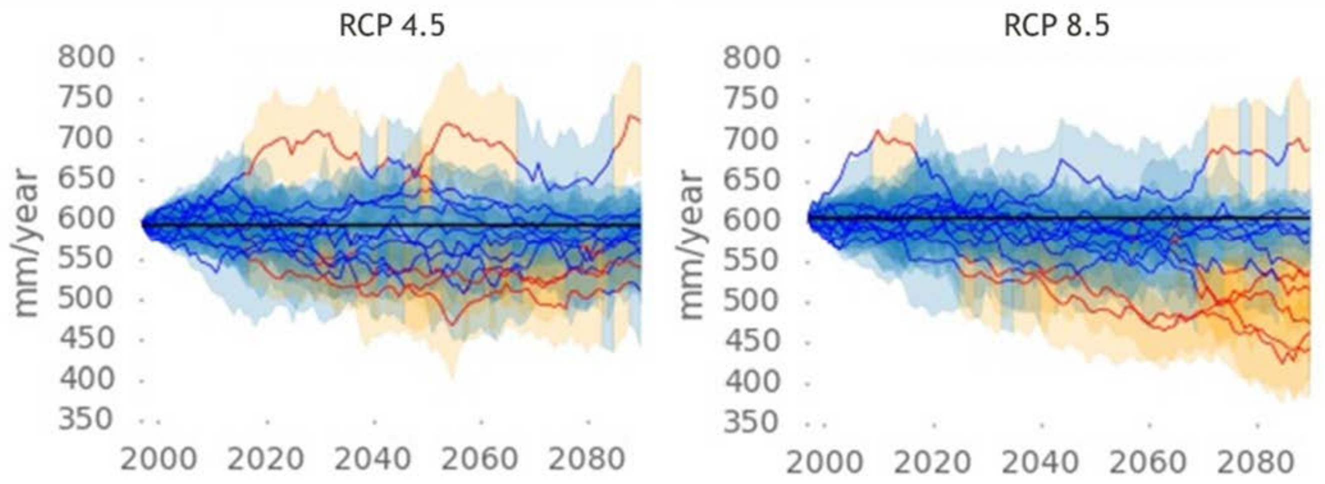

Figure 5. Downscaled projection of total annual rainfall under RCP 4.5 (left) and under RCP8.5 (right).

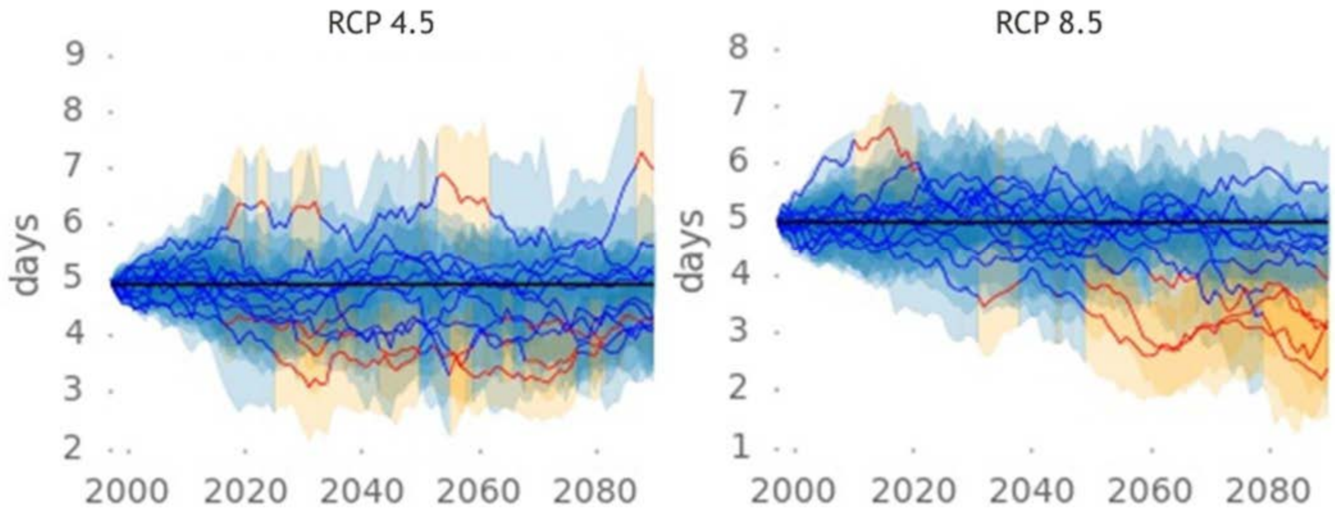

Figure 6. Downscaled projection of number of days in a year with over 20mm rain/day under RCP 4.5 (left) and under RCP8.5 (right).

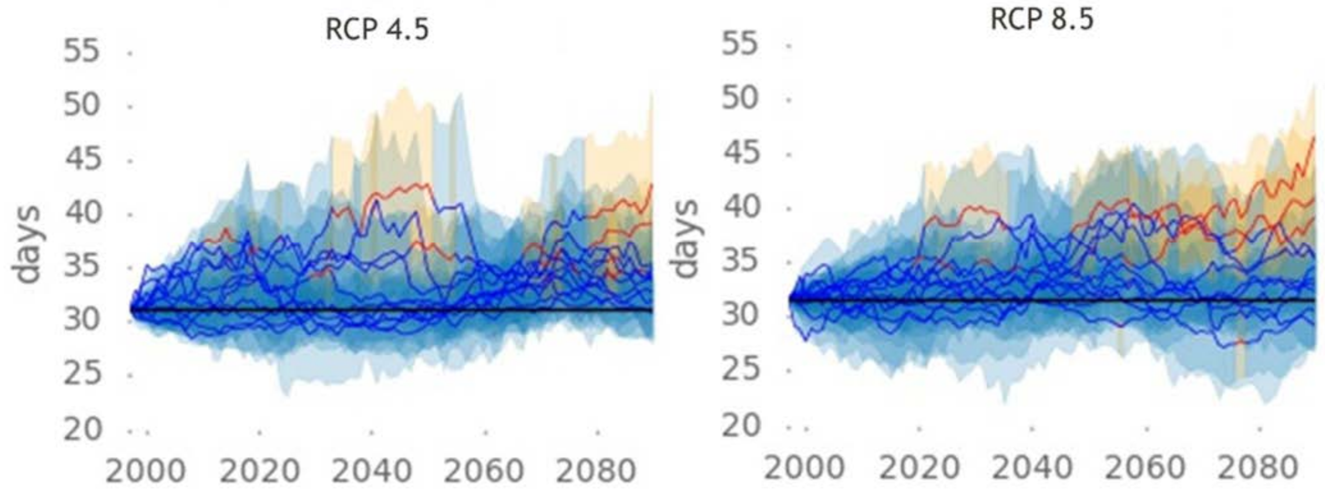

Figure 7. Downscaled projection of maximum count of consecutive dry days (i.e. less than 1mm of rainfall per day) in a year under RCP 4.5 (left) and under RCP8.5 (right).

Annex C: CHIRPS, CRU & WATCH WFDEI datasets

Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS)

The CHIRPS data comprises daily rainfall data only. It is a combination of satellite and weather station rainfall data, and is available for the period 1981-2014, gridded to 0.25 x 0.25 degree spatial resolution.

Climate Research Unit (CRU)

The CRU time-series data is made up of monthly time series of various climate variables, which include maximum and minimum temperature and rainfall. The data is based on over 4000 global weather stations, is available for the period 1901 – 2012, and is gridded to 0.5 x 0.5 degree spatial resolution.

WATCH Forcing Data methodology applied to ERA-Interim data (WFDEI)

WATCH is a European-Commission funded project to simulate the global terrestrial water cycle in the twentieth century via a suite of hydrological models. To allow direct comparison of model outputs, the WATCH Forcing Data (WFD) were created. The WFDEI was produced using WFD methodology applied to ERA-Interim data.[7] It is a meteorological forcing dataset extending into early 21st century (1979 – 2014). Eight meteorological variables are available at 3-hourly time steps, and as daily averages. Simulated rainfall is adjusted to observations from Global Precipitation Climatology Center (GPCC).

The three datasets used in the analysis have different origin, and this may cause discrepancies between them. CRU is based on interpolation of station data, WFDEI uses station data to bias-correct results of climate model simulations, while CHIRPS integrates satellite-derived product with observations.

TABLE 6. ANALYSED RAINFALL (P) AND AIR TEMPERATURE (T) DATASETS.

Dataset	Time period	Data	Temporal resolution	Spatial resolution
CHIRPS v2.0	1981- to date	P	Daily	0.25
CRU v3.23	1901-2012	P	Monthly	0.5
WFDEI	1979-2009	P,T	Daily	0.5

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[7] Weedon, Graham P., Gianpaolo Balsamo, Nicolas Bellouin, Sandra Gomes, Martin J. Best, and Pedro Viterbo. 2014. “The WFDEI Meteorological Forcing Data Set: WATCH Forcing Data Methodology Applied to ERA-Interim Reanalysis Data.” Water Resources Research 50 (9): 7505–14. doi:10.1002/2014WR015638. Accessed 8 April 2017 at http://onlinelibrary.wiley.com/doi/10.1002/2014WR015638/full

Annex D: GCMs downscaled in the analysis for this brief

The Coupled Model Intercomparision Project (CMIP) was established under the World Climate Research Program (WRCP) by the Working Group on Coupled Modelling (WGCM). The goal was to provide a standard experimental protocol for studying the output of coupled Atmosphere-Ocean GCMs in order to facilitate model improvement through better model quality control and a better understanding of model behaviour (Meehl et al., 2000). The fifth phase of the CMIP (CMIP5) is the latest set of coordinated climate model experiments. The table below lists the GCMs from the CMIP5 that were downscaled by CSAG for the analysis interpreted in this brief.

For a complete list of available GCMs in CMIP5, see http://cmip-pcmdi.llnl.gov/cmip5/availability.html

TABLE 7. GCMS FROM THE CMIP5 THAT WERE DOWNSCALED BY CSAG.

GCM code	Institutions	Country
BCC-CSM1.1	Beijing Climate Center, China Meteorological Administration	China
BNU-ESM	College of Global Change and Earth System Science, Beijing Normal University	China
CNRM-CM5	Météo-France / Centre National de Recherches Météorologiques	France
GFDL-ESM2G	US Department of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory	U.S.A.
HadGEM2-CC	Met Office Hadley Centre	U.K.
IPSL-CM5B-LR	Institut Pierre-Simon Laplace	France
MIROC-ESM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	Japan
MPI-ESM-LR	Max Planck Institute for Meteorology (MPI-M)	Germany
CMCC-CESM	Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
CanESM2	Canadian Centre for Climate Modelling and Analysis	Canada
GFDL-ESM2M	US Department of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory	U.S.A.
IPSL-CM5A-MR	Institut Pierre-Simon Laplace	France
MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	Japan
MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	Japan
MRI-CGCM3	Meteorological Research Institute	Japan

Annex E: Key Resources to inform planning

TABLE 8. SUMMARY OF ADDITIONAL RESOURCES TO INFORM PLANNING FOR CLIMATE CHANGE ADAPTATION

Tool	What used for	Links
FlowTracker App	Monitor near real-time river flow and dam levels for the Olifants River Catchment	https://play.google.com/store/apps/details?id=flowtracker.award.org.za.flowtracker
National Climate Change Information System (NCCIS)	This platform centralises climate change information and tools for South Africa in terms of sectoral impacts, relevant policies, and planning and implementing adaption and mitigation initiatives from the national to the local level. The platform also includes a database and map of climate change projects across South Africa.	https://ccis.environment.gov.za/#/
Green Book	An interactive planning tool based on scientific evidence for current and future social, economic and climate trends and risks to inform decisions about adaptation in settlements. It also provides a step-by-step process of identifying risks, and adaptation actions for specific local municipalities to be integrated into the local planning instruments.	https://www.greenbook.co.za/
National Integrated Water Information System (NIWIS)	This platform includes dashboards to facilitate analysis and reporting on water resources in South Africa. It provides information on the drought status of provinces, and several dashboards including climate change and disaster management relevant information.	http://niwis.dws.gov.za/niwis2/
Let’s Respond Toolkit	This tool provides a step-by-step guide to mainstream climate change risk and opportunities into local government, targeting the Integrated Development Plan (IDP) process.	http://www.letsrespondtoolkit.org/
South African Weather Service (SAWS)	Provides several products and services extending beyond weather forecasting. They are currently also developing: i) impact-based forecast in collaboration with the National Disaster Management System to improve the country’s early warning systems for extreme weather events; and ii) a dictionary of meteorological terms translated to all 11 official languages of South Africa.	http://www.weathersa.co.za/

AWARD is a non-profit organisation specialising in participatory, research-based project implementation. Their work addresses issues of sustainability, inequity and poverty by building natural-resource management competence and supporting sustainable livelihoods. One of their current projects, supported by USAID, focuses on the Olifants River and the way in which people living in South Africa and Mozambique depend on the Olifants and its contributing waterways. It aims to improve water security and resource management in support of the healthy ecosystems to sustain livelihoods and resilient economic development in the catchment.

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About USAID: RESILIM-O

USAID: RESILIM-O focuses on the Olifants River Basin and the way in which people living in South Africa and Mozambique depend on the Olifants and its contributing waterways. It aims to improve water security and resource management in support of the healthy ecosystems that support livelihoods and resilient economic development in the catchment. The 5-year programme, involving the South African and Mozambican portions of the Olifants catchment, is being implemented by the Association for Water and Rural Development (AWARD) and is funded by USAID Southern Africa.

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