



# GREENBOOK

*adapting settlements for the future*



## Polokwane Local Municipality Climate Risk Profile Report

29 SEPTEMBER 2023

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## List of Acronyms and Abbreviations

°C	Degree Celsius
AFF	Agriculture, Forestry, and Fisheries
AR5	Fifth Assessment Report
CABLE	CSIRO Atmosphere Biosphere Land Exchange model
CBD	Central Business District
CCAM	Conformal-cubic atmospheric model
CDRF	Climate and Disaster Resilience Fund
CMIP5	Coupled Model Intercomparison Project 5
CRVA	Climate Risk and Vulnerability Assessment
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DHS	Department of Human Settlements
DRR	Disaster risk reduction
DWS	Department of Water and Sanitation
EcVI	Economic Vulnerability Index
EnVI	Environmental Vulnerability Index
GCM	General circulation model
GDP	Gross Domestic Product
GRiMMS	Groundwater Drought Risk Mapping and Management System
GVA	Gross Value Added
ICT	Information and communications technology
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
l/p/d	Litres Per Person Per Day
LM	Local Municipality
LED	Local Economic Development
LRT	Let's Respond Toolkit
mm	Millimetre
NDMC	National Disaster Management Centre
PHSHDA	Priority Human Settlement and Housing Development Area

PVI	Physical Vulnerability Index
RCP	Representative Concentration Pathways (mitigation scenarios)
SCIMAP	Sensitive Catchment Integrated Modelling and Prediction
SEVI	Socio-Economic Vulnerability Index
SPI	Standardised Precipitation Index
SPLUMA	Spatial Planning and Land Use Management Act, 2013 (Act No.16 of 2013)
SUDS	Sustainable Urban Drainage Systems
THI	Temperature Humidity Index
WMAs	Water Management Areas
WMO	World Meteorological Organisation
WRYM	Water Resources Yield Model
WUI	Wildland-Urban Interface



## Glossary of Terms

Adaptation actions	A range of planning and design actions that can be taken by local government to adapt to the impacts of climate change, reduce exposure to hazards, and exploit opportunities for sustainable development (CSIR, 2023).
Adaptation planning	The process of using the basis of spatial planning to shape built-up and natural areas to be resilient to the impacts of climate change, to realise co-benefits for long-term sustainable development, and to address the root causes of vulnerability and exposure to risk. Adaptation planning assumes climate change as an important factor while addressing developmental concerns, such as the complexity of rapidly growing urban areas, and considers the uncertainty associated with the impacts of climate change in such areas – thereby contributing to the transformational adaptation of urban spaces. Adaptation planning also provides opportunities to climate proof urban infrastructure, reduce vulnerability and exploit opportunities for sustainable development (National Treasury, 2018; Pieterse, 2020).
Adaptive capacity	“The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences” (IPCC, 2022, p. 2899).
Climate change adaptation	“In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects” (IPCC, 2022, p. 2898).
Climate change mitigation	“A human intervention to reduce emissions, or enhance the sinks, of greenhouse gases (GHGs)” (IPCC, 2022, p. 2915). The goal of climate change mitigation is to achieve a reduction of emissions that will limit global warming to between 1.5°C and 2°C above preindustrial levels (Behsudi, A, 2021).

Climate hazards	Climate hazards are a sub-set of natural hazards and a grouping of hydrological, climatological, and meteorological hazards. This includes the spatial extent and frequency of, among others, floods, fires, and extreme weather events such as extreme rainfall and extreme heat. Sometimes referred to as hydrometeorological hazards. The potential occurrence of a climate hazard may cause loss of life, injury, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources (IPCC, 2022). Climate hazards can increase in intensity and frequency with climate change (Pieterse et al., 2023).
Climate risk	Risk implies the potential for adverse consequences resulting from the interaction of vulnerability, exposure, and a hazard. Relevant adverse consequences include those on “lives and livelihoods, health and well-being, economic and sociocultural assets, infrastructure and ecosystems” (IPCC, 2022, p. 144). In the IPCC’s 6th Assessment Report, it is confirmed that risks may result from “dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system” (IPCC, 2022, p. 132).
Coping capacity	“The ability of people, institutions, organizations and systems, using available skills, values, beliefs, resources and opportunities, to address, manage, and overcome adverse conditions in the short to medium term” (IPCC, 2022, p. 2904).
Disaster risk reduction	“Denotes both a policy goal or objective, as well as the strategic and instrumental measures employed for anticipating future disaster risk; reducing existing exposure, hazard or vulnerability; and improving resilience” (IPCC, 2022, p. 2906).
Exposure	Exposure implies the physical exposure of elements to a climate hazard. It is defined as the “presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected [by climate hazards]” (IPCC, 2022, p. 2908).
Mainstreaming	The process of integrating climate change adaptation strategies and measures into existing planning instruments and processes as opposed to developing dedicated adaptation policies and plans (Pieterse et al., 2021).

Resilience	<p>“The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation” (IPCC, 2022, pp. 2920–2921).</p>
Sensitivity	<p>“The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)” (IPCC, 2022, p. 2922).</p>
Vulnerability	<p>Vulnerability is defined as the “propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including, sensitivity or susceptibility to harm and lack of capacity to cope and adapt” (IPCC, 2022, p. 2927). Vulnerability refers to the characteristics or attributes of exposed elements, i.e., elements that are exposed to potential climate-related hazards. Vulnerability is a function of sensitivity and (coping or adaptive) capacity (Pieterse et al., 2023).</p>

# 1. Introduction

This Climate Risk Profile report, as well as the accompanying Adaptation Actions Plan, were developed specifically for Polokwane Local Municipality (LM), also referred to as the City of Polokwane (CoP), to support its strategic climate change response agenda. Both documents are primarily informed by the GreenBook, which is an open-access online planning support system that provides quantitative scientific evidence in support of local government's pursuit in the planning and design of climate-resilient, hazard-resistant settlements. The GreenBook is an information-dense resource and planning support system offered to South African local governments to better understand their risks and vulnerabilities in relation to population growth, climate change, exposure to hazards, and vulnerability of critical resources. In addition to this, the GreenBook also provides appropriate adaptation measures that can be implemented in cities and towns, so that South African settlements are able to minimise the impact of climate hazards on communities and infrastructure, while also contributing to developmental goals (See [GreenBook I Adapting settlements for the future](#)).

The purpose and strategic objectives of the Climate Risk Profile and the Adaptation Actions Plan are to:

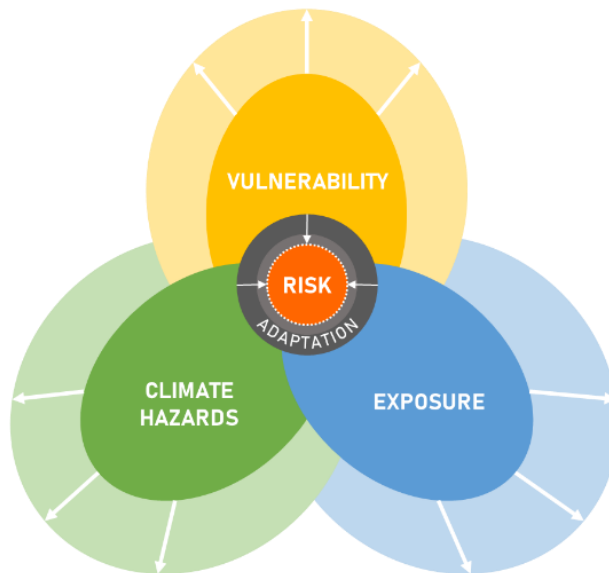
- Build and further the climate change response agenda,
- Inform strategy and planning in the Municipality,
- Identify and prioritise risks and vulnerabilities,
- Identify and prioritise interventions and responses, as well as
- Guide and enable the mainstreaming of climate change response, particularly adaptation.

The report first outlines the approach used to determine the risk information outlined in this report, as well as the existing policy framework for climate change response in South Africa. Thereafter, the City of Polokwane's local context is discussed in terms of locality, geography, demographics and economy, as well as the environment. This is followed by an overview of current and future risk in the Polokwane Municipal Area, where components of vulnerability and population change projections are unpacked at local municipal and settlement level; current and future climate is discussed in terms of temperature and rainfall; and current and future exposure to drought, heat, wildfire, and flooding is set out. The impact of climate change on the City's water supply and key sectors, including the agriculture, are also discussed. To conclude the report, adaptation goals are recommended in response to the risks and vulnerabilities facing the City. The greatest risks faced across the City of Polokwane are increasing temperatures and drought, with the risk of heat extremes becoming greater towards 2050. Moreover, several settlements in the City of Polokwane also face a high risk of wildfires and flooding into a climate changed future.

## 1.1. Approach followed

The approach used in the GreenBook, and the Climate Risk Profile report is centred around understanding climate-related risk. Climate-related risk implies the potential for adverse

consequences resulting from the interaction of vulnerability, exposure, and the occurrence of a climate hazard (see Figure 1). “Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets [as well as] investments, infrastructure, and services (including ecosystem services, ecosystems and species)” (Chen, et al., 2021, p. 64). The components of risk are dynamic. Climate hazards are driven by natural climate variability and anthropogenic climate change. Human activity contributes to Greenhouse Gas emissions that increase temperatures, which in turn affects changes in the occurrence of climate hazards such as drought, flooding, coastal flooding, and heat extremes. Planned as well as unplanned development and growth of our settlements drive the exposure of people, as well as the built- and natural environment to climate hazards. Vulnerability includes the inherent characteristics that make systems sensitive to the effects and impacts of climate hazards. Municipal risk is driven by vulnerability and exposure to certain climate-related hazards.



*Figure 1: The interaction between the various components of risk, indicating the opportunity to reduce risk through adaptation (based on IPCC, 2014 and IPCC, 2021)*

To understand climate risk across the municipal area, the exposure of settlements to certain climate hazards, and their vulnerability to climate change are unpacked. In this Climate Risk Profile report, multiple vulnerability indices are provided, as well as variables for the current and future projected climate. Climate-related hazards such as drought, heat extremes, wildfire, and flooding, as well as the impact of climate on key resources are also set out for the LM.

All information contained in this report is based on the GreenBook, unless otherwise specified. The information in the GreenBook is provided at local municipal level and settlement level. Information and data were derived using GIS analysis and modelling techniques using secondary data and is not based on local surveys.

## 1.2. Policy framework

There are various regulatory and legislative requirements for climate change response [planning] in South Africa, at local government level. For instance, the Disaster Management Amendment Act of 2015, which aims to provide measures to reduce disaster risks through climate change adaptation and the development of early warning systems, requires each organ of state, provincial government, and municipality to identify measures for, as well as indicate plans to invest in disaster risk reduction (DRR) and climate change adaptation. The Spatial Planning and Land Use Management Act, No. 16 of 2013 (SPLUMA) outlines five principles intended to guide spatial planning, land development and land use management at all levels of planning, including local government level. Amongst them are the principles of (1) spatial resilience, which encourages “flexibility in spatial plans, policies and land use management systems, to ensure sustainable livelihoods in communities most likely to suffer the impacts of economic and environmental shocks” (Republic of South Africa, 2013, p. 20) – some of which may be induced by the impacts of climate change, and (2) spatial sustainability, which sets out requirements for municipal planning functions such as spatial planning and land use management to be carried out in ways that consider protecting vital ecosystem features such as agricultural land, i.e., from both anthropogenic and natural threats, including the impacts of climate change, as well as in ways that consider current and future costs of providing infrastructure and social services in certain areas (e.g., uninformed municipal investments may lead to an increase in the exposure of people and valuable assets to extreme climate hazards).

Furthermore, the National Climate Change Response White Paper – which outlines the country’s comprehensive plan to transition to a climate resilient, globally competitive, equitable and low-carbon economy and society through climate change adaptation and mitigation, while simultaneously addressing the country’s key priorities, including job creation, poverty reduction, social equality and sustainable development, amongst others – identifies local governments as critical role players that can contribute towards effective climate change adaptation through their various functions, including “[the] planning [of] human settlements and urban development; the provision of municipal infrastructure and services; water and energy demand management; and local disaster response, amongst others.” (Republic of South Africa, 2011, p. 38). The Climate Change Bill takes it further by setting out reporting requirements on climate change response needs and interventions for every municipality in the country.

The National Climate Change Adaptation Strategy outlines several actions that are applicable at municipal level, including the development and implementation of adaptation strategies and vulnerability reduction programmes targeting communities and individuals that are most at risk to the impacts of climate change; the development of municipal early warning systems; as well as the integration of climate change adaptation measures into municipal development plans and relevant sector plans, i.e., mainstreaming. The National Climate Risk and Vulnerability Assessment Framework – which is aimed at all actors, including local governments – guides the development and review of climate risk and vulnerability assessments (CRVAs) to enable

alignment, aggregation and comparison across all CRVAs, in an effort to inform an integrated and effective climate change adaptation response across all scales and sectors.

### 1.3. Local Municipal context

Polokwane – meaning “Place of safety” – is one of four Local Municipalities located within the Capricorn District in Limpopo, the country’s most northern province. The Local Municipality covers an area of approximately 5399.83 km<sup>2</sup>, which constitutes 3% of the province’s total surface area (Polokwane LM, 2021). Located in the central parts of the province, the City of Polokwane shares borders with Blouberg and Molemole Local Municipalities to the north, Mopani District’s Greater Tzaneen Local Municipality in the east, Lepelle-Nkumpi Local Municipality to the south, and Waterberg District’s Mogalakwena Local Municipality to the west. This Intermediary City is strategically located as the province’s administrative and economic capital.

With major national roads (i.e., N1 and N11) and several regional roads (i.e., R37, R71, R81, R101, and R521) passing through the Local Municipality, the City of Polokwane provides good access to other settlements, towns, and cities, including those situated outside the province and – considering its close proximity to neighbouring Botswana, Mozambique and Zimbabwe – the country itself. The main clusters of settlements found in the Local Municipality include Polokwane CBD, Seshego, Mankweng, Sebayeng/Dikgale, Ga-Chuene/Molepo/Maja, Moletjie and Aganang (Polokwane LM, 2014; Polokwane LM, 2021).

In 2011, Polokwane Local Municipality recorded a total population of 728 633, with 728 436 people located in settlements. The settlement-based population increased by 17.89% between 2001 and 2011, and is projected to increase by 29.25% between 2011 and 2030 and by 46.49% between 2011 and 2050. In 2020, the Intermediate City recorded a total population of 837 649, which constituted 60.52% of the total population in the Capricorn District, thus making the City of Polokwane the most populous region in the District (Polokwane LM, 2022).

The City of Polokwane’s leading economic sectors include Community Services, Finance and Trade; these sectors respectively contributed 25%, 20% and 15% to the Local Municipality’s Gross Value Added (GVA) in 2020 (Polokwane LM, 2022). The same sectors are also the Local Municipality’s major employing sectors, with the Community Services sector constituting the City of Polokwane’s biggest jobs contributor at 27%, followed by Trade at 26% and Finance at 13% (Polokwane LM, 2022). In 2020, Polokwane Local Municipality recorded an unemployment rate of 18.01%, the lowest in the Capricorn District, and significantly lower than the provincial and national average at the time (Polokwane LM, 2022).

The City of Polokwane is situated on the Pietersburg Plateau, which is bordered by the Strydpoort Mountains in the south, the Waterberg Mountains in the west and the north, as well as the Great Escarpment in the east. There are a number of ridges located on the Plateau (with the highest part found in the south near the Strydpoort Mountains – forming the watershed

between the Olifants and Sand River systems), and these often constrain development in the Local Municipality; however, their value lies in supporting sensitive plant and animal species, as well as other ecological assets that are critical in mitigating some of the impacts of climate change (Polokwane LM, 2021).

There are six vegetation types found in the Polokwane Municipal Area, namely the Pietersburg Plateau False Grassveld, Sourish Mixed Bushveld, Sour Bushveld, Mixed Bushveld, North-Eastern Mountain Sourveld and the Lowveld Sour Bushveld (Polokwane LM, 2021). There are also 19 catchment areas found in the City of Polokwane – these include 10 catchment areas found within the municipal boundary, as well as nine small portions of larger catchments located outside the municipal boundary – with the most notable one being the Sand River catchment. This catchment is drained by the Sand and Blood rivers, with the latter river impounded in the Seshego Dam, while most of the other water retention dams and stormwater channels in the Local Municipality eventually discharge into the Sand River via the Sterkloop Spruit. The Sand River catchment is also home to several important wetlands – which support rare or endangered frog and plant species (Polokwane LM, 2021). The City of Polokwane is also home to the Polokwane Game and Botanical Reserves (in addition to numerous other heritage and natural sites), both of which are home to a wide variety of species – including over 50 game species, 200 bird species, 110 grass types, 280 flowering plants, and over 60 tree species – some of which are endemic and endangered (Polokwane LM, 2021). It is therefore essential for the Municipality to conserve these spaces and their biodiversity, in the interest of ensuring that they continue to provide ecosystem services, such as tourism opportunities, as well as their capacity to mitigate the negative impacts of climate hazards.



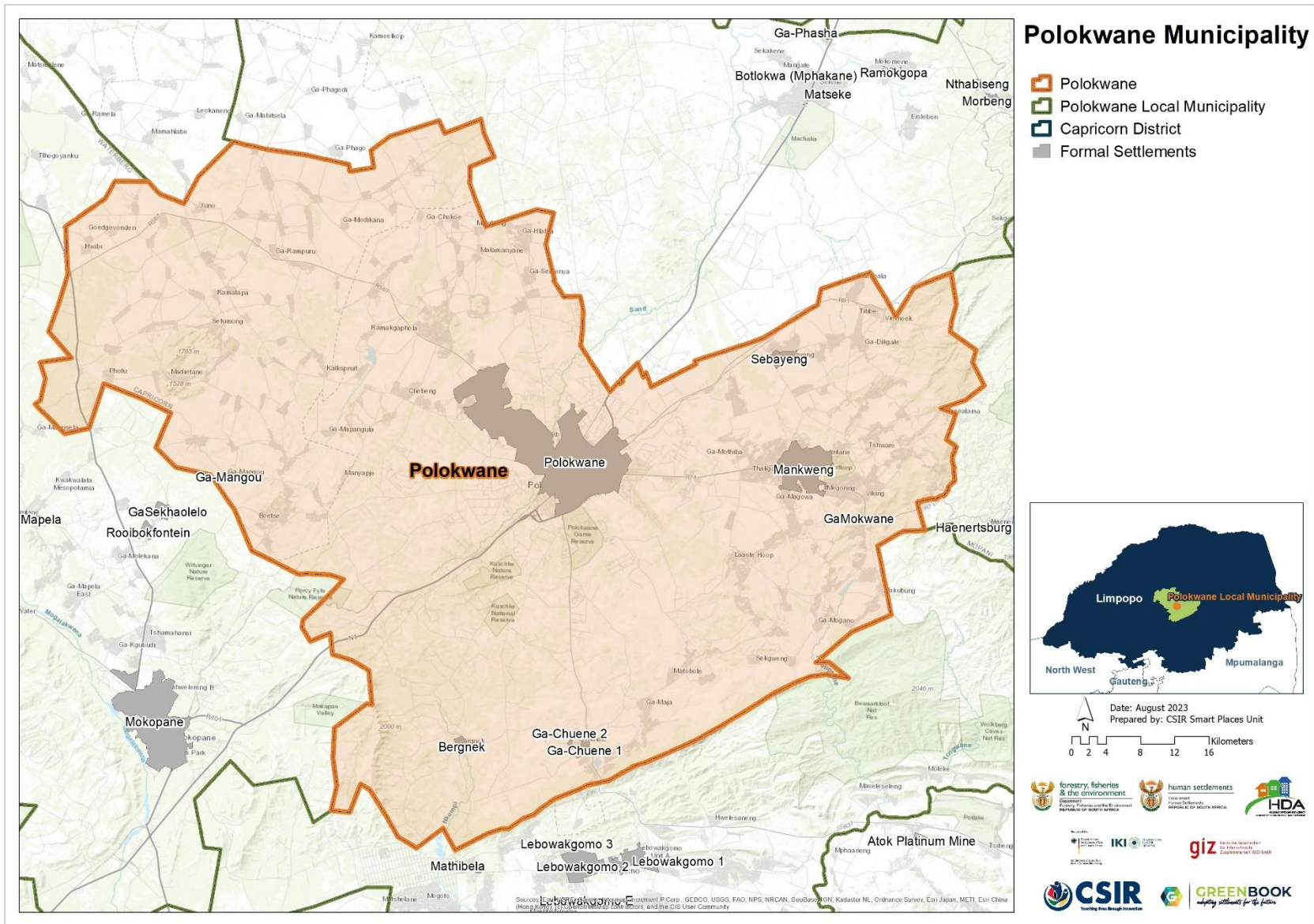


Figure 2: Polokwane Local Municipality

## 2. Baseline and future climate risk

This section starts with an overview of vulnerability and population change projections, unpacking the components of vulnerability on both the municipal and settlement level as well future population pressures. Thereafter the current and future climate is discussed in terms of temperature and rainfall. Current as well as future exposure to drought, heat, wildfire, and flooding are also set out. Together, this information provides an overview of current and future climate risk for the Polokwane Municipal Area to inform responsive planning and adaptation.

### 2.1. Vulnerability and population change

There are many factors that influence the vulnerability of our municipalities and settlements, some of which are unpacked in the following section. The current vulnerabilities for the Polokwane Local Municipality and its settlements are profiled using a framework which sets out indicators that can be used to profile the multi-dimensional and context-specific inherent vulnerability of settlements and municipalities in South Africa. The framework describes and quantifies, where possible, the inherent vulnerability of people, infrastructure, services, economic activities, and natural resources by setting out context and location-specific indicators that were specifically designed to support vulnerability risk assessments of South African municipalities. Population changes drive vulnerability into the future, and therefore population growth and decline of settlements across the Local Municipality are projected to 2050. Spatial population projections are integral in determining the potential exposure and vulnerability of a population to hazards.

#### 2.1.1. Municipal vulnerability

Municipal vulnerability is unpacked in terms of four vulnerability indices, each of which are described below and in Table 1, the vulnerability scores are provided for Polokwane Local Municipality.

The Socio-Economic Vulnerability Index (SEVI) shows the vulnerability of households living in the municipality with regards to household composition, income composition, education, mobility, health, access to basic services, access to social government services, political instability, and safety and security of households. A high vulnerability score indicates that the municipality houses a high number of vulnerable households with regards to their ability to withstand adverse shocks from the external environment.

The Economic Vulnerability Index (EcVI) speaks toward the economic resilience of the municipality, and considers economic sector diversification, the size of economy, labour force, the GDP growth/decline pressure experienced in the municipality, and the inequality present in the municipality. The higher the economic vulnerability, the more susceptible the municipality is to being adversely affected by external shocks.

The Physical Vulnerability Index (PVI) relates to the built environment and the connectedness of the settlements in the local municipality. It is a composite indicator that considers road infrastructure, housing types, the maintenance of the infrastructure, densities, and general accessibility. A high physical vulnerability score highlights areas of remoteness and/or areas with structural vulnerabilities.

The Environmental Vulnerability Index (EnVI) highlights municipalities where there is a high conflict between preserving the natural environment and accommodating the growth pressures associated with population growth, urbanisation, and economic development. The index considers the human influence on the environment, the amount of ecological infrastructure present that needs protection, the presence of critical water resources, environmental health, and environmental governance. A high vulnerability score highlights municipalities that experience increasing pressure relating to protecting the environment and allowing land use change due to growth pressures.

Polokwane Local Municipality is provided with a score out of 10 for each of the vulnerability indices. A score higher than 5 indicates an above national average, and a score lower than 5 indicates a below national average for vulnerability. Scores are provided for both 1996 and 2011, where a lower score in 2011 compared to 1996 indicates an improvement and a higher score indicates worsening vulnerability. Trend data is only available for Socio-Economic Vulnerability (SEVI) and Economic Vulnerability (EcVI).

*Table 1: Vulnerability indicators across Polokwane Local Municipality*

MUNICIPALITY	SEVI 1996	SEVI 2011	Trend	EcVI 1996	EcVI 2011	Trend	PVI	Trend	EnVI	Trend
Polokwane	4.19	3.19	↓	4.74	6.80	↑	7.22	N/A	6.17	N/A

As outlined in Table 1, the City of Polokwane's socio-economic vulnerability (SEVI) has decreased (improved) between 1996 and 2011 – thus indicating that the number of socio-economically vulnerable households has decreased, particularly in terms of their lack of access to basic and social services and essential resources, which influence their ability to withstand adverse shocks from the external environment, including those induced by climate change. However, in the same period, the Local Municipality's economic vulnerability (EcVI) increased (worsened), therefore indicating the high susceptibility of the Local Municipality's economy to the adverse consequences of external shocks. A big contributor to the increase in economic vulnerability (EcVI) for the City of Polokwane (at least during that period) was an increase in inequality, especially among urban and rural residents. While 23% of the Municipality's surface area is urbanised, 71% is classified as rural and "for cities to serve as engines of growth there must be strong economic linkages between urban and rural areas." (Polokwane LM, 2014, p.47). However, with the underutilisation of rural areas, as well as unequal service delivery and development planning (which often favours urban areas) prevalent in the Local Municipality, inequality remains high in the City, thus affecting its economy's resilience.

The City of Polokwane has a very high physical vulnerability (PVI) score, the third highest in the province, thus alluding to the insufficient connectivity and integration of settlements (Polokwane LM, 2014), as well as the high structural vulnerabilities present in the Municipality. The Polokwane Local Municipality has an environmental vulnerability (EnVI) score of 6.17, one of the highest in the province. This indicates the high presence of ecological infrastructure and resources that need protection, as well as the growing conflict between the need to preserve the natural environment, while accommodating the growth pressures associated with urbanisation, economic development, and (notably) population growth. Between 2010 and 2020, the City of Polokwane experienced an average population growth rate of 1.42% per annum, the highest in the District (Polokwane, 2022).

### 2.1.2. Settlement vulnerability

The unique set of indicators outlined below highlight the multi-dimensional vulnerabilities of the settlements within the Polokwane Municipal Area with regards to six composite indicators. This enables the investigation of the relative vulnerabilities of settlements within the Local Municipality.

A high vulnerability score (closer to 10) indicates a scenario where an undesirable state is present e.g., low access to services, high socio-economic vulnerabilities, poor regional connectivity, environmental pressure, or high economic pressures. An indicator of growth pressure, providing a temporal dimension (15-year trend), was added to show which settlements are experiencing growth pressures on top of the other dimensional vulnerabilities.

The Socio-economic Vulnerability Index comprises of three indicators (and eight variables) that show the vulnerability of households occupying a specific settlement with regards to their (1) household composition (household size, age dependency, female/child headed household), (2) income composition (poverty level, unemployment status, and grant dependency of the households), as well as (3) their education (literacy and level of education).

The Economic Vulnerability Index comprises of five variables grouped into three indicators that highlight the economic vulnerability of each settlement with regards to (1) its size (GDP per capita and GDP production rates), (2) the active labour force (taking note of unemployed and discouraged work seekers), and (3) the GDP growth rate for the past 15 years.

The Environmental Vulnerability Index considers the footprint composition of the settlement taking the ration of built-up versus open spaces into account.

The Growth-Pressure Vulnerability Index shows the relative (1996-2011 growth rates) and anticipated pressure on settlements.

The Regional Economic Connectivity Vulnerability Index looks at the regional infrastructure of each settlement (measured through a remoteness/accessibility index), as well as the role of the town in terms of its regional economy.

The Service Access Vulnerability Index comprises of 10 variables grouped into four indicators, that show the level of services offered and rendered within a settlement and includes the settlement's (1) access to basic services (electricity, water, sanitation, and refuse removal), (2) settlement's access to social and government services (health access, emergency service access, access to schools, and early childhood development), (3) access to higher order education facilities, and (4) access to adequate housing.

A brief description of the settlement vulnerability in Polokwane Local Municipality follows below.

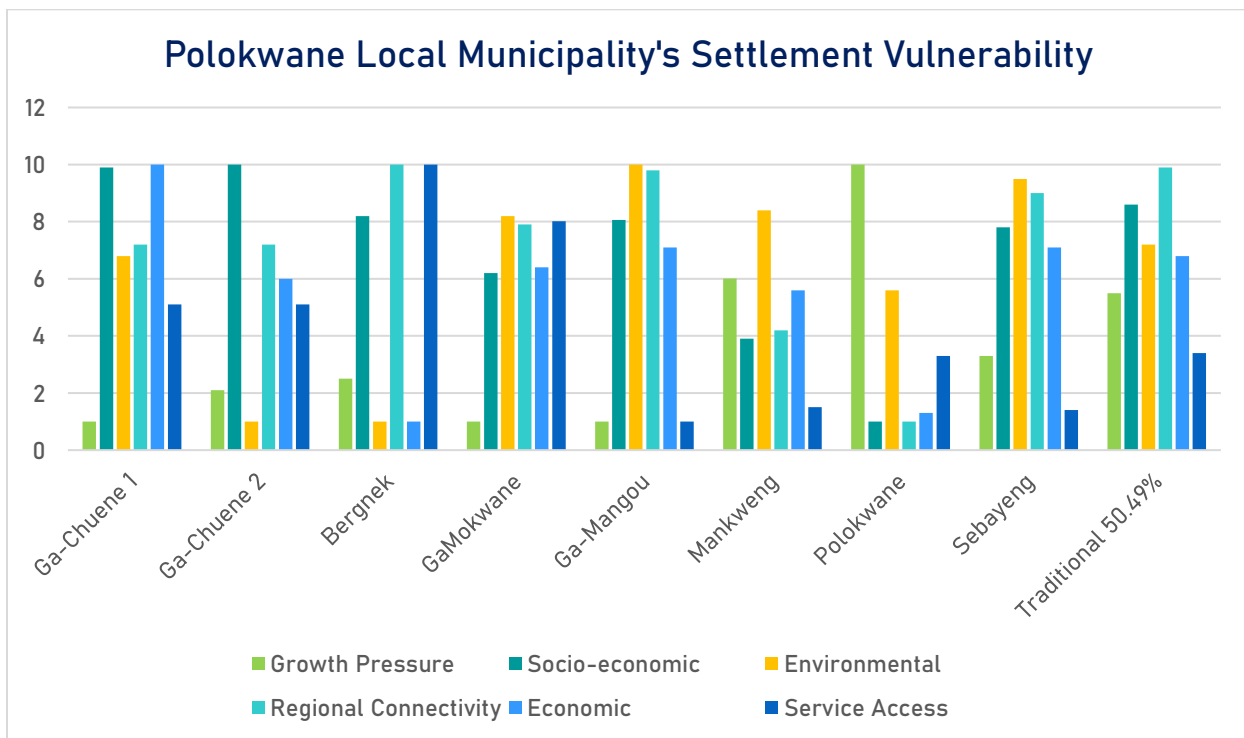


Figure 3: Polokwane Local Municipality's settlement vulnerability

The major settlements in the City of Polokwane are Ga-Chuene, Bergnek, GaMokwane, Ga-Mangou, Mankweng, Polokwane and Sebayeng, as well as several clusters of traditional areas. The settlement of Polokwane, which includes the Central Business District (CBD), faces the highest growth pressure, while Bergnek has the highest service access vulnerability in the City. Ga-Chuene has a highest economic vulnerability, and is home to the most socio-economically vulnerable populations in the Local Municipality. Ga-Mangou has the highest environmental vulnerability in the Municipality, thus indicating the presence of critical ecological assets and natural resources, as well as the growing conflict between the need to preserve the natural environment and accommodating the pressure associated with population growth, urbanisation



and/or economic growth in the settlement. Bergnek, Ga Mangou and several traditional areas have the highest regional connectivity vulnerability in the Local Municipality, thus indicating the remoteness of the settlements.

### 2.1.3. Population growth pressure

The core modelling components of the settlement growth model are the demographic model and the population potential gravity model. The demographic model produces the long-term projected population values at the national, provincial, and municipal scale using the Spectrum and Cohort-Component models. The spatially-coarse demographic projections were fed into the population potential gravity model, a gravity model that uses a population potential surface to downscale the national population projections, resulting in 1x1 km resolution projected population grids for 2030 and 2050. The availability of a gridded population dataset for past, current, and future populations enables the assessment of expected changes in the spatial concentration, distribution, and movement of people.

Using the innovative settlement footprint data layer created by the CSIR, which delineates built-up areas, settlement-scale population projections were aggregated up from the 1 x 1 km grids of South African projected population for a 2030 and 2050 medium and high growth scenario. These two population growth scenarios (medium and high) are differentiated based on their in- and out-migration assumptions. The medium growth scenario (see Table 2) assumes that the peak of population influx from more distant and neighbouring African countries into South Africa has already taken place. The high growth scenario assumes that the peak of migrant influx is yet to happen.

*Table 2: Population growth pressure across Polokwane Local Municipality*

Municipal Population Growth	2011	Medium Growth Scenario	
		2030	2050
Polokwane Local Municipality	728 436	941 494	1 067 109

Polokwane Local Municipality's population is projected to increase by 46.49% between 2011 and 2050, under a medium growth scenario. Most of the growth will occur between 2011 and 2030 (i.e., 29.25% increase). Figure 4 depicts the growth pressures that the settlements across the City of Polokwane will likely experience. The map is accompanied by a table that provides, in addition to the expected growth pressure (under a medium population growth scenario), the baseline (2011) and projected (2030 and 2050) population figures for each settlement in the Local Municipality.

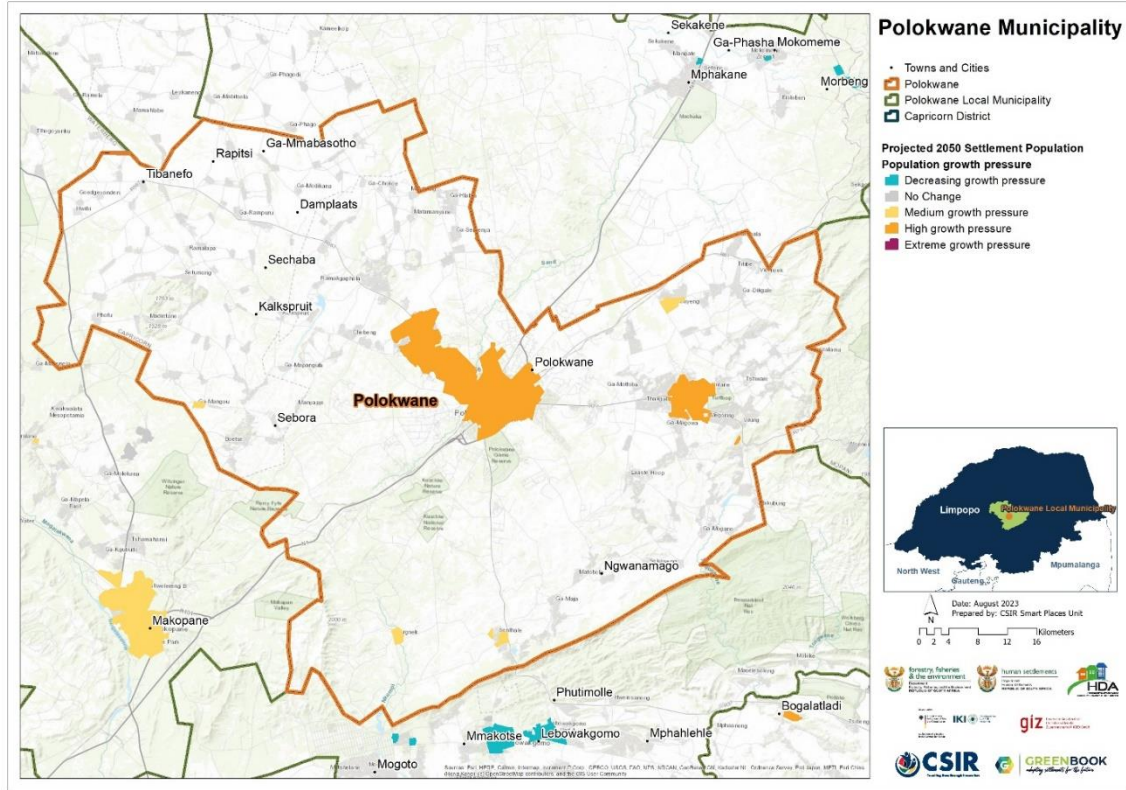


Figure 4: Settlement-level population growth pressure across Polokwane Local Municipality

Table 3: Settlement-level population growth pressure across Polokwane Local Municipality

Polokwane Local Municipality				
Town	Pressure	2011	2030	2050
Ga-Chuene 1	Medium	4 372	5 509	6 179
Bergnek	Medium	1 481	1 725	1 869
Ga-Chuene 2	Medium	2 261	2 819	3 148
Ga-Mokwane	High	2 668	3 574	4 109
Ga-Mangou	Medium	1 143	1 337	1 451
Mankweng	High	69 417	92 833	106 527
Polokwane	High	260 225	378 819	448 732
Sebayeng	Medium	12 582	15 688	17 519

As displayed in Figure 4 and outlined Table 3, no settlements are projected to experience extreme growth pressure. However, Polokwane and Mankweng, the Local Municipality's two most populous settlements, as well as Ga-Mokwane, are projected to experience high growth pressure – thus alluding to the potential increase in the exposure of people and their assets to

future climate conditions and their impacts. The rest of the Municipality's major settlements are expected to experience medium growth pressure into the future (at least up to 2050).

## 2.2. Climate

An ensemble of very high-resolution climate model simulations of present-day climate and projections of future climate change over South Africa has been performed as part of the GreenBook. The regional climate model used is the Conformal-Cubic Atmospheric Model (CCAM), a variable-resolution Global Climate Model (GCM) developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). CCAM runs coupled to a dynamic land-surface model CABLE (CSIRO Atmosphere Biosphere Land Exchange model). GCM simulations of the Coupled Model Inter-Comparison Project 5 (CMIP5) and the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), obtained for the emission scenarios described by Representative Concentration Pathways 4.5 and 8.5 (RCP 4.5 and RCP 8.5) were first downscaled to 50 km resolution globally. The simulations span the period 1960–2100. RCP 4.5 is a high mitigation scenario (assuming a reduction in CO<sub>2</sub> emissions into the future), whilst RCP 8.5 is a low mitigation scenario (assuming “business as usual” emissions).

After completion of the 50 km resolution simulations described above, CCAM was integrated in stretched-grid mode over South Africa, at a resolution of 8 x 8 km (approximately 0.08° degrees in latitude and longitude). The model integrations performed at a resolution of 8 km over South Africa offer several advantages over the 50 km resolution simulations:

- a) Convective rainfall is partially resolved in the 8 km simulations, implying that the model is less dependent on statistics to simulate this intricate aspect of the atmospheric dynamics and physics.
- b) Important topographic features such the southern and eastern escarpments are much better resolved in the 8 km resolution simulations, implying that the topographic forcing of temperatures, wind patterns and convective rainfall can be simulated more realistically.

For more information on the climate simulations, see the GreenBook [Climate Change Story Map](#) and the [full technical report](#).

For each of the climate variables discussed below:

- a) The simulated baseline (also termed “current” climatological) state over South Africa calculated for the period 1961–1990 is shown (note that the median of the six downscaled GCMs are shown in this case).
- b) The projected changes in the variable are subsequently shown, for the time-slab 2021–2050 relative to the baseline period 1961–1990.
- c) An RCP 8.5 scenario (low mitigation) is shown.



### 2.2.1. Temperature

The model was used to simulate annual average temperatures (°C) for the baseline (current) period of 1961–1990, and the projected change for period 2021–2050 under a RCP8.5, i.e., “business as usual”, emissions scenario.

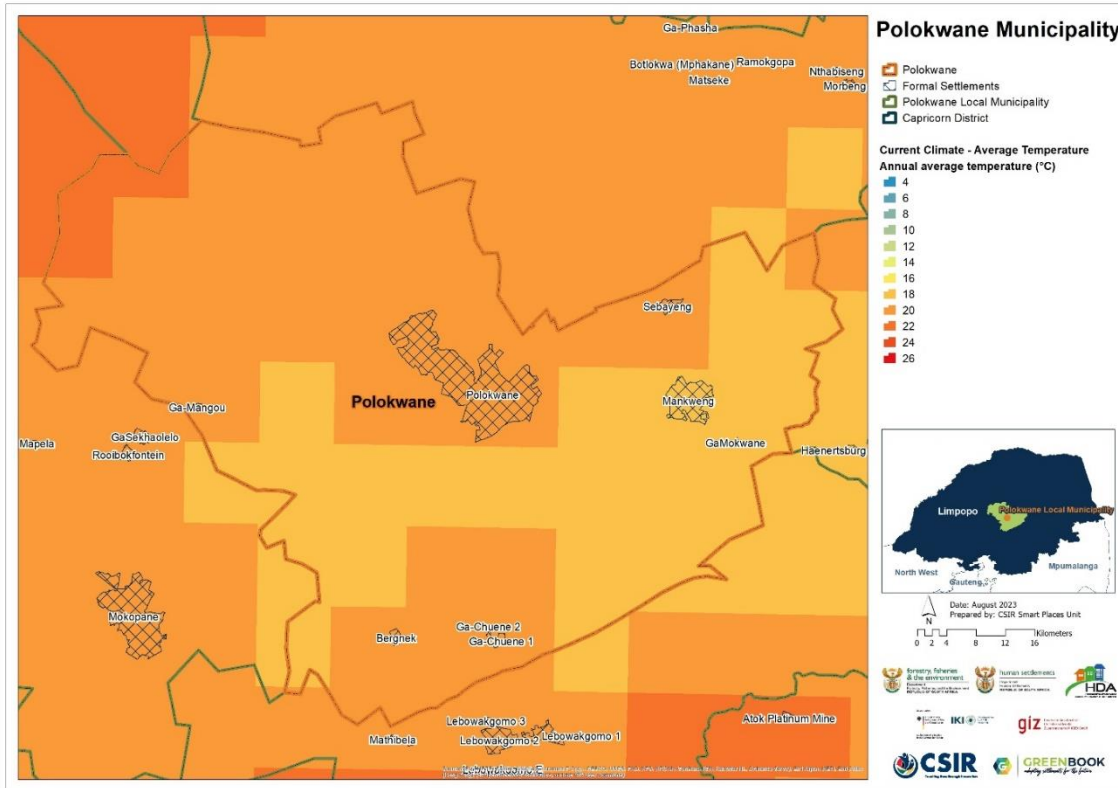


Figure 5: Average annual temperature (°C) for the baseline period 1961 – 1990 for Polokwane Local Municipality

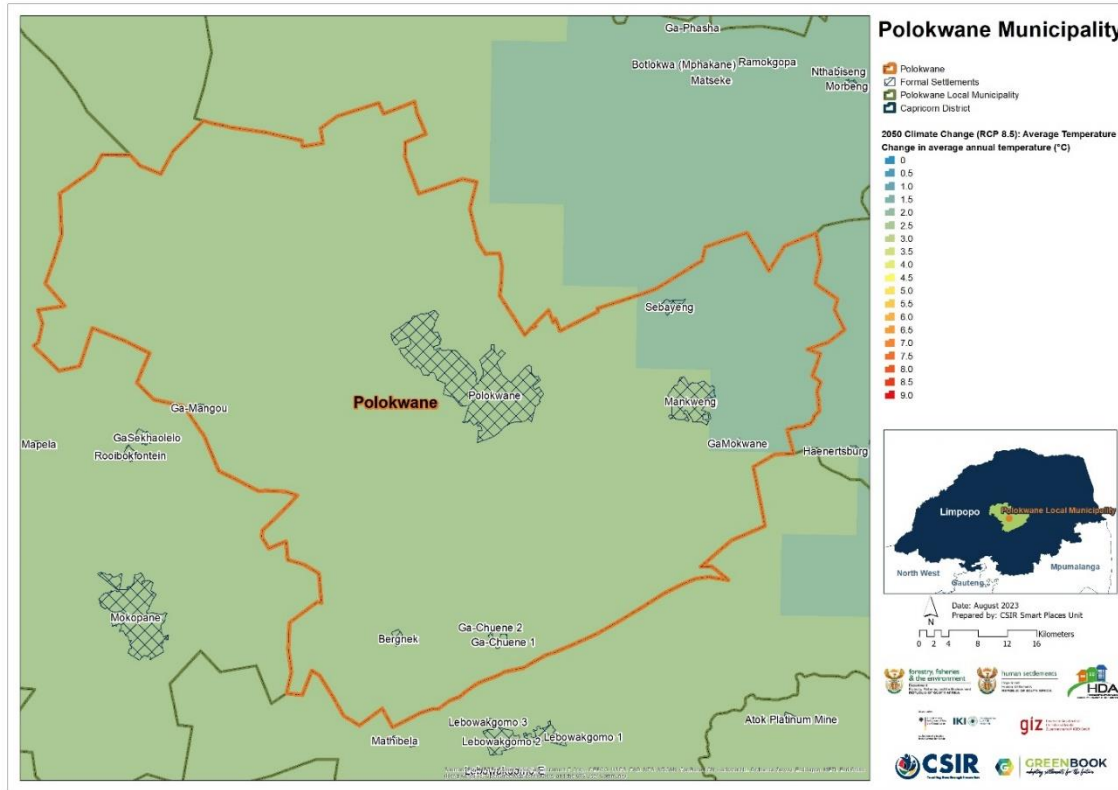


Figure 6: Projected change in average annual temperature (°C) from the baseline period to the period 2021 – 2050 for Polokwane Local Municipality, assuming an (RCP 8.5) emissions pathway

At the baseline (i.e., current), the City of Polokwane experiences current average annual temperatures of between 18 and 22 °C, with higher averages found on the northwestern border of the Local Municipality (Figure 5). The projections show average annual temperature increases of between 2 and 2.5 °C by 2050, under a “business as usual” emissions scenario (RCP 8.5). The greatest increases are expected in most parts of the Municipality, with the least increases expected in the north-eastern part of the City (Figure 6).

**2.2.2. Rainfall**

The multiple GCMs were used to simulate average annual rainfall (depicted in mm) for the baseline (current) period of 1961–1990, and the projected change from the baseline to the period 2021–2050 under an RCP8.5 emissions scenario. Model projections of precipitation manifest uncertain due to several factors, including model sensitivity to spatial resolution at which processes are resolved. At 8 x 8km horizontal resolution, for example, some processes (such as convective systems) that contribute to rainfall are not adequately resolved by the climate models. The precipitation projections therefore could reflect uncertainty in some locations since fine-scale processes that contribute to precipitation and its extremes are not captured. When the modelling ensemble approach used in the online GreenBook is considered, and the 10<sup>th</sup>, 50<sup>th</sup> and 90<sup>th</sup> percentiles, per grid point, agree on the directional change relative to the reference period, the signal is considered well developed and conclusive. In the case where the respective

model percentiles show conflicting signs, the model ensemble manifest uncertainty and therefore reflect low confidence on which future model realisation/outcome is more likely. It is therefore critical to consider the ensemble distribution uncertainty when devising long-term adaptation strategies.

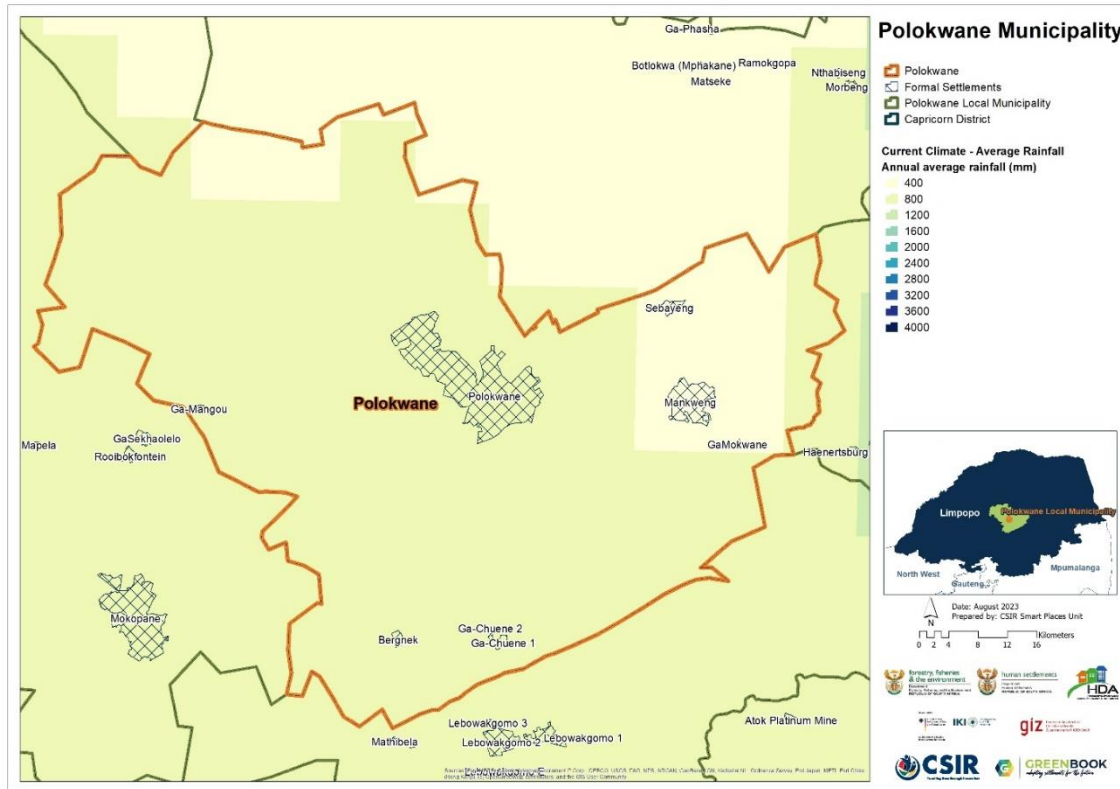


Figure 7: Average annual rainfall (mm) for the baseline period 1961 – 1990 for Polokwane Local Municipality

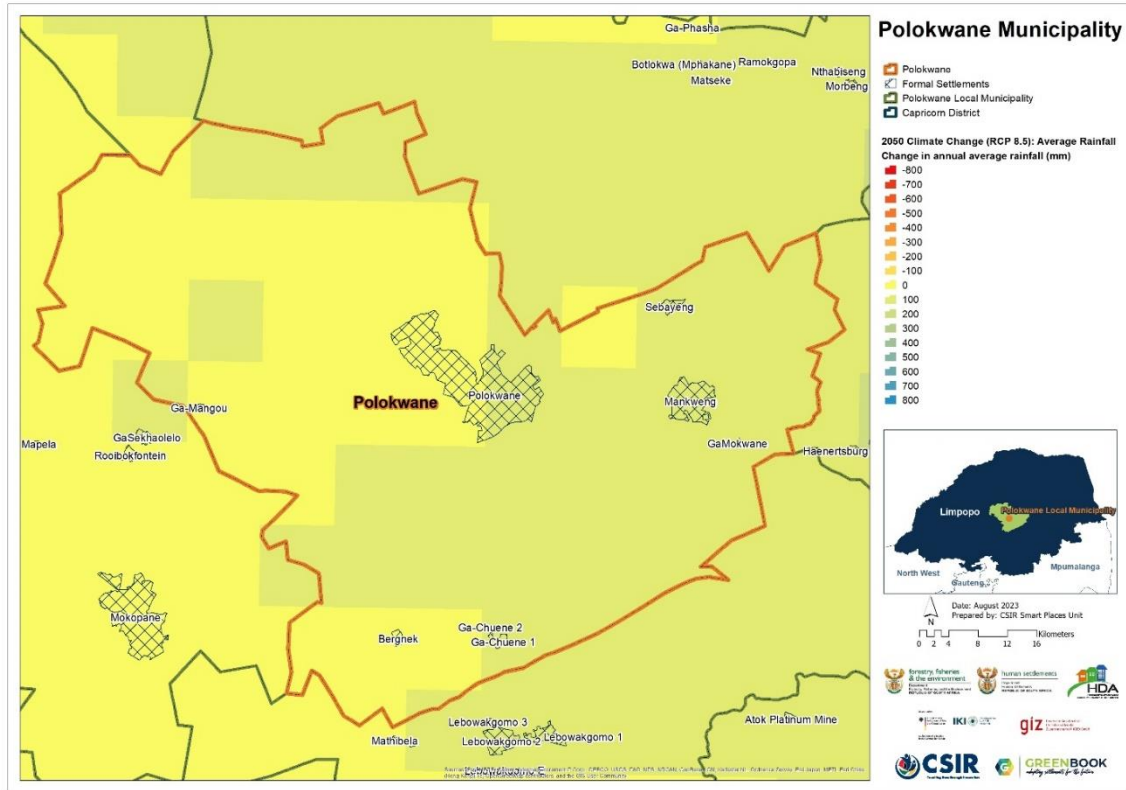


Figure 8: Projected change in average annual rainfall (mm) from the baseline period to the period 2021 – 2050 for Polokwane Local Municipality, assuming an (RCP 8.5) emissions pathway

The City of Polokwane experiences current GCM derived average annual rainfall of between 400 and 800 mm, with most parts of the Local Municipality experiencing average annual rainfall of 800 mm. The projections show increases in average annual rainfall of between 0 and 100 mm.

### 2.3. Climate Hazards

This section showcases information with regards to Polokwane Local Municipality’s exposure to climate-related hazards.

#### 2.3.1. Drought

The southern African region (particularly many parts of South Africa) is projected to become generally drier under enhanced anthropogenic forcing, with an associated increase in dry spells and droughts. To characterise the extent, severity, duration, and time evolution of drought over South Africa, the GreenBook uses primarily the Standardised Precipitation Index (SPI), which is recommended by the World Meteorological Organisation (WMO) and is also acknowledged as a universal meteorological drought index by the Lincoln Declaration on Drought. The SPI, with a two-parameter gamma distribution fit with maximum likelihood estimates of the shape and scale parameters, was applied on monthly rainfall accumulations for a 3-, 6-, 12-, 24- and 36-months base period. The SPI severity index is interpreted in the context of negative values

indicating droughts and positive values indicating floods. These values range from exceptionally drier (<-2.0) or wetter (>2.0) to near-normal (region bounded within -0.5 and 0.5).

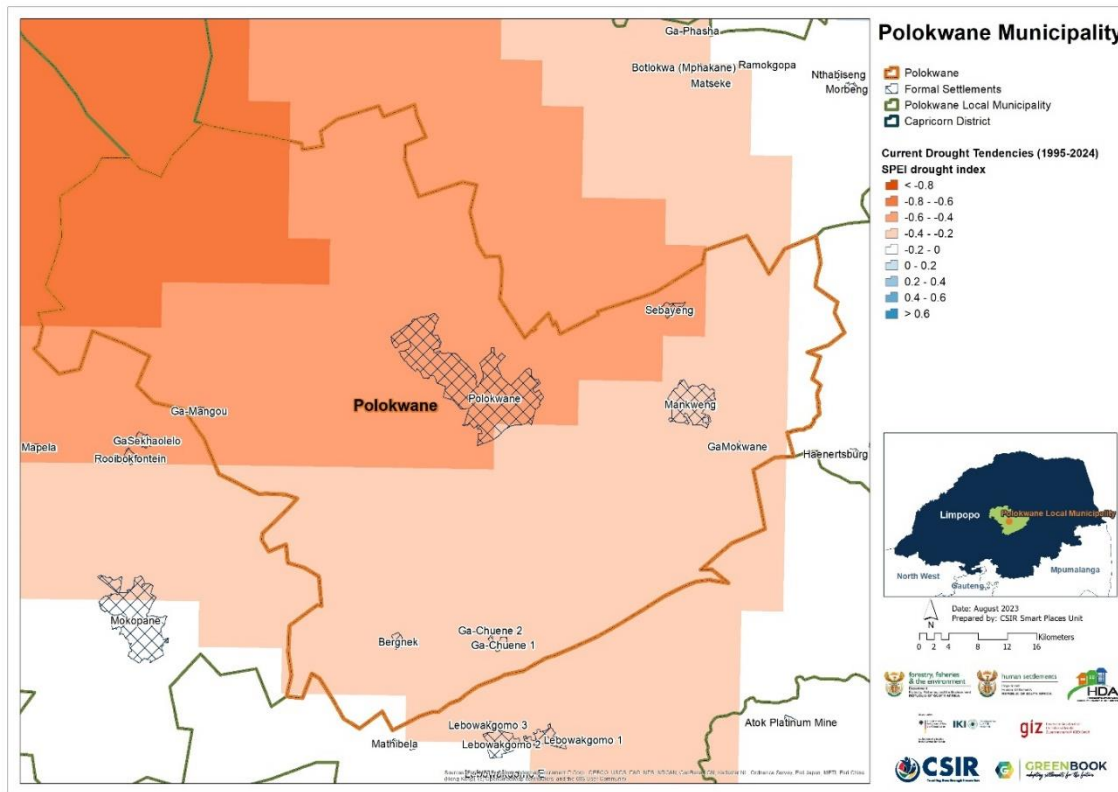


Figure 9: Projected changes in drought tendencies from the baseline period (1986 - 2005) to the current period (1995 - 2024) across Polokwane Local Municipality

Figure 9 depicts the projected change in drought tendencies (i.e., the number of cases exceeding near-normal per decade) for the period 1995–2024, relative to the 1986–2005 baseline period, under an RCP 8.5 “business as usual” emissions scenario. A negative value is indicative of an increase in drought tendencies per 10 years (more frequent than the observed baseline), with a positive value indicative of a decrease in drought tendencies. The current period is projected to experience drought tendencies.

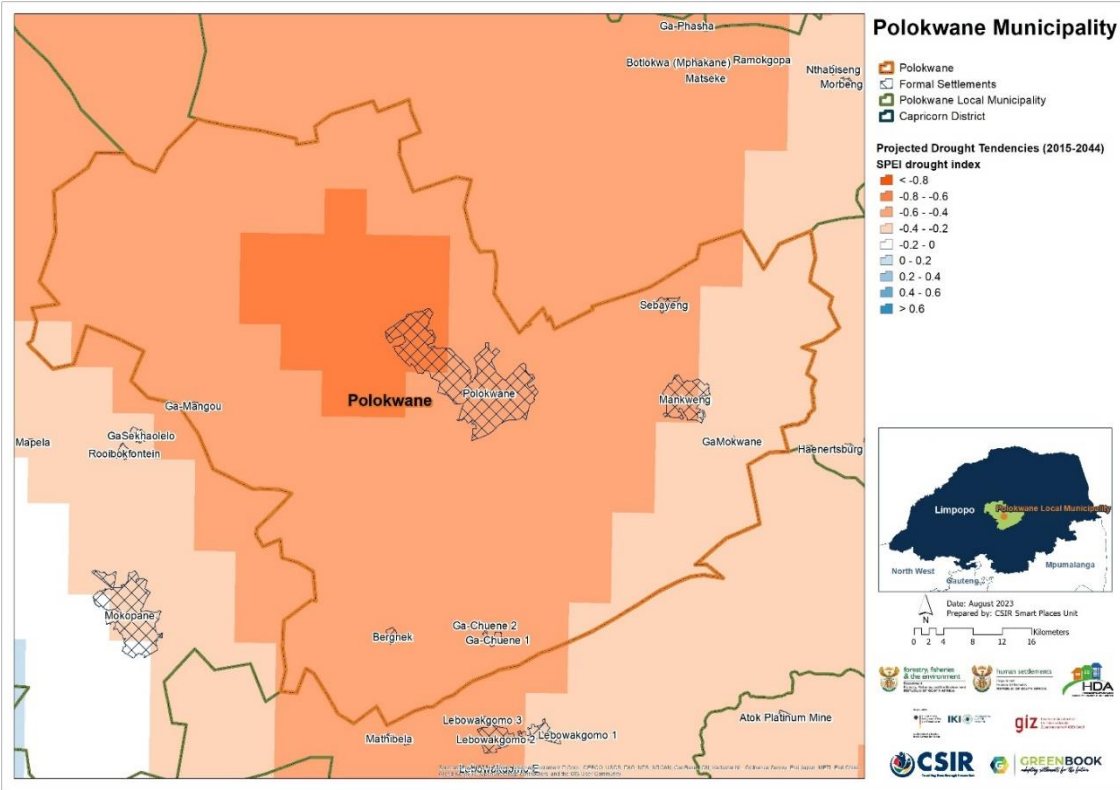


Figure 10: Projected changes in drought tendencies from the baseline period (1986 – 2005) to the future period (2015 – 2044) for Polokwane Local Municipality

Figure 10 depicts the projected change in drought tendencies (i.e., the number of cases exceeding near-normal per decade) for the period 2015–2044, relative to the 1986–2005 baseline period, under the low mitigation “business as usual” emissions scenario (RCP 8.5). A negative value is indicative of an increase in drought tendencies per 10 years (more frequent than baseline) into the future period and a positive value indicative of a decrease. Drought tendencies are projected to continue into the future and over larger areas.

At the baseline, most parts of the City of Polokwane are exposed to drought tendencies, with the tendency for more intense droughts predicted into the future. Moreover, all settlements in the Local Municipality face a high risk of drought into the future (at least up to 2050), including the populous areas of Polokwane and Mankweng (Figure 11).



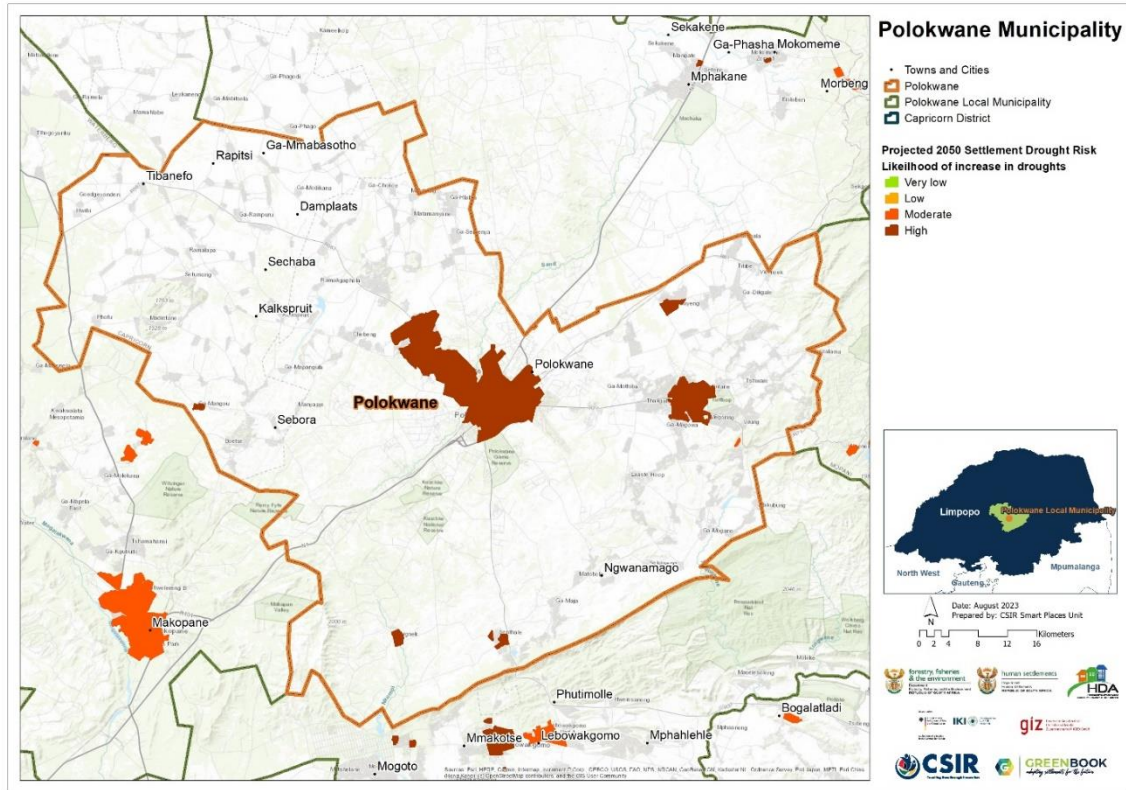


Figure 11: Settlement-level drought risk for Polokwane Local Municipality

2.3.2. Heat

The GCMs were used to simulate bias-corrected, annual average number of very hot days, defined as days when the maximum temperature exceeds 35°C per GCM grid point for the baseline (current) period of 1961–1990 (Figure 12), and for the projected change for period 2021–2050 (Figure 13), assuming a “business as usual” (RCP 8.5) emissions pathway.

The annual heatwave days map under baseline conditions (Figure 14) depicts the number of days (per 8x8 km grid point) where the maximum temperature exceeds the average maximum temperature of the warmest month of the year at that location by at least 5°C, i.e., for a period of at least three consecutive days. The projected change for the period 2021–2050 (Figure 15), assuming a “business as usual” (RCP 8.5) emissions pathway, is also shown.

Under baseline conditions, large parts of the City experience between 0 and 10 very hot days, with several pockets in the northwestern and southern parts of the Municipality experiencing between 11 and 30 very hot days per year (Figure 12). Heatwave events are more likely to take place in the north and eastern parts of the Local Municipality (Figure 14). The number of very hot days and heatwave days are projected to increase into the future, especially in the areas that are already more likely to experience heat extremes (See Figure 13 and 15).

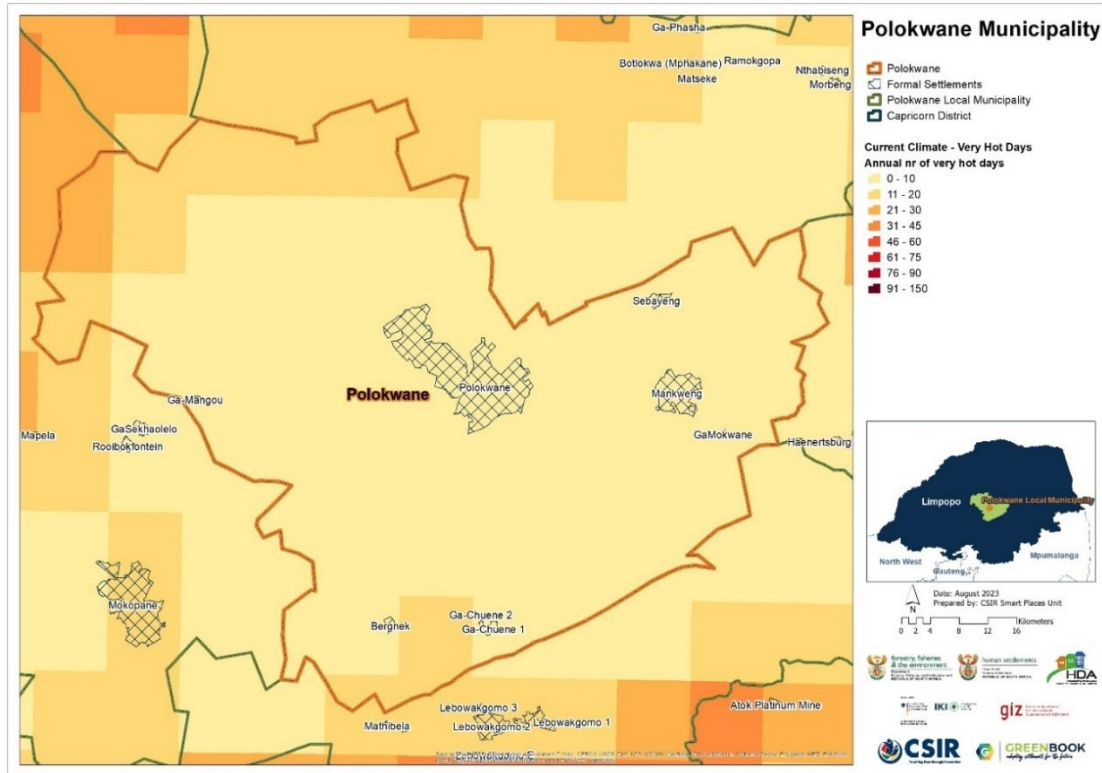


Figure 12: Annual number of very hot days under baseline climatic conditions across Polokwane Local Municipality with daily temperature maxima exceeding 35 °C

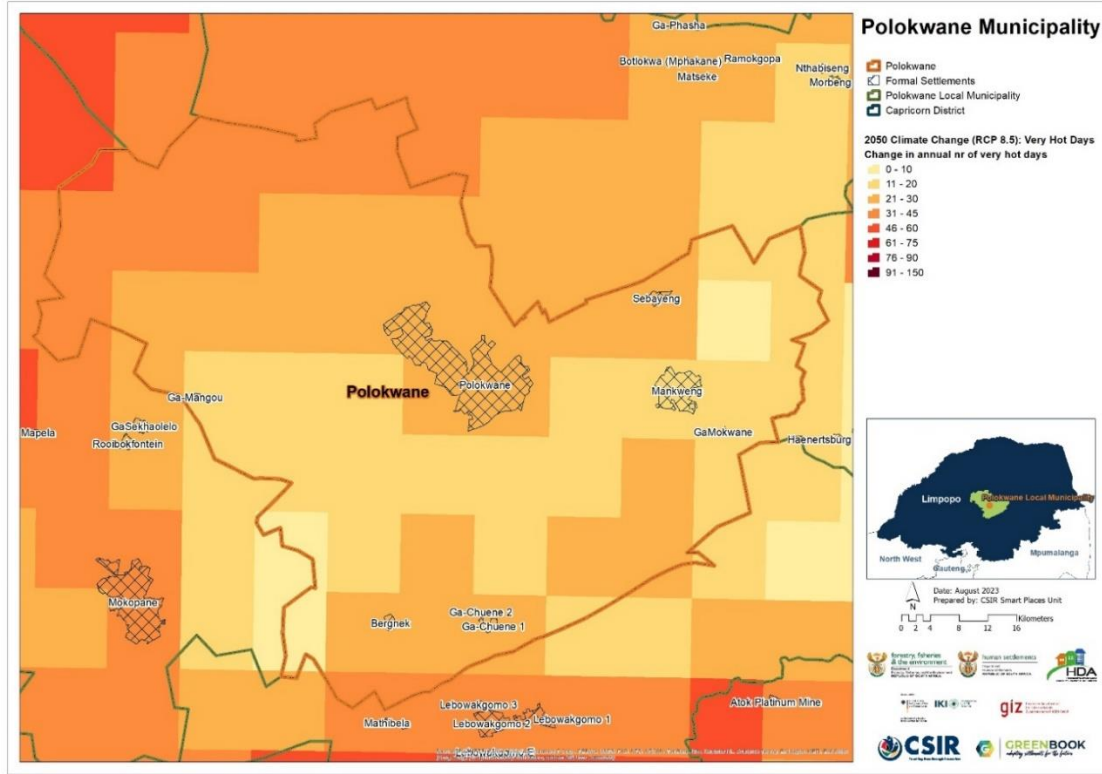


Figure 13: Projected change in annual number of very hot days across Polokwane Local Municipality with daily temperature maxima exceeding 35 °C, assuming an (RCP 8.5) emissions pathway





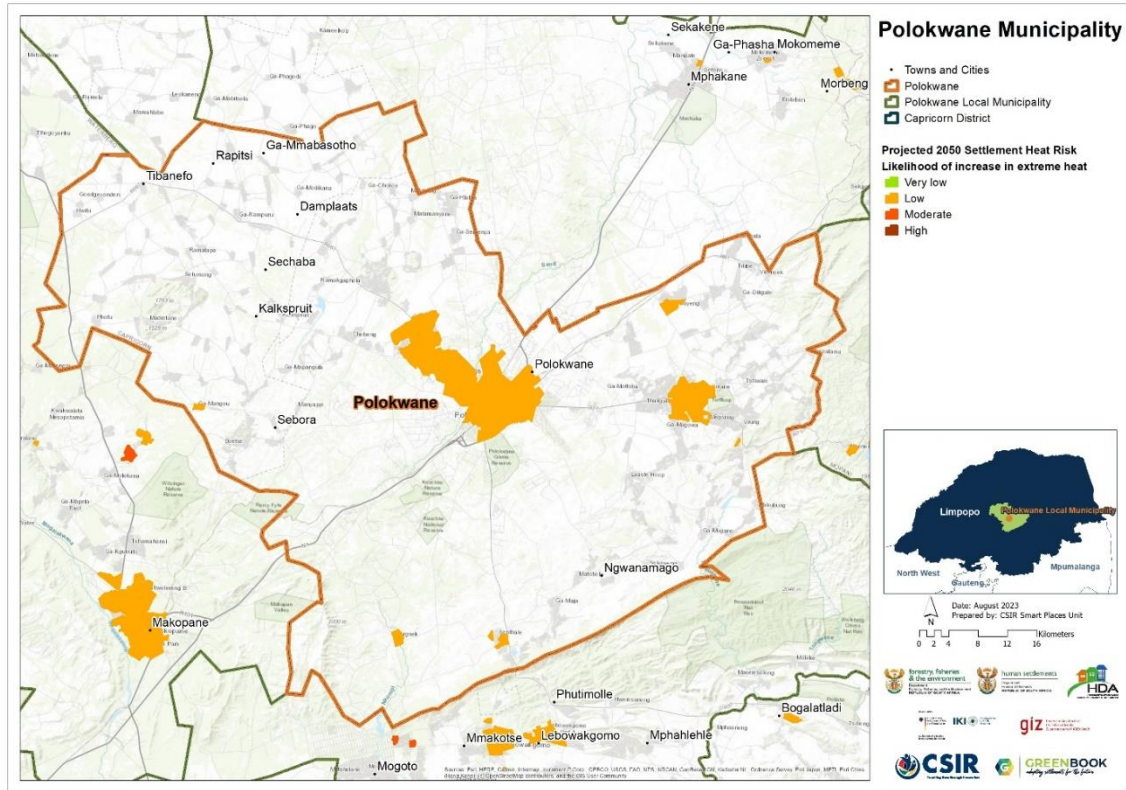


Figure 16: Heat stress risk across Polokwane Local Municipality at settlement level in the 2050s

Figure 16 depicts the settlements that are at risk of increases in heat risk. With the changing climate, it is expected that the impacts of heat will only increase in the future. The heat-absorbing qualities of built-up urban areas make them, and the people living inside them, especially vulnerable to increasingly high temperatures. The combination of the increasing number of very hot days and heatwave days over certain parts of South Africa is likely to significantly increase the risk of extreme heat in several settlements. As outlined in Figure 16, all settlements within the Polokwane Municipal Area face a low risk of heat stress into the future (i.e., up to 2050).

**2.3.3. Wildfire**

Wildfires occur regularly in South Africa and often cause significant damage. The main reasons for recurring wildfires are that we have climates with dry seasons, natural vegetation that produces sufficient fuel, and people who light fires when and where they should not. Much of the natural vegetation requires fires to maintain the ecosystems in good condition. At the same time fires are a threat to human lives, livelihoods, and infrastructure. More and more people, assets and infrastructure are placed on the boundary or interface between developed land and fire-prone vegetation – what we call the wildland-urban interface (WUI) – where they are exposed to wildfires. The combination of climate and vegetation characteristics that favour fires, and growing human exposure, results in significant wildfire risk across the country, especially in the southern and eastern parts.

Fire risk is determined by combining the typical fire hazard for a fire-ecotype (i.e., likelihood, fire severity) and the social and economic consequences (i.e., the potential for economic and social losses). The typical fire hazard was used to develop a plausible fire scenario for each fire-ecotype, i.e., what a typical wildfire would be like. The fire scenarios were then combined with the vulnerability to estimate the economic and social consequences. We used a scale where the likelihood was rated from 'rare' to 'almost certain' and the consequences were rated from 'insignificant' to 'catastrophic' to determine a level of fire risk which ranged from 'low' to 'high'. The risks were then summarised for all the settlements within a local authority. Changes in the fire risk in future were accommodated by adjusting either the fire scenarios or the likelihood, or both. Figure 17 depicts the likelihood and the risk of wildfires occurring in the wildland-urban interface (the boundary or interface between developed land and fire-prone vegetation) of the settlement.

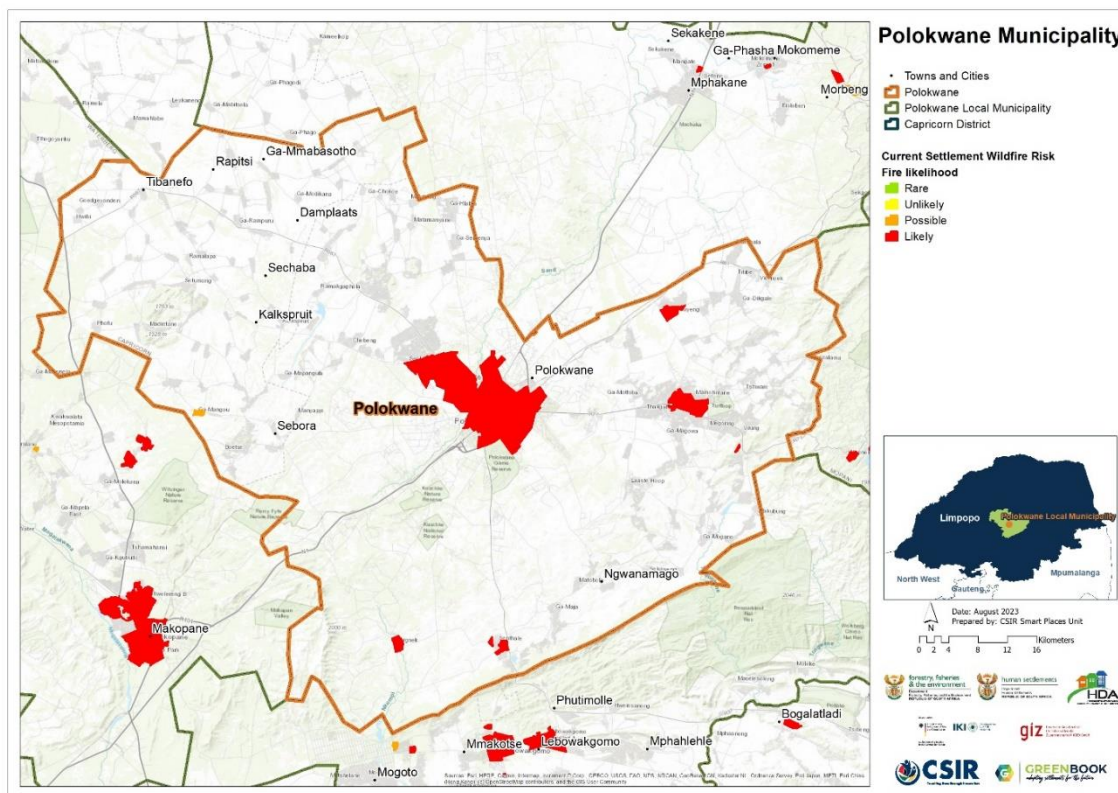


Figure 17: The likelihood of wildfires under current climatic conditions across settlements in Polokwane Local Municipality

The projected number of fire danger days for an 8 x 8 km grid-point under an RCP 8.5 “business as usual” emissions scenario was calculated. A fire danger day is described as a day when the McArthur fire-danger index exceeds a value of 24. The index relates to the chances of a fire starting, its rate of spread, its intensity, and its difficulty of suppression, according to various combinations of air temperature, relative humidity, wind speed and both the long and short-term



drought effects. Future settlement risk of wildfires is informed by the projected change in the number of fire danger days. Figure 18 depicts the settlements that could be at risk of increases in wildfires by the year 2050.

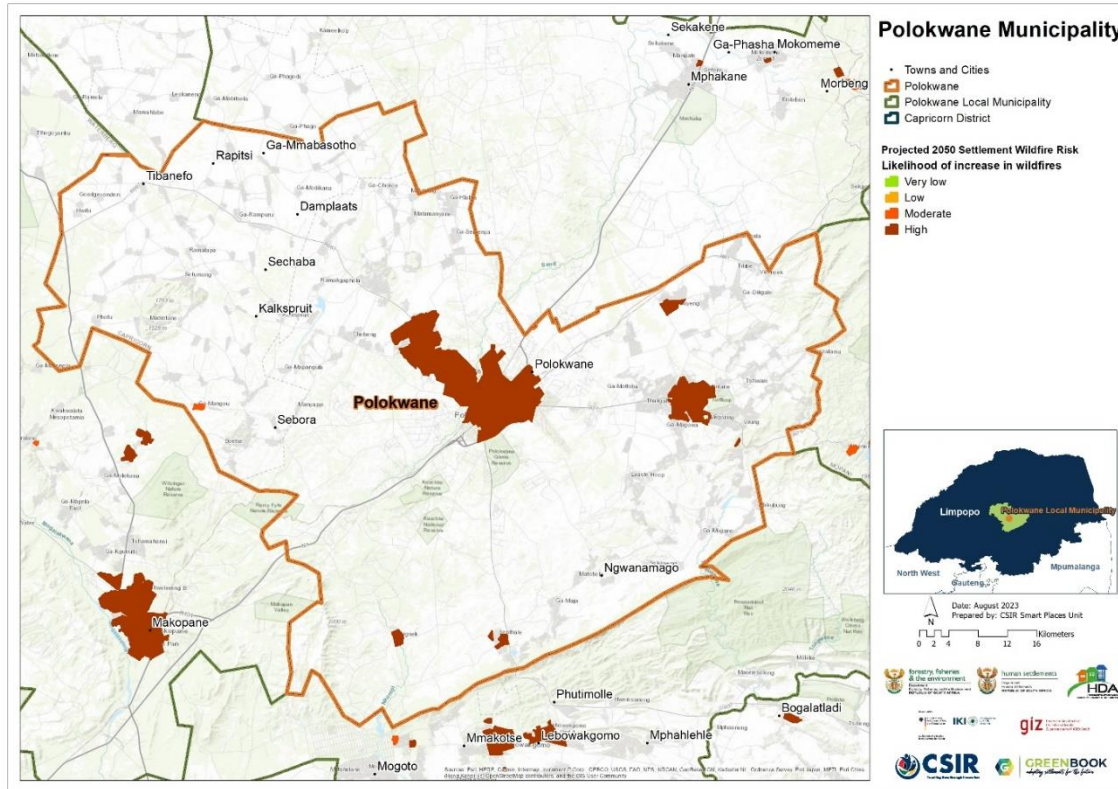


Figure 18: The likelihood of wildfires under projected climatic conditions across settlements in Polokwane Local Municipality

Figure 17 depicts the likelihood and the risk of wildfires occurring in the wildland-urban interface (the boundary or interface between developed land and fire-prone vegetation) of the settlement, while Figure 18 depicts the settlements that could be at risk of increases in wildfires by the year 2050. All settlements within the Polokwane Municipal Area face a high likelihood of wildfires on their wildland-urban interface, and it is projected that the same settlements face an increased risk of wildfires into a climate-changed future, at least up to 2050 (Figure 18).

### 2.3.4. Flooding

The flood hazard assessment combines information on the climate, observed floods, and the characteristics of water catchments that make them more or less likely to produce a flood. The climate statistics were sourced from the South African Atlas of Climatology and Agrohydrology, and a study of river flows during floods in South Africa (Schulze et al. 2008). The catchment characteristics that are important are those that regulate the volume and rate of the water flowing down and out of the catchment. The SCIMAP model was used to analyse the hydrological responsiveness and connectivity of the catchments and to calculate a Flood Hazard Index.

Changes in land cover, such as urbanisation, vegetation and land degradation, or poorly managed cultivation, reduce the catchment’s capacity to store or retain water. More dynamic changes in land cover could not be considered in this analysis, such as for example, recent informal settlements that may increase exposure and risk. Additional local and contextual information should be considered to further enrich the information provided here.

Since the magnitude and intensity of rainfall are the main drivers of floods and rainfall intensity is likely to increase into the future, estimates of extreme daily rainfall into the future were obtained from high-resolution regional projections of future climate change over South Africa. The settlements that are at risk of an increase in floods were calculated using a risk matrix, that considered the flood hazard index and the change in extreme rainfall days from the baseline period of 1961-1990, to the 2050s.

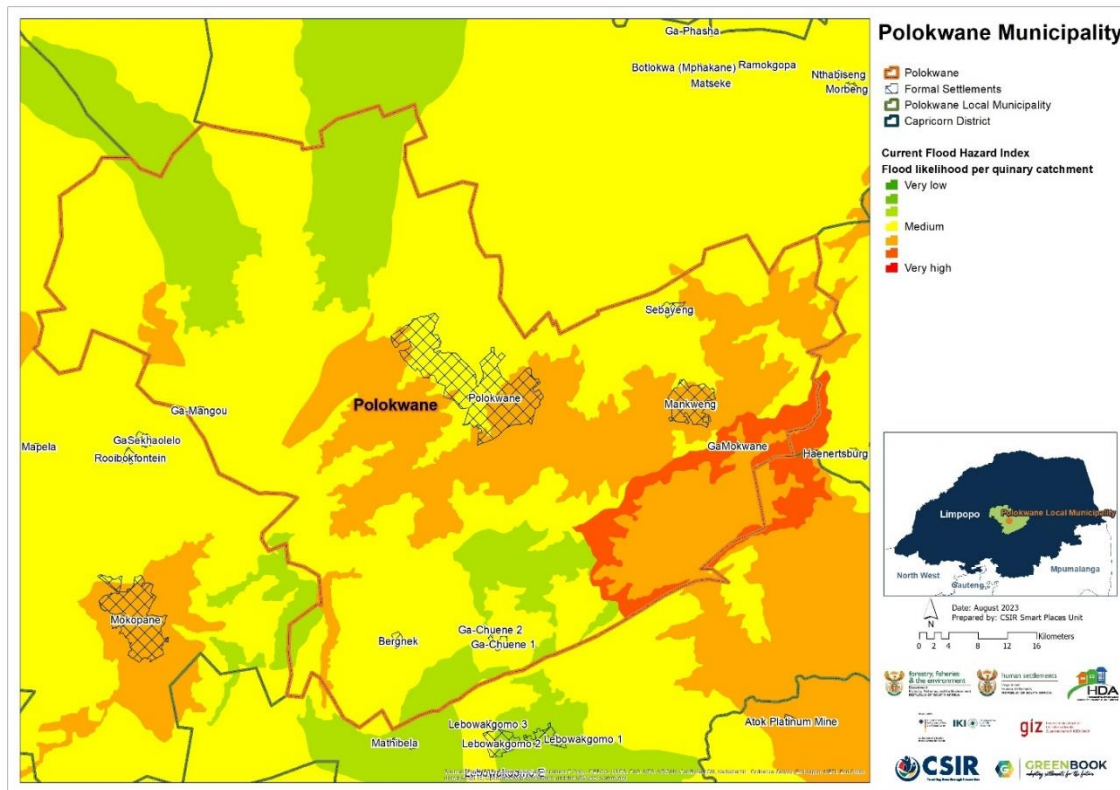


Figure 19: The flood hazard index across Polokwane Local Municipality under current (baseline) climatic conditions

Figure 19 depicts the flood hazard index of the individual quinary catchments present or intersecting with the Local Municipality. The flood hazard index is based on the catchment characteristics and design rainfall, averaged at the quinary catchment level. Green indicates a low flooding hazard, while red indicates a high flood hazard. There is significant variation of the flood hazard index across the City of Polokwane. Most parts of the Municipality have a medium flooding hazard, with pockets of low flooding hazard in the south and northwestern parts of the Local Municipality, and high to very high flooding hazard in the eastern parts of the Municipality.

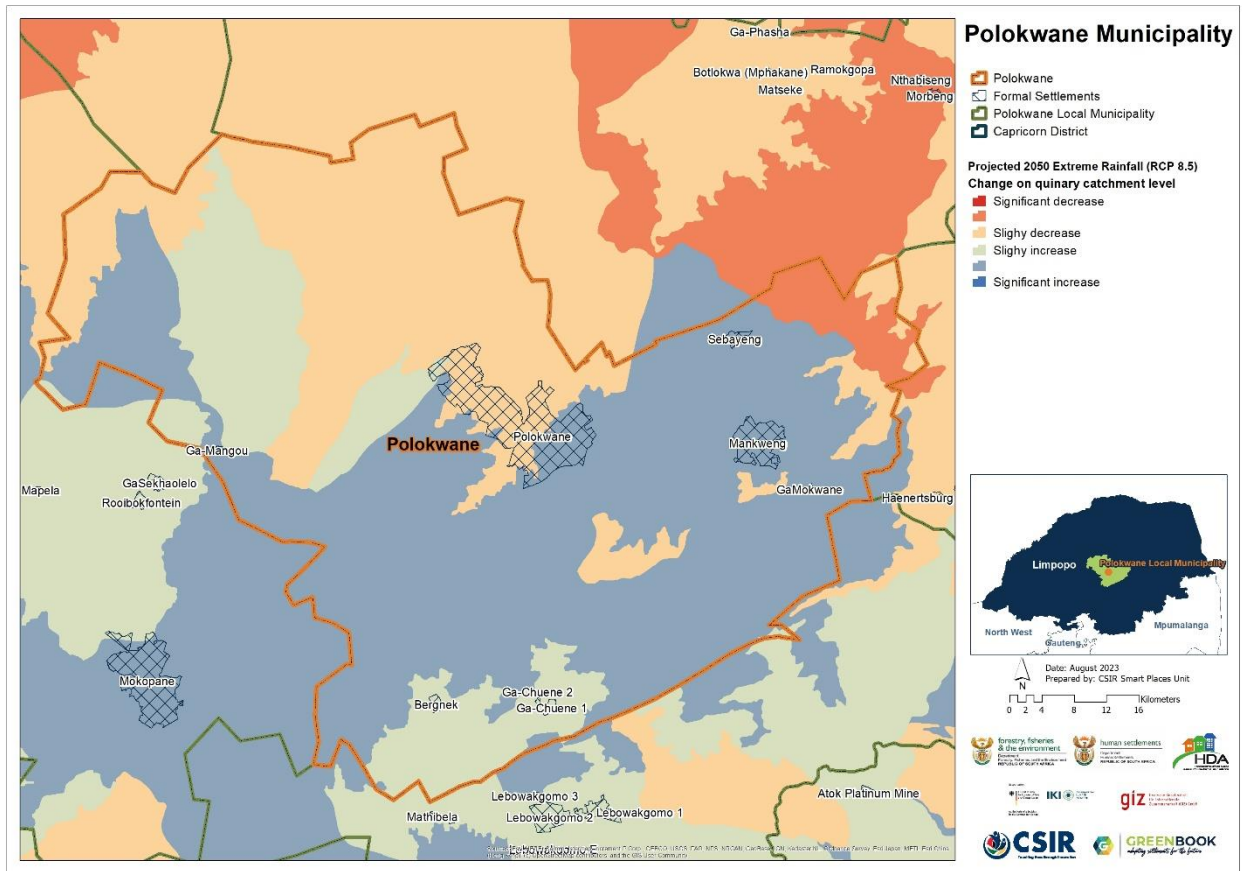


Figure 20: Projected change into the future in extreme rainfall days across Polokwane Local Municipality

Figure 20 depicts the projected change for the year 2050 in extreme rainfall days for an 8 x 8 km grid. This was calculated by assessing the degree of change when future rainfall extremes (e.g., 95<sup>th</sup> percentile of daily rainfall) are compared with those under the current rainfall. A value of more than one indicates an increase in extreme daily rainfalls. Significant increases in the number of rainfall days are projected for large parts of the municipal area, especially in the south and eastern parts. The rest of the Local Municipality is projected to experience either slight increases or slight decreases in the number of extreme rainfall days, under an RCP 8.5 “business as usual” emissions scenario.



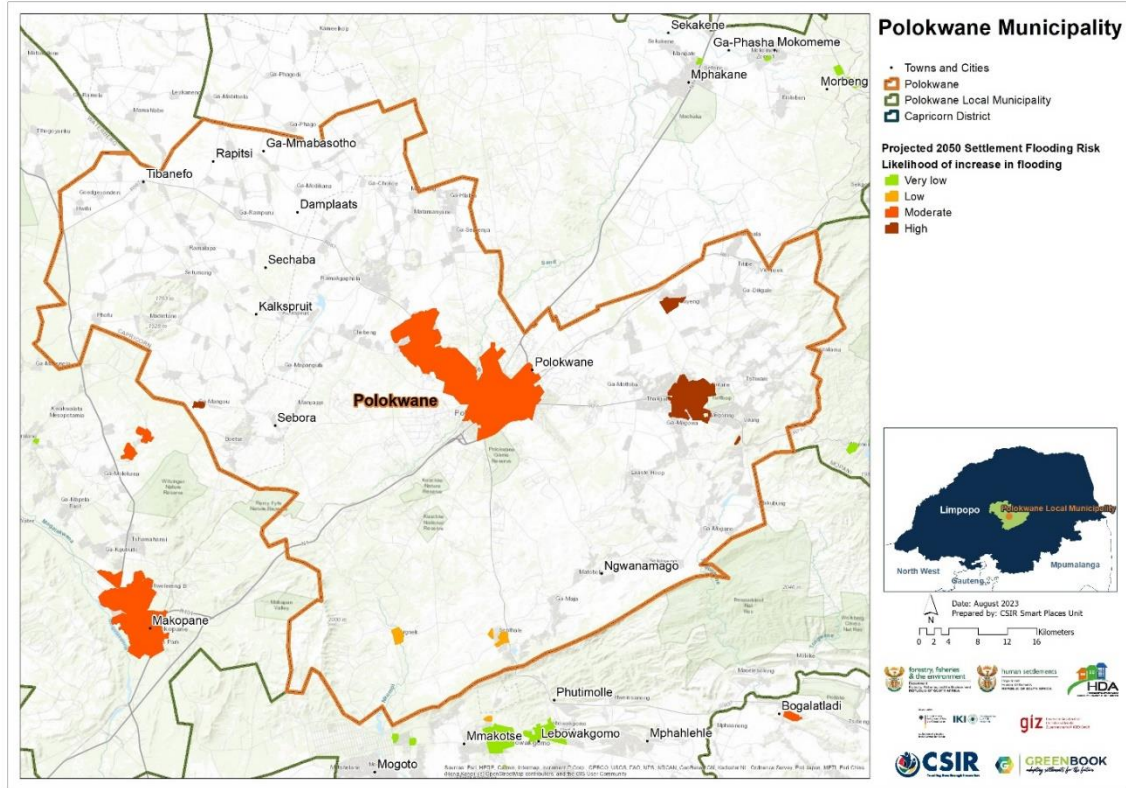


Figure 21: Flood risk into a climate change future at settlement level across Polokwane Local Municipality

Figure 21 depicts the settlements that are at increased risk of urban flooding under an RCP 8.5 low mitigation (worst case of greenhouse gas emissions) scenario. The settlements of Sebayeng, Mankweng and Ga Mangou, face a high risk of flooding in the future (2050), while a medium risk of flooding is projected for the settlement of Polokwane. The rest of the settlements in the Local Municipality, including Bergnek, are projected to have a low risk of flooding.

**2.4. Climate impacts on key resources and sectors**

To understand the impact that climate change might have on major resources, this section explores the impact that climate change is likely to have on the resources and economic sectors of the City of Polokwane.

**2.4.1. Water resources and supply vulnerability**

South Africa is a water-scarce country with an average rainfall of approximately 450 mm per year, with significant annual and seasonal variability, Rainfall also varies from over 1900 mm in the east of the country and in the mountainous areas, to almost zero in the west and northwest of the country. Conversion of rainfall to runoff is also low with an average mean annual runoff (MAR) of only 40 mm, one seventh of the global average of 260 mm per year. Runoff is even more highly variable than precipitation, both in space and time. Furthermore, demand for water is not evenly distributed, with most of the major water demand centres located far from the

available water resources. This has resulted in a need to store water and transfer water around the country to meet current and future demands.

Water availability is directly impacted by the climate and climate change. It is not just changes in precipitation that need to be considered, but also increasing temperatures that will lead to increased evaporation which could further reduce runoff and increase water losses from dams. Increasing temperatures will also impact on water demand, particularly for irrigation, but also from urban and industrial users. This could also contribute to reduced water security if existing systems are not able to meet these increasing demands. Increasing air temperatures will also increase water temperatures and hence increase pollution and water quality risks.

To obtain a high-level first order assessment of the relative climate change risks for water supply to different towns and cities across South Africa, a general risk equation was developed to determine the current and future surface water supply vulnerability that combines both climate change and development risks (i.e., due to an increase in population and demand). The current vulnerability of individual towns was calculated based on the estimated current demand and supply as recorded across the country by the Department of Water and Sanitation's (DWS) All Towns study of 2011 (Cole, 2017). The future vulnerability was calculated by adjusting the water demand for each town proportional to the increase in population growth for both a high and medium growth scenario. The level of exposure was determined as a factor of the potential for increasing evaporation to result in increasing demands, and for changes in precipitation to impact directly on the sustainable yield from groundwater, and the potential for impacts on surface water supply. These were then multiplied by the proportion of supply from surface and groundwater for each town. Exposure to climate change risk for surface water supply was calculated in two ways. The first was by assuming surface water supply was directly related to changes in streamflow in the catchment in which the local municipality was located (E1) and alternatively (E2) taking into account the potential benefits offered by being connected to a regional water supply system by using the result from a national study of climate change impacts on regional water supply derived from a high level national configuration of the Water Resources Yield Model (WRYM) that calculated the overall impacts on urban, industrial and agriculture water supply to each of the original 19 (now 9) Water Management Areas (WMAs) in South Africa.

In South Africa, groundwater plays a key strategic role in supporting economic development and sustaining water security in several rural and urban settlements that are either entirely or partially dependent on groundwater supply. Groundwater is, however, a natural resource the availability and distribution of which are highly influenced by climate variability and change. An analysis of the impact of climate change on potential groundwater recharge was conducted for the period 2031 to 2050. The Villholth GRiMMS (Groundwater Drought Risk Mapping and Management System) formulation (Vilholth et al., 2013), which implemented a composite mapping analysis technique to produce an explicit groundwater recharge drought risk map, was adapted to formulate a series of potential groundwater recharge maps for the far-future across



South Africa. Finally, the future period 2031 to 2050 was compared with the historical period 1961 to 1990.

Figure 22 indicates where settlements get their main water supply from, be it groundwater, surface water or a combination of both sources. Settlements that rely on groundwater, either entirely or partially, are deemed groundwater dependent. In the City of Polokwane, there is a mix of surface and groundwater dependent towns, with most of the settlements relying on a combination of the two.

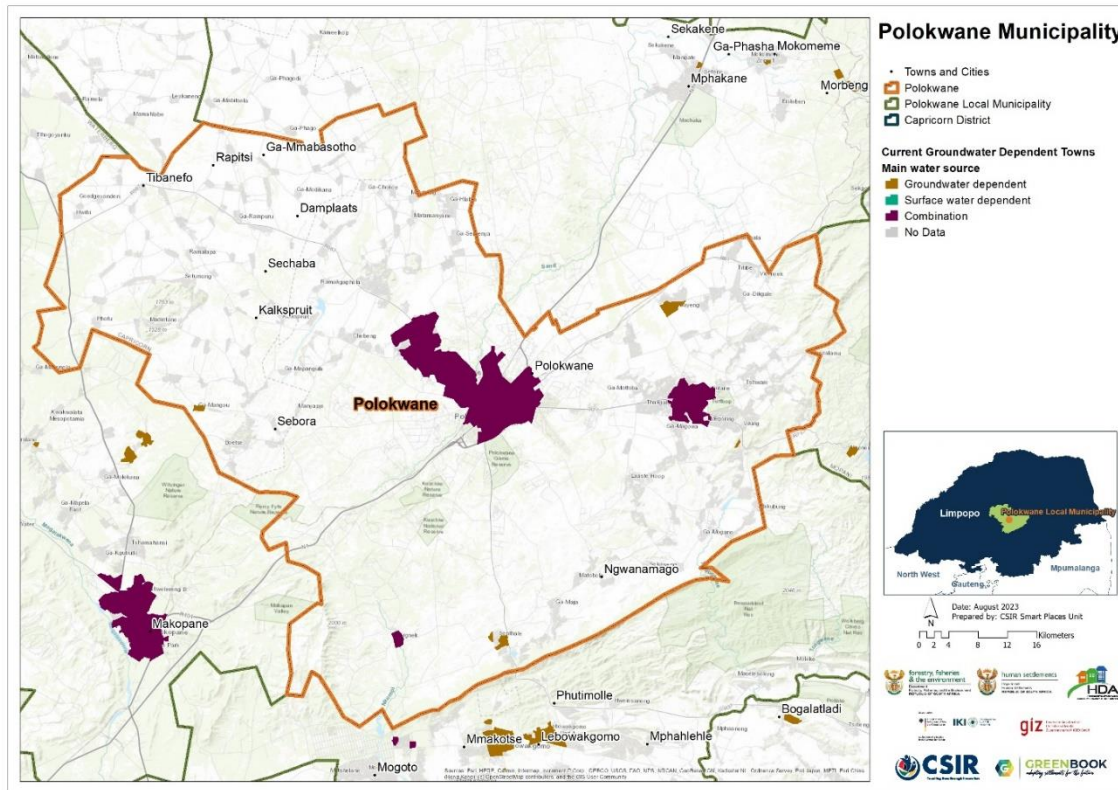


Figure 22: Main water source for settlements in Polokwane Local Municipality

Figure 23 indicates the occurrence and distribution of groundwater resources across the Local Municipality, showing distinctive recharge potential zones, while Figure 24 indicates the projected change in groundwater recharge potential. Figure 25 indicates the groundwater dependent settlements that may be most at risk of groundwater depletion based on decreasing groundwater aquifer recharge potential and significant increases in population growth pressure by 2050. Under baseline conditions, large parts of the City of Polokwane have a moderate groundwater recharge potential, with pockets of low and high recharge potential scattered across the southern parts of the Local Municipality (Figure 23). Most parts of the City are expected to experience a decrease in groundwater recharge potential by 2050 (Figure 24). However, increases in groundwater recharge potential are expected in the areas that currently have a high recharge potential. The settlements of Polokwane, Mankweng and Sebayeng face a

high risk of groundwater depletion in the future (at least up to 2050) due to the projected decrease in groundwater recharge potential and the expected population growth (Figure 25). The City's groundwater reserves are further threatened by pollution from the Polokwane Cemetery and the Seshego Sewerage Works (PLM, 2021, p. 193-194).

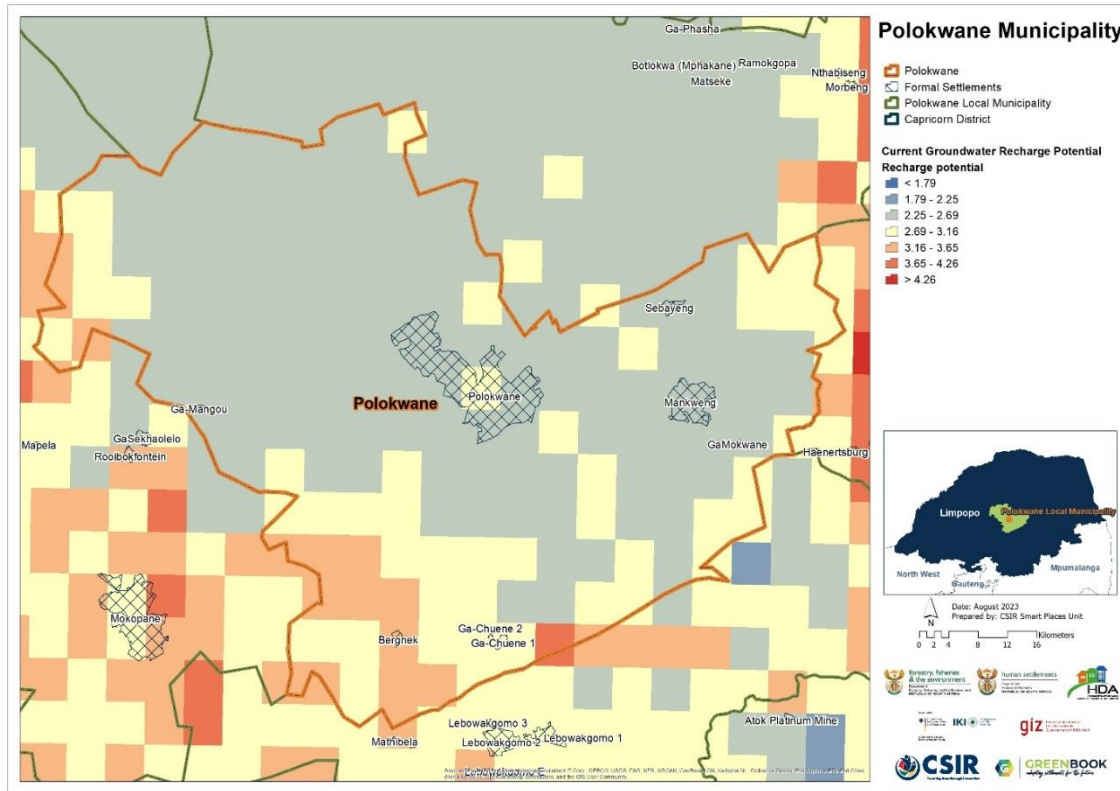


Figure 23: Groundwater recharge potential across Polokwane Local Municipality under current (baseline) climatic conditions

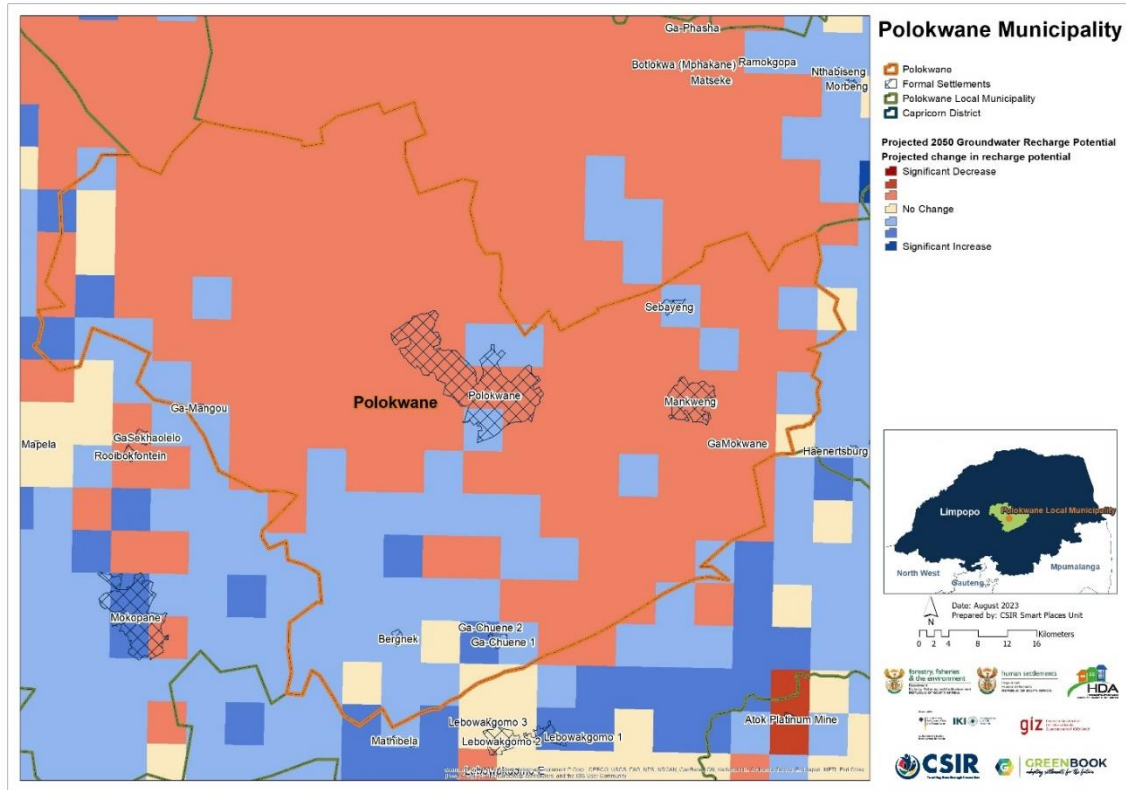


Figure 24: Projected changes in groundwater recharge potential from baseline climatic conditions to the future across Polokwane Local Municipality

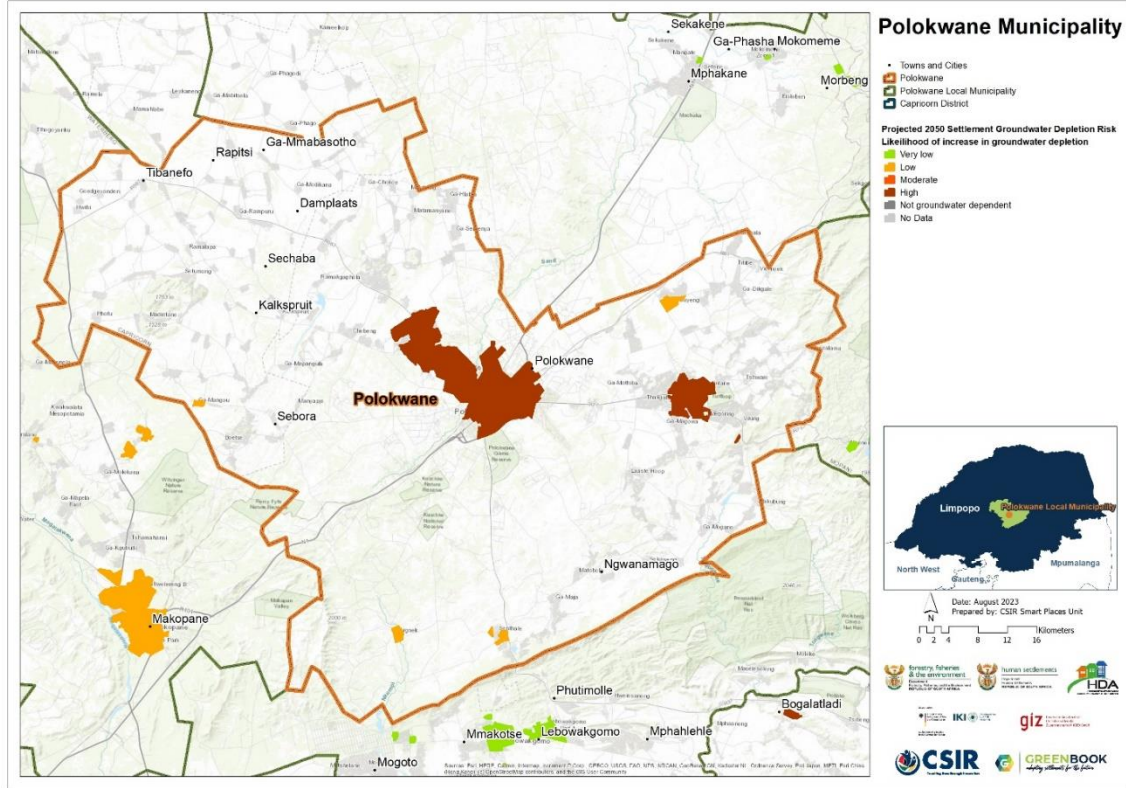


Figure 25: Settlement-level groundwater depletion across Polokwane Local Municipality

Table 4 provides an overview of current water supply vulnerability (i.e., demand versus supply) in the City of Polokwane based on the data compiled for the Department of Water and Sanitation's (DWS) All Town's Study (Cole, 2017). A water supply vulnerability score above 1 indicates that demand is more than supply, while a score below 1 indicates that supply is meeting demand.

Table 4: Current water supply and vulnerability across Polokwane Local Municipality

Polokwane Local Municipality	Water Demand per Capita (l/p/d)	Water Supply per Capita (l/p/d)	Current Water Supply Vulnerability
	111.43	140.01	0.8

Current and future water supply vulnerability estimations are based on: 1) a local water supply perspective incorporating changes to population growth coupled with exposure to climate risk and 2) a regional water supply perspective, based on impacts of regional water supply assuming supply is part of the integrated regional and national bulk water supply network. The water supply vulnerability estimations do not consider current state of water supply and reticulation infrastructure. The current context and conditions within the Local Municipality need to be considered when interpreting the information provided in this report. The water supply vulnerability of the City of Polokwane is discussed below. Figure 26 shows the City's estimated current and future water supply vulnerability, under a medium growth scenario. The factors contributing to the estimated water supply vulnerability are outlined in Table 5.

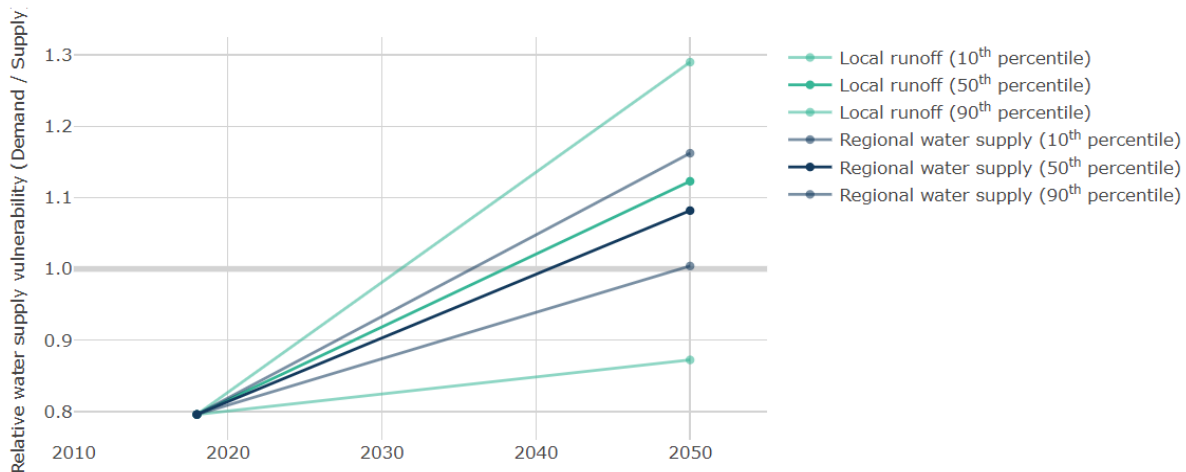



Figure 26: Current and future water supply vulnerability for Polokwane Local Municipality



*Table 5: Future water supply vulnerability contributors for Polokwane Local Municipality, under a medium population growth scenario*

VULNERABILITY CONTRIBUTION FACTORS		PERCENTAGE CHANGE	
	Mean annual precipitation		-10%
	Mean annual evaporation		12.59%
	Mean annual runoff		15.69%
	Regional urban water supply		28.53%
	Population growth		22.08%

In 2011, the City of Polokwane's water demand was lower than supply (Table 4), this is still the case according to the various water supply vulnerability estimations (see Figure 26). The City's water supply vulnerability is projected to increase to between 0.88 to 1.30 by 2050, i.e., under a medium population growth scenario, due to the projected decrease in mean annual precipitation, as well as projected increases in mean annual evaporation and population growth (Table 5).

#### 2.4.2. Agriculture, forestry, and fisheries

Agriculture and food production is arguably the sector most vulnerable to climate impacts in South Africa. Many settlements in South Africa owe their existence to the primary sector of the country. Agriculture, forestry, and fisheries (AFF) form the bulk of the primary sector and act as catalysts for the economic development of secondary and tertiary sectors. Where these sectors are the primary economic activity in an area, they contribute to the local economy, employment, food security, and livelihoods. They also indirectly benefit from services such as health care, education, and basic infrastructure. In such regions, social and economic stability are linked with the profitability of the agricultural sector.

Climate change, through increased temperature and changing rainfall patterns, can have fundamental impacts on agriculture if the climatic thresholds of the commodities being farmed are breached. However, the nature and extent of these impacts depends on the type of commodity being farmed and the relative geographic location of the farmer in relation to the industries served, and on the resources available to the farmer. The same climate impact can have different impacts on different commodities and farms. Overall, climate change could make it more difficult to grow crops, raise animals, and catch fish in the same ways and same places as we have done in the past.

The methodological approach to understanding the impact of climate and climate change on AFF consisted of four components. Firstly, the most important areas in terms of Gross Value Added (GVA) and employment for the AFF sector relative to the other sectors of the South African economy were determined. Secondly, an analysis of climate change scenarios was done using historical climate variables, as well as multi-model projections of future climates to help identify

specific climate-related risk factors for agriculture within specific regions. Thirdly, crop suitability modelling was done to indicate how the area suitable for crop production under the present climate conditions might shift or expand under the scenarios of future climate change, in addition to using the Temperature Humidity Index (THI) to assess heat stress in livestock. Finally, the climate change analysis was used in conjunction with the crop modelling outputs to assess the potential impacts of climate change over a specific area, or for a specific crop, to give more detail on how predicted climate changes translate into location/crop specific impacts. This was developed at a local municipal level and guided by the outcome of the agricultural industry sector screening and climate scenario analysis.

In the City of Polokwane, the AFF sector contributes 0.93% to the local GVA, which is a contribution of 0.49% to the national GVA for the AFF sector. Of the total employment, 3.48% is within the AFF sector. The main commodities are chicken, maize for grain and potatoes. Climate projections, i.e., under an RCP 8.5 “business as usual” GHG emissions scenario, show a generally hotter and drier climate for the City, with wetter conditions projected into the future. This could result in increased production costs for chicken farmers, as increased investment in ventilation and cooling will be required to maintain optimal seasonal temperatures and reduce the risk of heat stress for birds, which often results in reduced body weight and reproduction efficiency, as well as poor egg quality. The projected climate may also lead to maize yield reductions due to the projected decline in rainfall, at least in the near future, and increasing temperatures. However, the same climate may yield some benefits for the AFF sector by resulting in increased yields for potato farmers, due to increased concentration of CO<sub>2</sub>, as root crop plants often benefit from elevated carbon dioxide levels due to higher rates of photosynthesis.

### 3. Recommendations

The greatest risks faced across the City of Polokwane are increased temperatures and drought, with the risk of heat extremes becoming greater towards 2050. Moreover, the City’s three most populous settlements, including Polokwane, Sebayeng and Mankweng, also face a high risk of wildfires and flooding – the cascading effects of which pose severe health risks to people and animals; for instance, through smoke pollution from wildfires, as well as the spread of water- and vector borne diseases from flooding and high temperatures. It is therefore necessary to ensure that systems are in place to maintain and ensure the public’s health, should the need arise. The same settlements, with the exception of Sebayeng, are also expected to experience high population growth pressure in the future, thus alluding to an increase in the exposure of people to those climate hazards. High population growth pressure also alludes to increased competition for resources – which contribute to the adaptive capacity of the City and its inhabitants, thus making it more difficult for people to adapt to, respond to and recover from climate hazards and impacts.

The City of Polokwane’s water supply vulnerability is expected to increase into the future as a result of reduced rainfall and runoff generation, as well as population growth. Furthermore, the

City's populous areas, which rely on a combination of groundwater and surface water, face a high risk of groundwater depletion into the future (2050). This therefore indicates the need to diversify potable water supply (i.e., water sources), improve groundwater recharge and conserve available water.

In addition to these risks, the City of Polokwane has a highly vulnerable economy (EcVI), settlement fabric (PVI) and natural environment (EnVI), which will undermine the City's ability to recover from external shocks, including climate hazards, if not properly addressed. With urban-rural inequality identified as the biggest contributor to the City's high economic vulnerability, it is essential to manage this inequality by developing rural areas, providing services, and reviving the rural economy; and with the availability of arable land in rural areas, as well as the low levels of skills amongst rural populations – the agricultural sector emerges as a key avenue for job creation and economic growth in rural areas. The City therefore stands to benefit from adapting the sector to future climate conditions and their impacts. Moreover, in so doing, City of Polokwane will also be contributing towards ensuring its food security into the future.

Therefore, in response to these climate risk and impacts, the following adaptation goals are recommended:

1. To prioritise the health and safety of communities in the face of a changing climate: Climate change hazards such as heat extremes, wildfires and flooding pose serious risks to public health and safety. Heat-related illnesses such as heatstroke, as well as health challenges associated with smoke pollution, which is a cascading effect of wildfires, are some of the health risks associated with these hazards. Moreover, hot and wet conditions, which are expected to be more prevalent in the City of Polokwane, often lead to the increased spread of water- and vector-borne diseases, while extreme weather events may cause people physical harm. It is therefore necessary to ensure that adequate systems are in place to mitigate (or respond to) the adverse consequences of such impacts. Implementing early warning systems for extreme weather events, ensuring access to climate-sensitive health services (such as heat illness prevention or disease surveillance), and improving emergency response capacity, are some of the measures that the City could look into. Furthermore, public education about the risks of climate change to health and safety is also crucial.
2. To ensure water security in the face of climate change: Given the water scarcity challenges in the country, as well as the effects that the projected increase in population growth and drought tendencies will have on the City's future water supply – developing comprehensive strategies for water resource management is crucial. As part of these strategies, the City of Polokwane could therefore prioritize water infrastructure maintenance; invest in efficient water supply infrastructure to meet future demand; promote water conservation practices by implementing strategies such as public awareness campaigns, leak detection and repairs, water metering and billing; as well as explore measures to secure alternative water sources



such as rainwater (harvesting), groundwater (recharge and extraction) and wastewater (reuse).

3. To reduce the exposure and vulnerability of human and natural systems to climate change and extreme weather events: To minimise the damage and loss stemming from the unavoidable impacts of climate change, it is essential to reduce the exposure and vulnerability of elements found in both human and natural systems present in the City, to climate-related hazards and extreme events. Reducing exposure and vulnerability will therefore involve a combination of infrastructural, behavioural, and institutional changes. For human systems, this might involve building climate-resilient infrastructure, developing or improving existing disaster risk reduction strategies, and enhancing social safety nets for the most vulnerable. For natural systems, this can involve protecting and restoring ecosystems and ecological assets that provide natural buffers against climate impacts, such as wetlands that absorb flood waters and natural fire breaks (e.g., creeks, bluffs).
4. To develop climate-resilient, low-carbon, diverse and inclusive rural economies that are socially responsible, environmentally sustainable and that provide job opportunities for unskilled, semi-skilled and skilled local residences: A climate-resilient rural economy would be one that can absorb and recover from climate shocks; that also contributes minimally to climate change. This might involve promoting sustainable agricultural practices that are adaptive to changing climate conditions, investing in renewable energy sources, and encouraging diversification of the rural economy into sectors that are less climate-sensitive. Furthermore, efforts to create more inclusive economies, that also provide job opportunities at all skill levels, may involve training programs for local residents, policies to support small and medium enterprises, as well as the implementation of measures designed to ensure that the benefits of economic activities are equitably distributed.
5. To increase resilience of the agricultural sector: Considering the various agricultural opportunities available in the City of Polokwane, including the extent of undeveloped and arable land, as well as the sector's potential in bridging the urban-rural inequality gap – it will be to the City's benefit to increase the sector's resilience to the impacts of climate change. The potential impact of climate change on the City's agricultural sector is notable when also considering its contribution to the City's GVA, as well as the number of people dependent on the sector for employment. Moreover, agricultural development constitutes one of five strategic pillars for the City's Local Economic Development (LED) Strategy – further demonstrating the need to strengthen the sector's resilience to the impacts of climate change. This can be done by providing farmers with (i) access to resilient crop varieties and efficient irrigation systems; (ii) training in sustainable farming techniques; (iii) financial risk management tools; and (iv) market opportunities, i.e., to help the agricultural sector withstand shocks and stresses such as climate change impacts, market fluctuations, and pest outbreaks.

These goals are not exhaustive and could be complemented by other strategies tailored to the specific context and needs of the City of Polokwane. The potential for success lies in integrating the goals (or the principles behind them) into all aspects of municipal decision-making and operations, as well as engaging communities in these efforts.

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## Annexure A: Sector-specific impacts

Climate hazards and climate events can have far-reaching impacts across a range of sectors. This section summarises the impact of climate change on the City of Polokwane's key sectors. Given that climate projections, are showing a generally hotter and drier climate for the local municipal area, those changes and their impact on key sectors should be considered.

Below are the six pillars identified to help guide the City of Polokwane's efforts towards achieving sustainable economic development and -growth, as well as its smart city vision.

### Smart City Pillars

- Smart Living
- Smart Environment
- Smart Mobility
- Smart Economy
- Smart People
- Smart Governance (Polokwane LM, 2022)

These pillars were further translated into strategic objectives for the City's 2021-2026 Integrated Development Plan (IDP), which are outlined below.

- To ensure efficiency and effectiveness of Municipal administration.
- To ensure the provision of basic and environmental services in a sustainable way to our communities.
- To ensure social protection and education outcomes.
- To promote economic growth, job creation and sustainable human settlements.
- To ensure community confidence in the system of local government.
- To enhance Financial Viability and Financial Management (Polokwane LM, 2022).

The sectors that are important in supporting the achievement of these strategic objectives are discussed in the subsections that follow, with the various climate impacts summarised in the tables provided.

## Ecosystem services

Urban areas are dependent on natural ecosystems in and around towns to provide communities with services such as safe and plentiful drinking water, increased food security, better health, decreased exposure to natural disasters and extreme weather, and increased recreational opportunities. For these ecosystems to continue to provide these services they need to be in a healthy condition. Unfortunately, many ecosystems have been degraded because of misuse and overuse of soil, water, plant, and animal species. At the same time global climate change is aggravating the vulnerabilities of these ecosystems and therefore diminishing the benefits that ecological infrastructure can provide. It is therefore critical to rehabilitate and maintain ecological infrastructure in the urban environment to help residents adapt to risks posed by future climate change. The table below outlines the cascading effects of selected climate change impacts on ecosystem services.

Increased temperatures and heat extremes	Drought and decreased rainfall	Increase in rainfall and inland flooding
<ul style="list-style-type: none"> <li>• Increased risks of water shortages increasing demand for irrigation of gardens and agriculture.</li> <li>• Increased evapotranspiration rates with rising temperatures, reducing the water available in reservoirs and water available for reliant ecosystems.</li> <li>• Increase in temperature leading to water loss via evapotranspiration resulting in decreased water quality and loss of wetlands.</li> <li>• Loss or degradation of indigenous species, including threatened species or ecosystems.</li> <li>• Increased threat from invasive species as competition for water increases.</li> <li>• Dieback or death of susceptible plants (e.g.,</li> </ul>	<ul style="list-style-type: none"> <li>• Decreased amounts of rainfall reaching ecosystems as settlements use rainwater harvesting techniques for increased household use.</li> <li>• Increased reliance on irrigation and greater demand for water to maintain public open space and gardens.</li> <li>• Reduced planting and pollination leading to greater risk of erosion and soil loss.</li> <li>• Increasing temperatures together with increased intensity of drought will potentially increase the occurrence of algal blooms in reservoirs and dams which are damaging to ecosystem functioning and water services.</li> </ul>	<ul style="list-style-type: none"> <li>• Rainfall in shorter and more violent spells making recharging groundwater difficult.</li> <li>• Increase in intensity of rainfall and flooding leading to increased surface runoff, resulting in increased soil erosion, soil loss and degradation.</li> <li>• Increasingly saturated soils leading to more standing water (ponding) which can result in more insect (pest) activity and their potential to carry diseases.</li> </ul>



<p>street trees) and animals (e.g. fish).</p> <ul style="list-style-type: none"> <li>• Increased water temperature leading to increased growth of aquatic weeds which increases breeding of disease vectors and reduces water oxygen levels.</li> <li>• Milder winters and reduced frost increase the duration of the growing season, increasing the survival rate of insects and diseases.</li> </ul>	<ul style="list-style-type: none"> <li>• Drought and decreased rainfall causing wetland habitat loss.</li> <li>• Reduced soil moisture availability increasing moisture stress leading to dieback and death of plants and the loss or degradation of indigenous communities, including threatened species or ecosystems.</li> <li>• Drying up of aquatic systems, perennial systems will become seasonal and seasonal systems will die off and be replaced by terrestrial plants.</li> <li>• Increased spread of drought-adapted alien invasive plant species.</li> </ul>	
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**Stormwater**

A stormwater drainage system collects, conveys and discharges stormwater with the aim to reduce the risk of flooding in settlements and control water quality (traditional pollutants that are commonly associated with municipal and industrial discharges, e.g., nutrients, sediment, and metals). Conventionally rainwater falling onto a hard surface will be collected and drained through surface channels to a collection point or culvert where it will enter a storm water pipe. The pipe will use gravity to discharge the water into a watercourse or a dam. Where a gravity-fed system cannot be used the water will be collected into a storage dam and pumped to the discharge location. Sustainable Urban Drainage Systems (SUDS) seeks to minimize the volume of storm water entering the drainage system. It does this in three ways: first, collect and store as much rainwater at source as possible; second, filtrate as much surface water into the ground as possible as close to the source as possible; third, collect storm water at grade in various storage systems (weirs, wetlands, attenuation ponds, etc.). The table below outlines the secondary effects of selected climate change impacts on stormwater infrastructure and processes.

<p>Increased temperatures, heat extremes, and drought</p>	<p>Increase in rainfall and inland flooding</p>
<ul style="list-style-type: none"> <li>• Potential risk of undermining the temperature regime of temperature-sensitive stormwater ponds and receiving waters, resulting in a decrease in water quality.</li> <li>• Increased corrosion in stormwater drains due to a combination of higher temperatures, increased strengths, longer retention times, and stranding of solids.</li> <li>• Increased shrinking soils increasing the potential for cracking, increased infiltration and exfiltration of water mains and sewers, which in turn exacerbates treatment and groundwater or storm water contamination.</li> </ul>	<ul style="list-style-type: none"> <li>• Increased risk of flooding due to pressure on stormwater systems.</li> <li>• Increased risk of litter entering the stormwater systems.</li> <li>• Increased risk of damage and failure of stormwater systems due to overloading during floods and intense rainfall events.</li> <li>• Failure of stormwater treatment devices during high flow events leading to by-pass and / or flushing of contaminated water.</li> <li>• High wet-weather hydraulic loads and bottle-necks in stormwater and networks due to inflow and sewer infiltration, leading to local inundation and overflows of untreated wastewater.</li> <li>• Increased rainfall causes soil erosion thus damaging underground stormwater systems.</li> <li>• Increased surface and stream erosion causing deposition of sediments in receiving environments.</li> <li>• Stream morphology for undeveloped, developing and fully developed urban areas may change, hence affecting existing outfall structures and potential stormwater pond locations.</li> </ul>

**Solid waste**

Human settlements generate massive amounts of solid waste that needs to be managed effectively so as not to cause air, water, and soil pollution. As cities grow and need more land, suitable collection and disposal sites can be difficult to acquire and develop. Most households in South Africa (64% in 2015) receive a waste removal service at least once a week, but there are still households that rely on their own or communal rubbish dump sites. Illegal dumping and littering are problems in most municipalities resulting in solid waste often accumulating in waterways and areas otherwise intended for water run-off and flood control. These conditions make municipalities vulnerable to flooding, contamination of water resources, adverse health

effects and rehabilitation costs that may overwhelm the resilience of cities. The table below outlines the secondary effects of selected climate change impacts on the solid waste sector.

Increased temperatures and heat extremes	Increase in rainfall and inland flooding
<ul style="list-style-type: none"> <li>• Increased risk of combustion at open waste disposal sites and illegal dumps, and increase in explosion risk associated with methane gas.</li> <li>• Increased rate of decay of putrescible waste resulting in increased odour, breeding of flies, and attracting of vermin.</li> <li>• Increased health and safety concern regarding heat stroke to staff collecting waste.</li> <li>• Increased risk of landfill site instability and failure due to changes in consumption patterns with increased waste creation (i.e., glass, plastic and paper cups).</li> </ul>	<ul style="list-style-type: none"> <li>• Increased risk of flooding due to pressure on stormwater and leachate management systems at landfills.</li> <li>• Increased demand for capacity to cope with large volumes of waste generated by flood events.</li> <li>• Increase in soil saturation causing decreased stability of slopes and landfills linings (if clay or soil based) at waste management facilities.</li> <li>• Inundation of waste releasing contaminants to waterways, pathways and low elevation zones.</li> <li>• Potential loss of value and degradation of paper and cardboard for recycling due to increased moisture content.</li> <li>• Increased flooding causing the risk of localised disruption of waste collection rounds.</li> <li>• Flooding in areas with untreated, dumped waste causing the risk of groundwater contamination.</li> <li>• Increased flooding causing the risk of litter entering the storm water systems.</li> </ul>

### Sanitation

Sanitation and wastewater management poses several operational challenges to governments and settlements. Managing water resources involves contributions from various stakeholders at different points in the value chain. The sanitation value chain comprises eight broadly defined stages, as follows: collection/containment; storage; transport; treatment; distribution; wastewater treatment; and discharge. Re-use of wastewater is becoming more acceptable and feasible because of increasing water shortages, improved purification technology and decreasing treatment costs. A water reuse strategy that is forward thinking over ten to twenty years needs to take these possible changes into account. The direct re-use of treated wastewater can pose a risk to public health and safety and thus must be managed carefully and be subject to water quality management and control. Advanced treatment technologies, sufficient operating capacity and proper monitoring of all processes, and quality of potable water

produced is essential. The table below outlines the cascading effects of selected climate change impacts on the sanitation sector.

Increased temperatures and heat extremes, as well as drought and decreased rainfall	Increase in rainfall and inland flooding
<ul style="list-style-type: none"> <li>• Increased heat waves, accompanied by dry weather, can exacerbate already stressed water supply systems leading to competition between sectors for water services; affecting sanitation.</li> <li>• Decrease in water supply for sanitation through decrease in available water to flush sewage systems adequately.</li> <li>• Declining annual rainfall threatening the viability of water-borne sanitation systems, and the capacity of surface water to dilute, attenuate and remove pollution.</li> <li>• Sewers are structurally vulnerable to drying, hence shrinking soils increase the potential for cracking, increased infiltration and exfiltration, which in turn exacerbates treatment and groundwater or storm water contamination.</li> <li>• Increased corrosion in sewers due to a combination of higher temperatures, increased strengths, longer retention times, and stranding of solids.</li> </ul>	<ul style="list-style-type: none"> <li>• Increased wet-weather hydraulic loads and bottlenecks in stormwater and sanitary sewer networks due to inflow and sewer infiltration, causing local inundation and overflows of untreated wastewater.</li> <li>• Increased rainfall and heavy rainfall events increasing the washing of faecal matter into water sources due to flooding of wastewater treatment works.</li> <li>• Increased risk of flooding resulting in both infrastructure damage and contamination of surface and groundwater supplies.</li> <li>• Increased groundwater levels due to flooding, putting at risk sewage treatment plants (which are often positioned on low-lying ground as sewerage systems rely on gravity).</li> <li>• Increased vulnerability of sewerage pipe systems due to their size and complexity, and their exposure to multiple flood damage threats from source, through treatment, to delivery.</li> <li>• Increased vulnerability of pit toilets (widely used in rural areas) due to flooding, causing serious environmental contamination.</li> <li>• Increase in groundwater recharge and groundwater levels causing flooding of subsurface infrastructure such as pit toilets or septic tanks.</li> </ul>

## Energy

South Africa's energy mix is primarily dominated by the use of fossil fuels to derive grid supplied electricity and imported crude oil and petroleum products. Regarding access to energy within our human settlements, grid-supplied electricity is transmitted from power stations to substations to settlements typically through overhead powerlines. Electricity supply is not equally

distributed within the country with many people within informal settlements still not connected to the electricity grid. Many thus rely on the combustion of fuels within or near their homes to meet their cooking, heating, and lighting needs. Electricity infrastructure is exposed to weather and climate and is vulnerable to the effects of climate change. Variations in temperature (hotter and colder days) will increase the demand for energy for both cooling and heating within homes and buildings, as will urban growth. Thus, both the electricity supply and demand of a settlement are likely to be impacted by climate change. The table below outlines the cascading effects of selected climate change impacts on the energy sector.

Increased temperatures and heat extremes	Increase in rainfall and inland flooding
<ul style="list-style-type: none"> <li>• Increased heat causing expansion of overhead cables, and cable sag. Sagging below a certain amount can result in a reduction in the amount of electricity transmitted.</li> <li>• Increased heat stress on electricity transmission networks (overhead cables).</li> <li>• Increase in heat island effect increasing energy demand for cooling, leading to grid stress.</li> <li>• Increased threat of wildfires causing widespread damage to infrastructure and causing disruptions to service provision.</li> </ul>	<ul style="list-style-type: none"> <li>• Increase in flooding causing damage to electricity transmission and distribution infrastructure, poles, lines and sub-stations.</li> <li>• Increase in frequency and cost of maintenance of concrete structures due to frequent and intense rainfall and flooding events.</li> <li>• Increased repair events increasing stress put on service crews and resulting in delays to power restoration.</li> </ul>

### Information and communication technology

Information and communications technology (ICT), or telecommunications, plays a critical role in society and is central to the operations of every industry and sector, and society relies on it for social and leisure purposes as well as work. Climate change impacts that are likely to affect ICT infrastructure in the City of Polokwane's settlements include increased warming and precipitation, extreme weather events, as well as strong winds. These weather-related impacts are expected to worsen due to ongoing climate variability and climate change. Compared to 'heavy' infrastructure sectors like energy, water or transportation, the ICT sector has smaller infrastructure and shorter lifetimes, reliance on a combined network instead of individual structures, redundancy of service and infrastructure and service providers, and fast-paced technological change and innovation. While technologies in the ICT sector in the future may converge towards wireless technologies and reduce dependence on current infrastructure, this will not negate the need for infrastructure altogether, for example, there will still be a requirement for equipment such as mobile or fixed wireless towers to operate this technology. The table below outlines the cascading effects of selected climate change impacts on the ICT sector.

Increased temperatures and heat extremes	Increase in rainfall and inland flooding
<ul style="list-style-type: none"> <li>• Increased weathering and deterioration of infrastructure resulting in increased maintenance and repair costs.</li> <li>• Heat stress causing structural damage to infrastructure.</li> <li>• Increased energy demands during heatwaves resulting in power outages which can impact on delivery of telecommunications services.</li> <li>• Increases in temperature and higher frequency, duration, and intensity of heat waves increasing the risk of overheating in data centres, exchanges, and base stations, which can result in increased failure rates of equipment.</li> <li>• Increased mean temperature increasing operating temperature of network equipment which may cause malfunctions if it surpasses design limits.</li> <li>• Decreased precipitation leading to land subsidence and heave, reducing the stability of telecommunications infrastructure above and below ground (foundations and tower structures).</li> </ul>	<ul style="list-style-type: none"> <li>• Increased risk of flooding of low-lying infrastructure, access holes and underground facilities.</li> <li>• Increases in storm frequency or intensity increasing the risk of damage to aboveground transmission infrastructure and impacting on telecommunications service delivery.</li> <li>• Increases in storm frequency leading to more lightning strikes, consequently damaging transmitters and overhead cables, causing power outages.</li> <li>• Increased cost of insurance for infrastructure in areas with repeated incidents of flooding, as well as withdrawal of risk coverage in vulnerable areas by private insurers.</li> <li>• Road closures due to flooding thus inhibiting service and/or restoration efforts.</li> </ul>

**Transport and mobility**

Within settlements, transport networks comprise of nodes (e.g., buildings and public transport stops and stations) and various connector links (e.g., walkways, roads, bridges, railways, tunnels, and waterways). Apart from being a large asset base in themselves, these networks are indispensable conduits for the movement of people and goods for social, economic, political, health and recreational purposes. Within the context of climate change, therefore, climate resilient transport networks are necessary to ensure unimpeded functioning of society. Vulnerability of transport networks to climate change depends on infrastructure age, its materials, construction practices, design features, and maintenance history. Societal level of risk to infrastructure failure is dependent on individual functions of different parts of the transport network. Therefore, spatial differentiation should be an integral component of adaptation strategies. Disruption to transport networks due to climatic extreme events may lead to social exclusion, trade interruption, and consequently social disorder. It is imperative, therefore, that the design and in-situ upgrading of transport networks and their operations be responsive to threats posed by climate change, especially in high-risk areas. It is equally important to ensure transport networks do not add to landscape vulnerability – for example



increasing erosion of steep slopes, landslides or increasing vulnerability of natural habitats to fragmentation and overharvesting. The table below outlines the cascading effects of selected climate change impacts on the transport sector.

Increased temperatures and heat extremes	Increase in rainfall and inland flooding
<ul style="list-style-type: none"> <li>• Increased rate of infrastructure deterioration leading to pavement failure including cracking, rutting, potholes, flushing, and stripping.</li> <li>• Increased stress on bridges, particularly expansion joints, through thermal expansion and increased movement.</li> <li>• Corrosion of steel reinforcing in concrete structures due to increase in surface salt levels in some locations.</li> <li>• Increased infrastructure maintenance cost for road repair and reconstruction work, causing traffic delays and emergency service response delays.</li> <li>• Increased frequency and intensity of wildfires leading to more road closures.</li> <li>• Increased vehicle accidents, due to low pavement adhesion, leading to higher rates of transport-related fatalities.</li> </ul>	<ul style="list-style-type: none"> <li>• Increased rate of infrastructure deterioration, especially in areas with poor infrastructure maintenance history.</li> <li>• Temporary and permanent flooding of road, rail, port and airport infrastructure.</li> <li>• Structural integrity of roads, bridges and tunnels could be compromised by higher soil moisture levels.</li> <li>• Potential destruction of bridges and culverts.</li> <li>• Erosion of embankments and road bases leading to undermining of roads or railways.</li> <li>• Increased risk of landslides, slope failures, road washouts and closures.</li> <li>• Undermining of bridge structures (scouring).</li> <li>• Closure of roadways and tunnels leading to traffic delays.</li> <li>• Transportation system disruptions, impacts to traffic signalling and low water crossings.</li> <li>• Increased weather-related accidents.</li> </ul>

### Human health

Settlements are faced with a variety of challenges, which may include rapid unplanned urbanization, climate-related pressures such as floods and heat waves, as well as unequal economic growth between different communities. This affects the health and development status within settlements. Climate-health linkages are complex and multi-faceted, and it can confidently be stated that climate change will amplify some of the existing health threats that are already faced by communities. Certain people and communities are especially vulnerable, including children, the elderly, the sick and the poor. Natural disasters (e.g., floods, drought, fires) can have immediate and long-term impacts on health. Poor emergency service delivery immediately after a disaster can impact health, and damage to services such as water reticulation can have longer-lasting impacts on public health. Natural disasters can also create a conducive environment for the occurrence of mental health problems. The table below outlines

the cascading effects of selected climate change impacts on the community/human health sector.

Increased temperatures and heat extremes	Drought and decreased rainfall	Increase in rainfall and inland flooding
<ul style="list-style-type: none"> <li>• More exposure to high temperatures causing increased health risks including heat strokes.</li> <li>• Heat waves increase threat of cardiovascular, kidney, and respiratory disorders.</li> <li>• Increase in fire danger days causing increased loss of life and damage to health infrastructure.</li> <li>• Wildfire smoke significantly reducing air quality, both locally and in areas downwind of fires. Smoke exposure increases respiratory and cardiovascular hospitalizations; emergency department visits; medication dispensations for asthma, bronchitis, chest pain, chronic obstructive pulmonary disease, and respiratory infections; and medical visits for lung illnesses.</li> <li>• Increased emissions in biogenic volatile organic compounds from vegetation causing increases in air pollution.</li> <li>• Increase in evaporative emissions from cars contributing to exposure</li> </ul>	<ul style="list-style-type: none"> <li>• Decreased soil moisture potentially creating more wind-blown dust which has negative impacts on air quality.</li> <li>• Increase in water-washed diseases and diarrhoeal diseases due to inadequate water availability.</li> <li>• Decreased precipitation causing changes in salinity of water, resulting in an increase in algal blooms which can likely lead to increases in food- and waterborne exposures.</li> <li>• Increase in stagnant air, decreasing air quality.</li> </ul>	<ul style="list-style-type: none"> <li>• Wetter climate combined with increased temperatures may have negative health impacts as many diarrheal diseases vary seasonally, typically peaking during the rainy season.</li> <li>• Extreme rainfall and higher temperatures increasing the prevalence of fungi and mould indoors, with increased associated health concerns.</li> <li>• Increased flooding increasing the risk of drinking and wastewater treatment facilities being flooded, meaning that diarrhoeal diseases can be transmitted as wastewater systems overflow or drinking water treatment systems are breached.</li> <li>• Increase in natural disasters (e.g., floods) creating a conducive environment for the occurrence of mental health problems.</li> </ul>

<p>to, and health impacts from, air pollution.</p> <ul style="list-style-type: none"> <li>• Increase in distribution of vector-borne diseases in warmer areas.</li> <li>• Increased water temperatures leading to an increase in algal blooms which can likely lead to increases in food- and waterborne exposures.</li> <li>• Increased temperatures combined with fewer clouds (e.g., from increased subsidence that is projected for parts of South Africa) causing increased exposure to UVR which will have negative impacts on health.</li> <li>• Increased temperatures increasing the reaction between certain pollutants and sunlight and heat, resulting in more severe hazardous smog events.</li> </ul>		
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**Culture and heritage**

Culture refers to the dynamic totality of distinctive spiritual, material, intellectual, emotional and aesthetic features that characterise a society or social group, including its arts, but also intangible aspects such as values, worldviews, ideas and beliefs, and the expression of these in individual and social behaviour, relationships, organisational and societal forms, and in economic, political, educational and judicial systems. The variance between these groups, known as cultural diversity, is illustrated by the many ways in which the cultures of groups and societies find expression. Within an urban context, culture may manifest itself spatially through heritage sites and resources. These areas are vulnerable to the effects of climate change and require particular management and sensitivity within planning. This heritage may include wildlife and scenic parks, sites of scientific or historic importance, national monuments, historic buildings, works of art, literature and music, oral traditions and museum collections together with their

documentation. Due to the sensitive nature of culture and heritage, the physical and cultural value associated with these sites and resources is vulnerable to any aesthetic and functional changes caused by climate change. Potential physical impacts may have indirect social consequences. The table below outlines the cascading effects of selected climate change impacts on the City's heritage and cultural resources.

Increased temperatures and heat extremes	Drought and decreased rainfall	Increase in rainfall and inland flooding
<ul style="list-style-type: none"> <li>• Increased temperature having significant impacts on the comfort levels of built heritage resources, resulting in the building no longer being fit-for-purpose.</li> <li>• Increased demand for additional heating and cooling resulting in the installation of heating, ventilation and air-conditioning systems with potential negative consequences on the heritage value.</li> <li>• Increased heat stress potentially impacting on the materials and structural integrity of heritage resources.</li> <li>• Migration of several plant species due to changing climate patterns, posing a threat to the conservation of biodiversity hotspots, and potentially altering heritage places.</li> <li>• Increase in veld and forest fires raising the threat of fire to all heritage resources, natural and built, as well as posing health risks to</li> </ul>	<ul style="list-style-type: none"> <li>• Decreased rainfall impacting negatively on ground moisture levels and thus the geological conditions of sensitive heritage resources. Drying out clays, for example, will shrink and potentially undermine founding conditions.</li> </ul>	<ul style="list-style-type: none"> <li>• Increased rainfall in areas with clay soils resulting in swelling which poses a threat to the structural integrity of heritage resources.</li> <li>• Increased floods and changes in precipitation resulting in increasing vulnerability of archaeological evidence buried underground due to changing stratigraphic integrity of the soils.</li> <li>• Increased threat to materials and structural integrity of heritage resources exposed to higher humidity/precipitation levels.</li> </ul>

heritage resource dwellers from exposure to smoke and ash pollution.		
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