



# GREENBOOK

*adapting settlements for the future*



**MOPANI**

**DISTRICT MUNICIPALITY**

## Mopani District Municipality

Risk Profile Report based on the GreenBook

31 JULY 2023

Report compiled by the CSIR

Funded by the CDRF with Santam as collaborative partner



**CLIMATE & DISASTER  
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# Table of Contents

Table of Contents .....	2
Figures .....	3
Tables .....	5
List of Acronyms and Abbreviations .....	6
Glossary of Terms .....	8
1. Introduction.....	11
1.1. Approach followed.....	12
1.2. Policy framework.....	13
1.3. District Municipal context.....	14
2. Baseline and future climate risk.....	17
2.1. Vulnerability and population change.....	17
2.1.1. Municipal vulnerability.....	17
2.1.2. Settlement vulnerability.....	19
2.1.3. Population growth pressure .....	21
2.2. Climate.....	22
2.2.1. Temperature.....	23
2.2.2. Rainfall.....	25
2.3. Climate Hazards .....	27
2.3.1. Drought.....	27
2.3.2. Heat.....	30
2.3.3. Wildfire.....	35
2.3.4. Flooding.....	37
2.4. Climate impacts on key resources and sectors.....	40
2.4.1. Water resources and supply vulnerability .....	40
2.4.2. Agriculture, forestry, and fisheries .....	46
3. Recommendations.....	50
4. Bibliography.....	53

## Figures

Figure 1: The Value-chain towards the implementation of climate change response and adaptation in municipalities .....	11
Figure 2: The interaction between the various components of risk, indicating the opportunity to reduce risk through adaptation (based on IPCC, 2014 and IPCC, 2021) .....	12
Figure 3: Mopani District Municipality (Municipal Demarcation Board, 2022), with Local Municipalities shaded in different colours .....	16
Figure 4: Settlement-level population growth pressure across Mopani District Municipality....	22
Figure 5: Average annual temperature (°C) for the baseline (°C) for the baseline period 1961-1990 for Mopani District Municipality .....	24
Figure 6: Projected change in average annual temperature (°C) the baseline period (1961 – 1990) to the future period (2021-2050) for Mopani District Municipality, assuming an RCP 8.5 emissions pathway.....	25
Figure 7: Average annual rainfall (mm) for the baseline period 1961-1990 for Mopani District Municipality.....	26
Figure 8: Projected change in average annual rainfall (mm) from the baseline period to the period for the period 2021-2050 for Mopani District Municipality, using an RCP8.5 emissions pathway. ....	27
Figure 9: Projected changes in drought tendencies from the baseline period (1986 – 2005) to the current period (1995 – 2024) for Mopani District Municipality.....	28
Figure 10: Projected changes in drought tendencies from the baseline period (1986 – 2005) to the future period (2015 -2044) for Mopani District Municipality .....	29
Figure 11: Settlement-level drought risk for Mopani District Municipality .....	30
Figure 12: Annual number of baseline annual very hot days across Mopani District Municipality with daily temperature maxim exceeding 35°C .....	31
Figure 13: Projected change in average annual number of very hot days with daily temperature maxima exceeding 35°C from 1961-1990 to 2021-2050 for Mopani District Municipality (RCP8.5) .....	32
Figure 14: Annual number of heatwave days under baseline climatic conditions across Mopani District Municipality .....	33
Figure 15: Heat risk across Mopani District Municipality at settlement level in the 2050s .....	34
Figure 16: The likelihood of wildfire under current climatic conditions across settlements in Mopani District Municipality .....	36
Figure 17: The likelihood of wildfire under future climatic conditions across Mopani District Municipality.....	37
Figure 18: The flood hazard index across Mopani District Municipality under current (baseline) climatic conditions .....	38
Figure 19: Projected change into the future rainfall days across Mopani District Municipality...	39
Figure 20: Flood risk into a climate change future at settlement-level flood risk across Mopani District Municipality. ....	40
Figure 21: Main water source for settlements in the Mopani District Municipality.....	42

Figure 22: Groundwater recharge potential across Mopani District Municipality under current (baseline) climatic conditions.....43

Figure 23: Projected changes in groundwater recharge potential from baseline climatic conditions to the future across Mopani District Municipality .....44

Figure 24: Settlement-level groundwater depletion risk across Mopani District Municipality...45

## Tables

Table 1: Vulnerability indicators across Mopani District Municipality .....	18
Table 2: Settlement population growth pressure across Mopani District Municipality.....	21
Table 3: Current water supply and vulnerability across Mopani District Municipality .....	45

## List of Acronyms and Abbreviations

°C	Degree Celsius
AFF	Agriculture, Forestry, and Fisheries
AR5	Fifth Assessment Report
CABLE	CSIRO Atmosphere Biosphere Land Exchange model
CCAM	Conformal-cubic atmospheric model
CDM	Capricorn District Municipality
CDRF	Climate and Disaster Resilience Fund
CMIP5	Coupled Model Intercomparison Project 5
CoGTA	Department of Cooperative Governance and Traditional Affairs
CRVA	Climate Risk and Vulnerability Assessment
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEA	Department of Environmental Affairs
DM	District Municipality
DRR	Disaster Risk Reduction
DWS	Department of Water and Sanitation
EcVI	Economic Vulnerability Index
EnVI	Environmental Vulnerability Index
GCM	General circulation model
GRiMMS	Groundwater Drought Risk Mapping and Management System
GVA	Gross Value Added
GDP	Gross Domestic Product
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
l/p/d	Litres Per Person Per Day
LM	Local Municipality
MAR	Mean Annual Runoff
MDM	Mopani District Municipality
mm	Millimetre
NDMC	National Disaster Management Centre
PVI	Physical Vulnerability Index
RCP	Representative Concentration Pathways
SCIMAP	Sensitive Catchment Integrated Modelling and Prediction
SDF	Spatial Development Framework
SEVI	Socio-Economic Vulnerability Index
SPI	Standardised Precipitation Index
SPLUMA	Spatial Planning and Land Use Management Act, 2013 (Act No.16 of 2013)
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, 2019).
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).

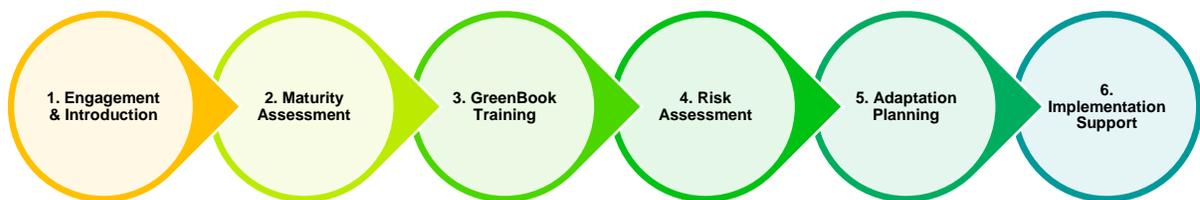
Climate hazards	Climate hazards are a sub-set of natural hazards and a grouping of hydrological, climatological, and meteorological hazards. This includes the spatial extent and frequency of, among others, floods, fires, and extreme weather events such as extreme rainfall and extreme heat. Sometimes 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 draft Climate Change Adaptation Plan, were developed specifically for Mopani District Municipality (MDM), 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 [Green Book I Adapting settlements for the future](#)).

The GreenBook was initially co-funded by the International Development Research Centre (IDRC) and the Council for Scientific and Industrial Research (CSIR), i.e., from 2016-2019, and in partnership with the National Disaster Management Centre (NDMC). With more partners coming on board since 2019 to support further research and development, and the roll-out and uptake of the GreenBook. More recently, Santam, the Climate and Disaster Resilience Fund (CDRF), and the CSIR established the GreenBook Roll-out Initiative to facilitate the uptake of the GreenBook and support resilience-building within local government. The initiative aims to roll out the GreenBook to 32 District Municipalities (DMs) by 2025 by supporting each District’s climate change response and adaptation planning and implementation efforts through the GreenBook. Each of the Districts targeted for support are guided along a value-chain towards the implementation of climate change response and adaptation plans in municipalities (See Figure 1 below). Thus, in fulfillment of steps four and five, each target DM is provided with a draft GreenBook Climate Risk Profile report, as well as a draft Climate Change Adaptation Plan.



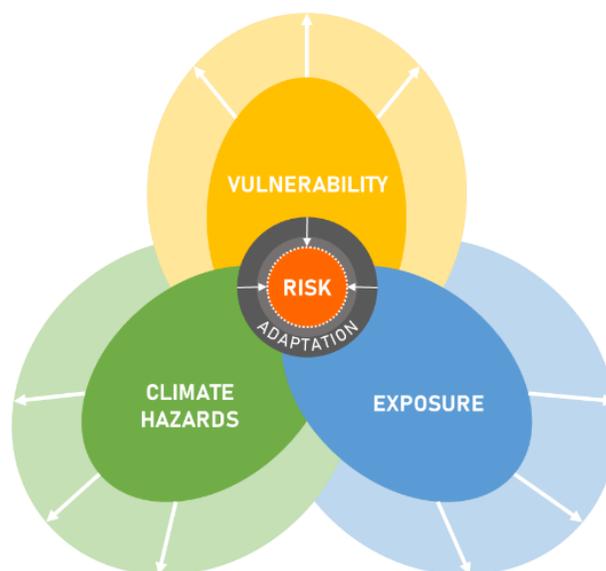
*Figure 1: The Value-chain towards the implementation of climate change response and adaptation in municipalities*

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

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

### 1.1. Approach followed

The approach used in the GreenBook, and the Climate Risk Profile 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 2). “Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, as well as 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 and 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 2: 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 are unpacked. In this Climate Risk Profile report, multiple vulnerability indices are provided on the municipal and settlement level, 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 District and its municipalities.

All information contained in this report is based on the GreenBook, unless otherwise specified. Information and data were derived using GIS analysis and modelling techniques using secondary data and is not based on local surveys. Additional information to this report is available for Local Municipalities through the GreenBook Municipal Risk Profile Tool. Municipalities are encouraged to consider both the information available in this report and on the Municipal Risk Profile tool to understand their risk profile. Access the GreenBook and its various resources and tools here: <https://greenbook.co.za/>

## 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” – 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 Bill also sets out requirements for every district intergovernmental forum to serve as a Municipal Forum on climate change that coordinates climate response actions and activities in its respective municipality.

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. 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.

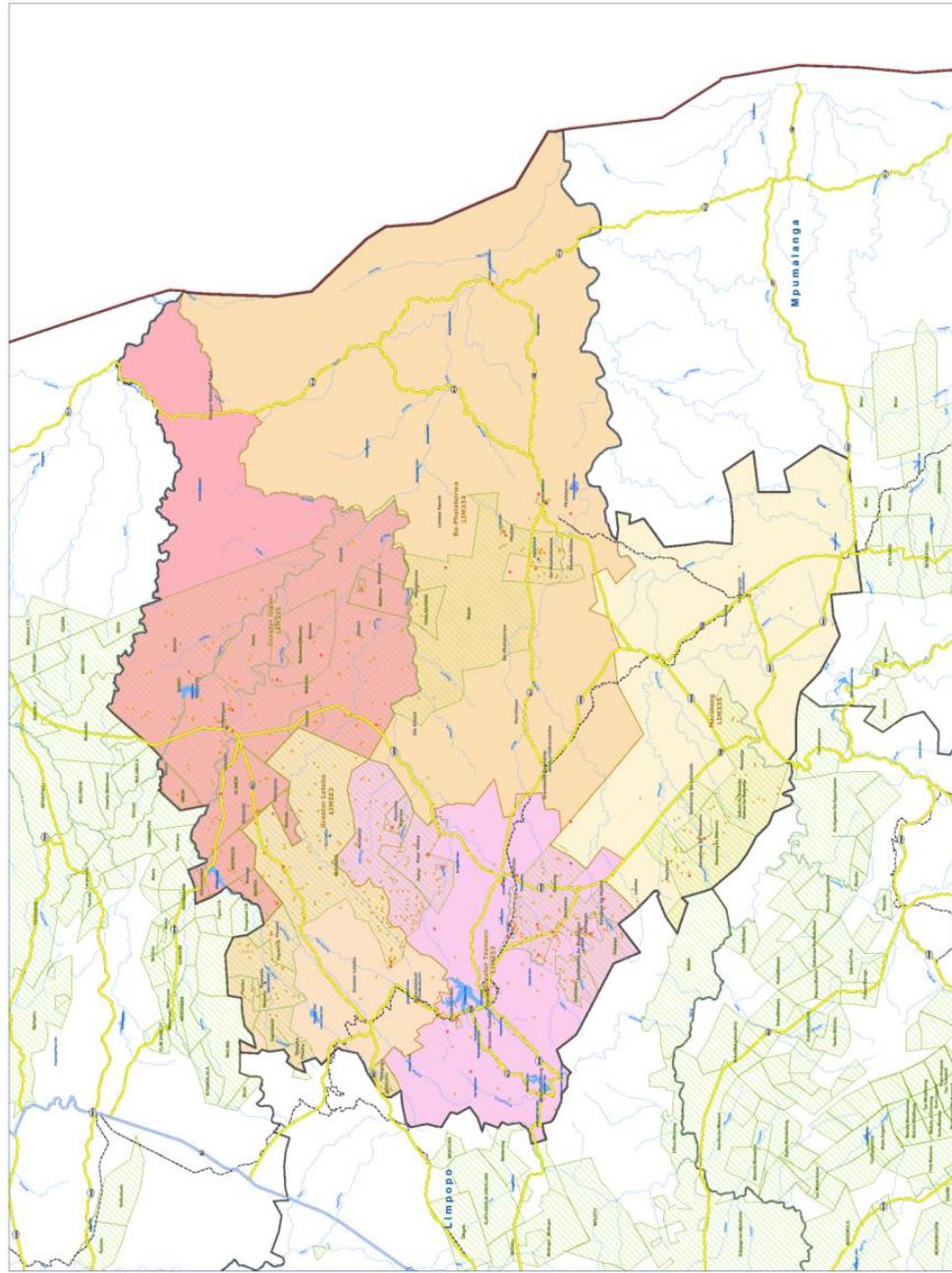
### 1.3. District Municipal context

The Mopani District Municipality (MDM) is situated in the north-eastern part of the Limpopo Province, bordering Mozambique in the east, the Vhembe District Municipality in the north and Mpumalanga province in the south. Its western border is shared with the Capricorn District Municipality. The District spans a total area of 20 011 km<sup>2</sup> and includes portions of the Kruger National Park from Olifants to Tshingwedzi camps (MDM, 2022). The District is named Mopani after the well-known nutritious Mopani worms which are found in abundance in the area. The District consists of five Local Municipalities (LMs), namely, Ba-Phalaborwa LM, Greater Giyani LM, Greater Letaba LM, Greater Tzaneen LM and Maruleng LM. The seat of Mopani is Giyani, and the District is part of the Great Limpopo Transfrontier Park. The Mopani District had a total population of 1 159 185 in 2016 which ranks it 4th out of the five District Municipalities (DMs) in terms of population size in Limpopo. Population size is expected to increase to 1 333 227 by 2050. Most of the District’s population live in rural areas (81 %) while around 14 % are urban dwellers and 5 % are farming based.

The District’s major employing sectors are Farming, Industry, Mining, Trade, Government, Transport, Tourism, Manufacturing, Construction and Energy. The Government Sector is the largest employer in the District and the farming sector, is the second largest employer in Mopani constituting 25,90 % of the employed people. The number of people unemployed as a percentage of the total employable population of the District (287 405) is 39 %. It is however important to note that of the unemployed people in the District, about 60% are women. People with no income in Mopani constitute 42.80 % of the total population (MDM, 2022).

The Mopani District experiences spatially distinct climatic conditions which are also influenced by the extensive topographic variation. This variance in topography and climate dictates the vegetation and land use. The area boasts exceptional biodiversity such as the indigenous Afromontane forests, wetlands, the critically endangered Woodbush Granite Grasslands, as well as endangered species such as Modjadji cycads, Cape Parrot, Pel's Fishing Owl, etc. There are several biodiversity hotspots and conservation areas, as well as numerous game farms and privately owned protected areas, which greatly contribute to tourism opportunities. The area is however also faced with environmental risks and threats that lead to environmental degradation.

# Mopani District Municipality (DC33)



**Municipal Demarcation Board**  
 Tel: (012) 342 2481  
 Fax: (012) 342 2480  
 email: [info@demarcation.org.za](mailto:info@demarcation.org.za)  
 web: [www.demarcation.org.za](http://www.demarcation.org.za)

### Legend

- Main Place
- Airports
- Schools
- Police Stations
- Health Facilities
- District Municipalities
- Local Municipalities
- Traditional Authorities
- Dams
- Rivers
- National Roads
- Main Roads
- Secondary Roads
- Railways

Data supplied by:  
 Statistics South Africa  
 Department: Water Affairs & Forestry  
 Department: Provincial & Local Government  
 Department: Health  
 Department: Safety & Security  
 Department: Education  
 Department: Transport



Figure 3: Mopani District Municipality (Municipal Demarcation Board, 2022), with Local Municipalities shaded in different colours

## 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 across the District. Current as well as future exposure to drought, heat, wildfire, and flooding is set out. The impact of climate on key resources such as water and agriculture are also discussed for the municipalities in the District. Together this information provides an overview of current and future climate risk across the Mopani District 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 Mopani District, its Local Municipalities, and 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 District 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 each of the local municipalities in Mopani District.

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 municipalities that house 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, as well as the inequality present in the municipality. The higher the economic vulnerability, the more susceptible these municipalities are 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.

Each municipality in the Mopani District are provided 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 and Economic Vulnerability

*Table 1: Vulnerability indicators across Mopani District Municipality*

LOCAL MUNICIPALITY	SEVI 1996	SEV 2011	Trend	EcVI 1996	EcVI 2011	Trend	PVI	Trend	EnVI	Trend
Ba-Phalaborwa	4.37	3.83	↘	7.54	10.0	↗	4.52	N/A	4.48	N/A
Greater Giyani	5.82	5.95	↗	4.34	6.46	↗	6.09	N/A	3.03	N/A
Greater Letaba	5.77	5.78	↗	4.98	7.06	↗	5.60	N/A	3.96	N/A
Greater Tzaneen	5.06	5.04	↘	5.67	8.14	↗	6.19	N/A	6.64	N/A
Maruleng	5.66	5.54	↘	7.92	9.89	↗	4.79	N/A	4.97	N/A

Socio-economic vulnerability has increased (worsened) in the Local Municipalities of Greater Giyani and Greater Letaba while economic vulnerability has increased across all LMs between 1996 and 2011. Ba-Phalaborwa LM has the highest economic vulnerability in the District and the highest in the Province as well. It has experienced the most significant population growth (14.90 %) of all LMs (MDM, 2022). The mining sector is the largest within MDM, accounting for 35 % of the total GVA (Gross Value Added), with mining concentrated in the Ba-Phalaborwa region. The sector that contributes the second most to the GVA of the DM is the community services sector at 20 %, followed by the finance and trade sectors with 13%. In 2019, there were 628 941 people living in poverty, using the upper poverty line definition, across MDM - this is higher than the 674 588 in 2009.

### 2.1.2. Settlement vulnerability

The unique set of indicators outlined below highlight the multi-dimensional vulnerabilities of the settlements within the Mopani District and its Local Municipalities, with regards to six composite indicators. This enables the investigation of the relative vulnerabilities of settlements within the District.

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 were experiencing growth pressures on top of the other dimensional vulnerabilities up to 2011.

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 ratio 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 each Local Municipality within the DM follows below

### Ba-Phalaborwa

This LM is bordered in the east by Mozambique, includes a portion of Kruger National Park and forms part of the Great Limpopo Trans-Frontier Park. The town of Phalaborwa and the nearby Namakgale/Lulekani towns and surrounding villages constitute the major population concentration areas in Ba-Phalaborwa. The settlements of Namakgale and Gravelotte have been identified as District growth points in the area. Gravelotte is facing significant growth pressure as well as very high service access vulnerability. Namakgale has very high environmental vulnerability and significant economic pressures. The popular tourist resort of Die Eiland is nearby the rural towns of Seloane/Nondweni. Nondweni has poor regional connectivity and high environmental and socio-economic pressures.

### Greater Giyani

Greater Giyani LM is located in the north of MDM, with Giyani as its only town. Giyani is the largest centre of population concentration, employment opportunities, shopping and recreational facilities in the LM. Other smaller settlements include Xawela, Ntsanwisi and KaNkuri. Xawela has extremely high environmental, economic and regional connectivity vulnerability. A large number of the sparsely located settlements are traditional villages.

### Greater Letaba

Greater Letaba LM is the smallest Municipality in the District in terms of land area. It is primarily rural/non-urban in nature, and the major settlements are Modjadjiskloof, Ga-Kgapane and Senwamokgope. Both the towns of Modjadjiskloof and Senwamokgope face extremely high growth pressure. Senwamokgope also has very high regional connectivity vulnerability combined with a socio-economically vulnerable population.

### Greater Tzaneen

The major settlements in this LM are Tzaneen, Nkowankowa, Lenyenye, Letsitele, and Haenertsburg. Traditional rural villages make up around 81 % of this Municipality. These villages experience very high socio-economic and economic vulnerability. Tzaneen, being the economic hub of the Municipality, experiences very high growth pressures. Haenertsburg has the highest regional connectivity vulnerability.

### Maruleng

The Maruleng LM is situated in the south of MDM. The major settlements in this Municipality are Hoedspruit, Kampersrus and Madeira. Hoedspruit experiences the highest growth pressures, while Madeira has very low access to services. Traditional rural villages make up around 87 % of this Municipality. These villages experience very high socio-economic, economic and environmental vulnerability.

### 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 (Table 2) assumes that the peak of population influx from African and neighbouring 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: Settlement population growth pressure across Mopani District Municipality*

Population per municipality	2011	Medium Growth Scenario	
		2030	2050
Ba-Phalaborwa	150 620	213 627	268 626
Greater Giyani	244 189	275 587	274 627
Greater Letaba	212 601	221 284	202 437
Greater Tzaneen	389 124	461 270	484 889
Maruleng	95 766	105 541	102 648
Mopani DM Total	1 092 300	1 277 309	1 333 227

The District's population will increase by 23.6 % between 2011 and 2050, under a medium growth scenario. Most of this growth will take place in the settlements within Ba-Phalaborwa LM, which will experience a growth of 78 % in its population. Greater Letaba LM will possibly see a decline in population between 2011 and 2050 for most of the settlements. Figure 4 depicts the growth pressures that the settlements across the District will likely experience. The settlements that will see extreme growth pressures up to 2050, include Phalaborwa, Namakgale and Majeje.

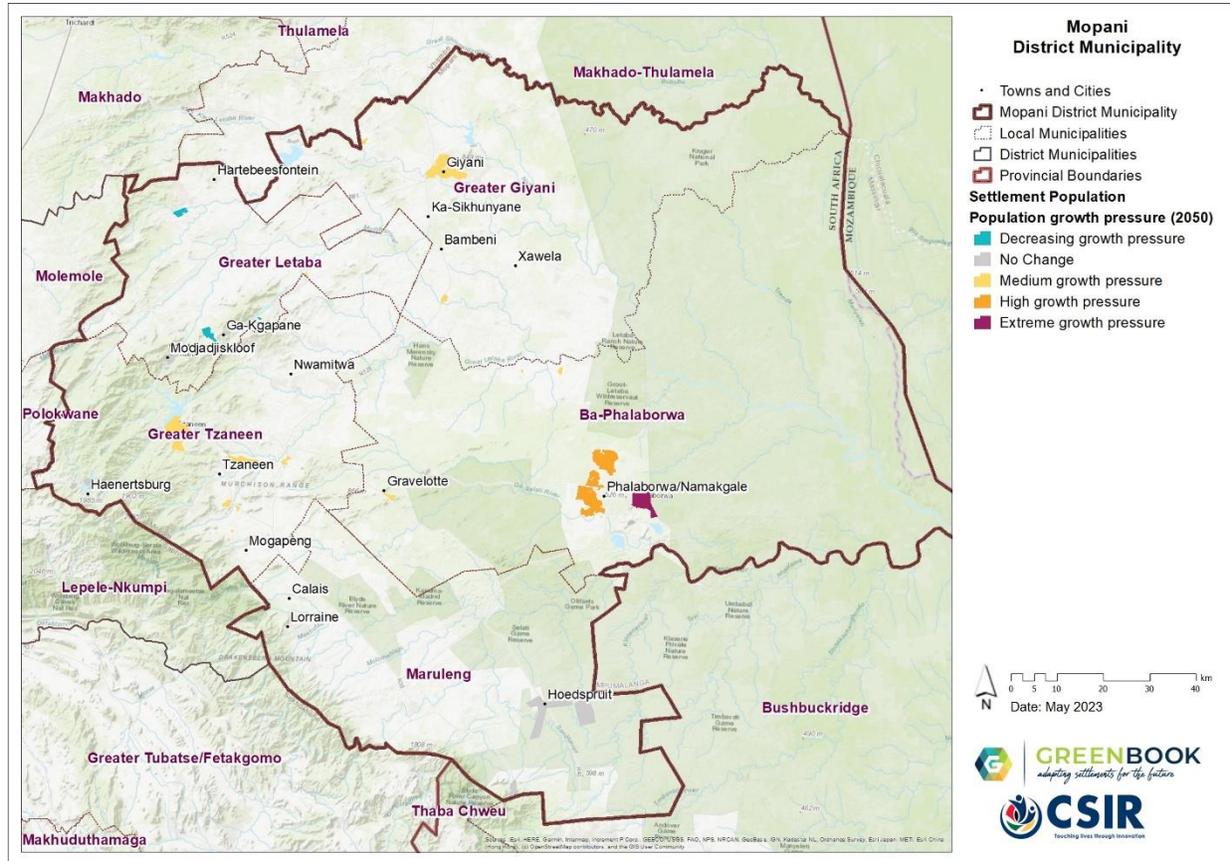


Figure 4: Settlement-level population growth pressure across Mopani District Municipality

## 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 Models (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 (CMIP5) and 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 a number of 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 6 downscaled GCMs is shown in this case).
- b) The projected changes in the variables are subsequently shown, for the time- period 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 mitigation scenario.

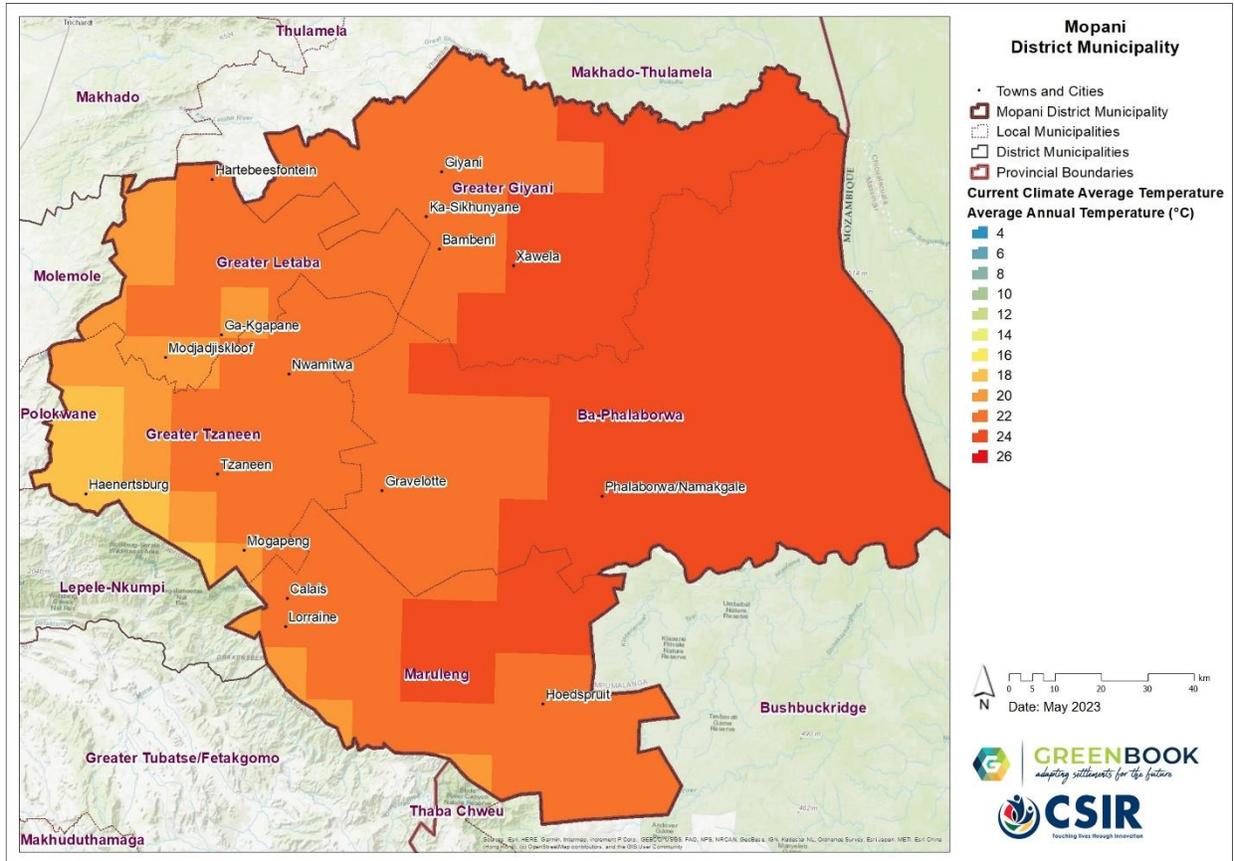


Figure 5: Average annual temperature (°C) for the baseline period 1961-1990 for Mopani District Municipality

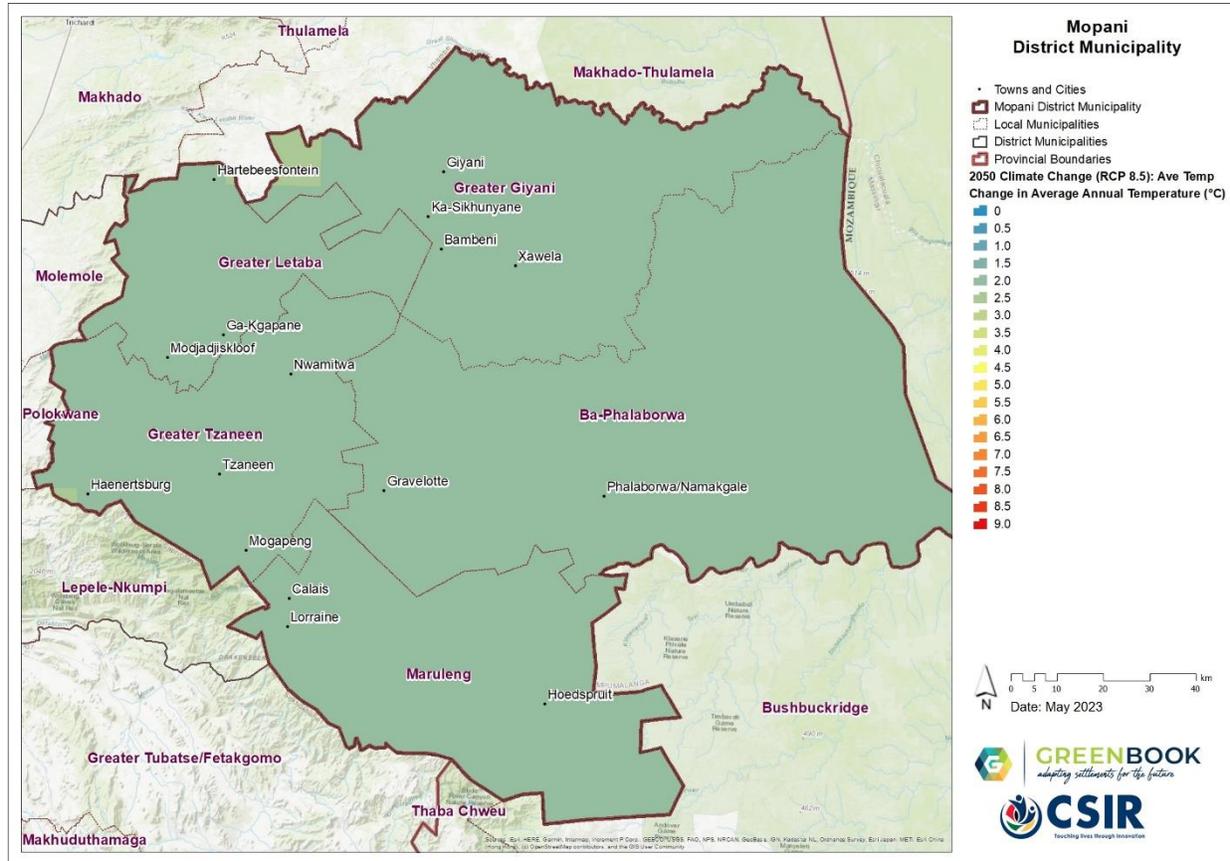


Figure 6: Projected change in average annual temperature (°C) the baseline period (1961 – 1990) to the future period (2021–2050) for Mopani District Municipality, assuming an RCP 8.5 emissions pathway

The District experiences current average annual temperatures of between 20 and 24 °C, with higher averages found in the east towards Mozambique, within the municipality of Ba-Phalaborwa. The projections show approximate average annual temperature increases of between 2.0 °C and 2.5 °C across the District by 2050, under a low mitigation scenario. There is not significant spatial variation in the increase in temperature across the DM.

### 2.2.2. Rainfall

The multiple GCMs used to simulate average annual rainfall (depicted in mm) for the baseline (current) period of 1961–1990, and the projected change for period baseline to the 2021–2050 under a RCP8.5 emissions mitigation scenario.

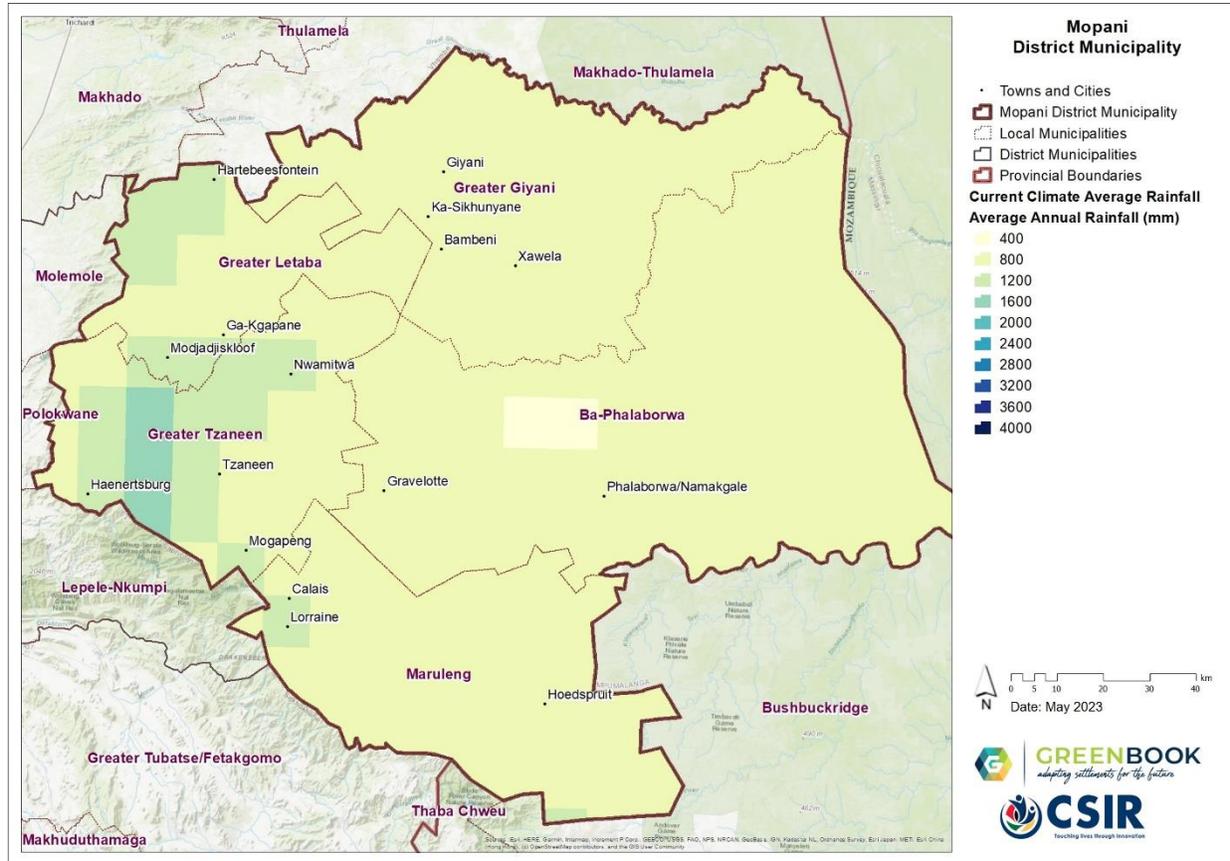


Figure 7: Average annual rainfall (mm) for the baseline period 1961-1990 for Mopani District Municipality

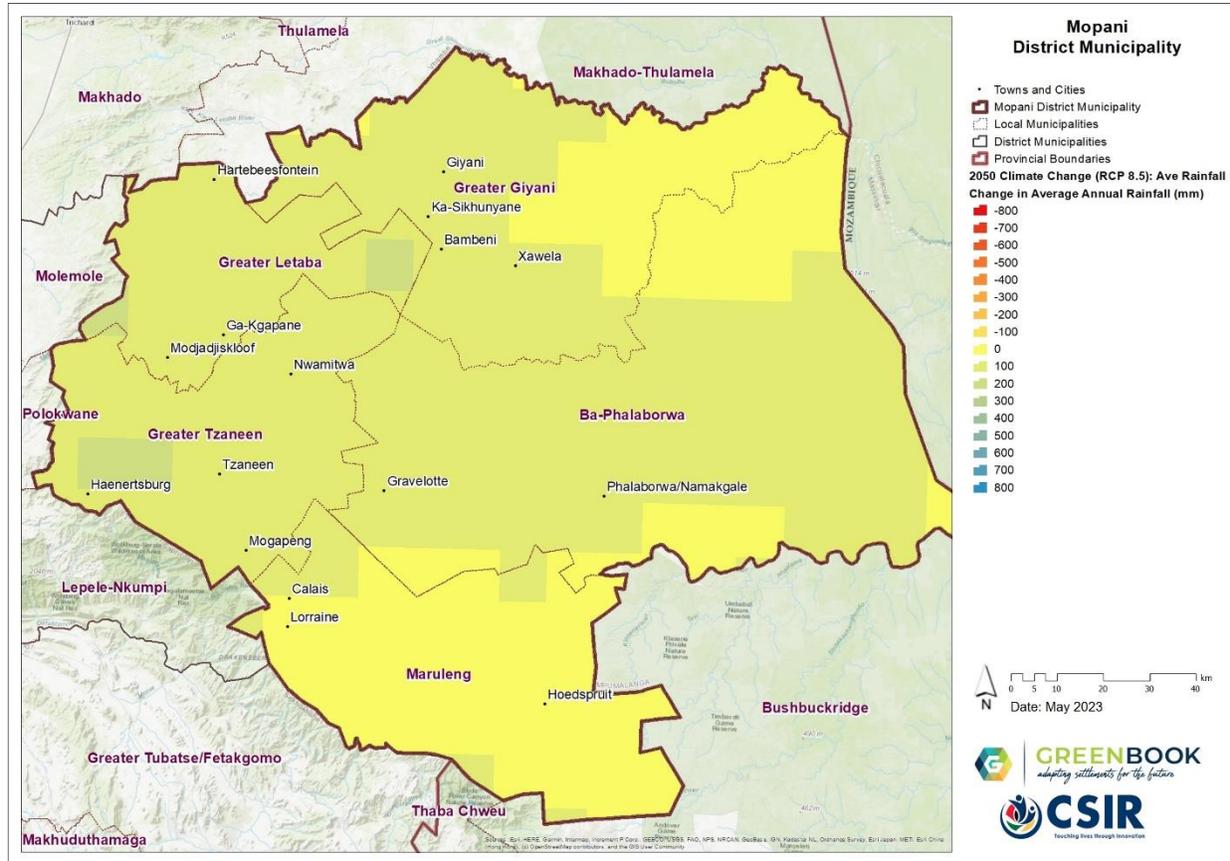


Figure 8: Projected change in average annual rainfall (mm) from the baseline period to the period for the period 2021-2050 for Mopani District Municipality, using an RCP8.5 emissions pathway.

The District experiences current average annual rainfall of between 450 mm in the east, and more than 1200 mm over the higher lying areas in the western parts of Greater Tzaneen. The projections show a change in average annual rainfall of between 50 mm less and 130 mm more across the DM by 2050, under a low mitigation scenario. Some decreases in rainfall are expected in areas of Ba-Phalaborwa and Maruleng, while the rest of the District will generally experience an increase in average annual rainfall.

**2.3. Climate Hazards**

This section showcases information with regards to Mopani District Municipality's' exposure to climate-related hazards.

**2.3.1. Drought**

The southern African region (particularly 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 primarily uses 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 (scale). 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  $0.5$ ).

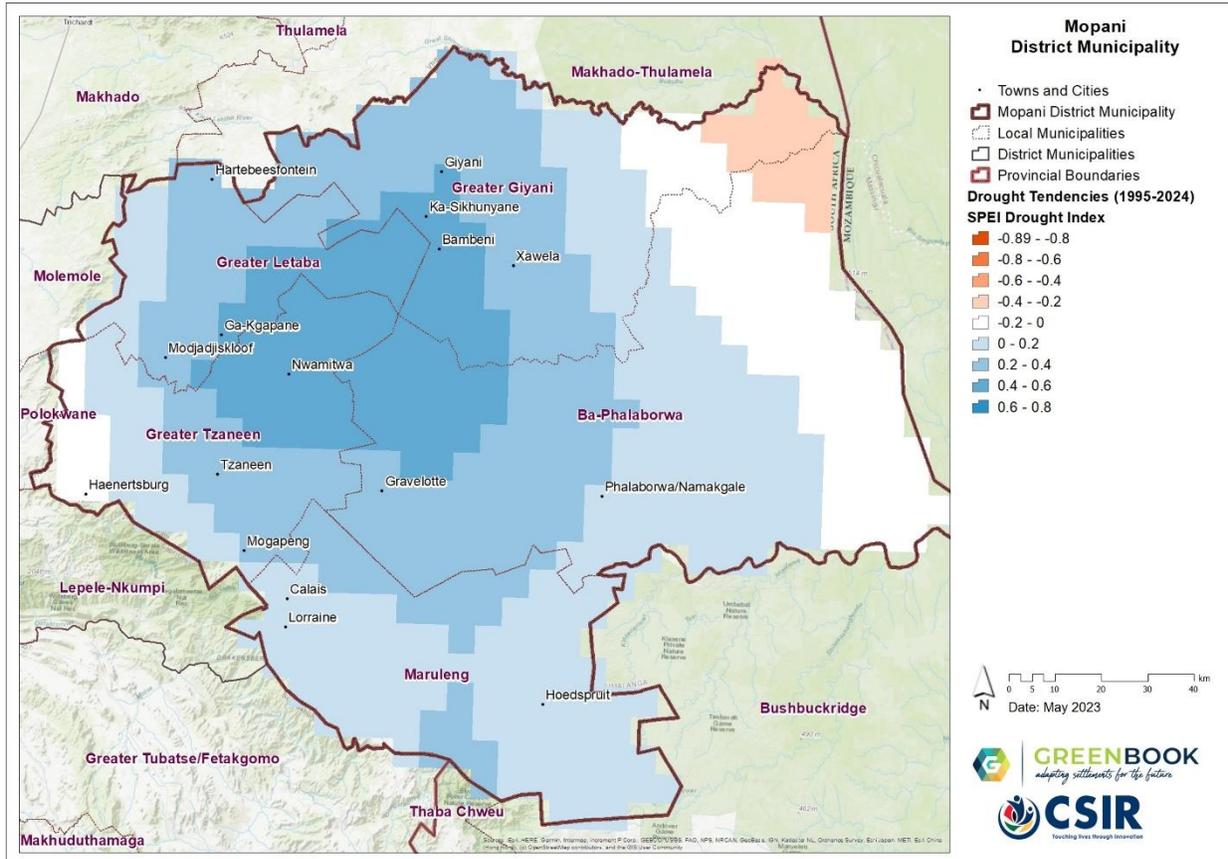


Figure 9: Projected changes in drought tendencies from the baseline period (1986 – 2005) to the current period (1995 – 2024) for Mopani District Municipality

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 a low mitigation scenario (RCP 8.5). A negative value is indicative of an increase in drought tendencies per 10 years (more frequent than the observed baseline).

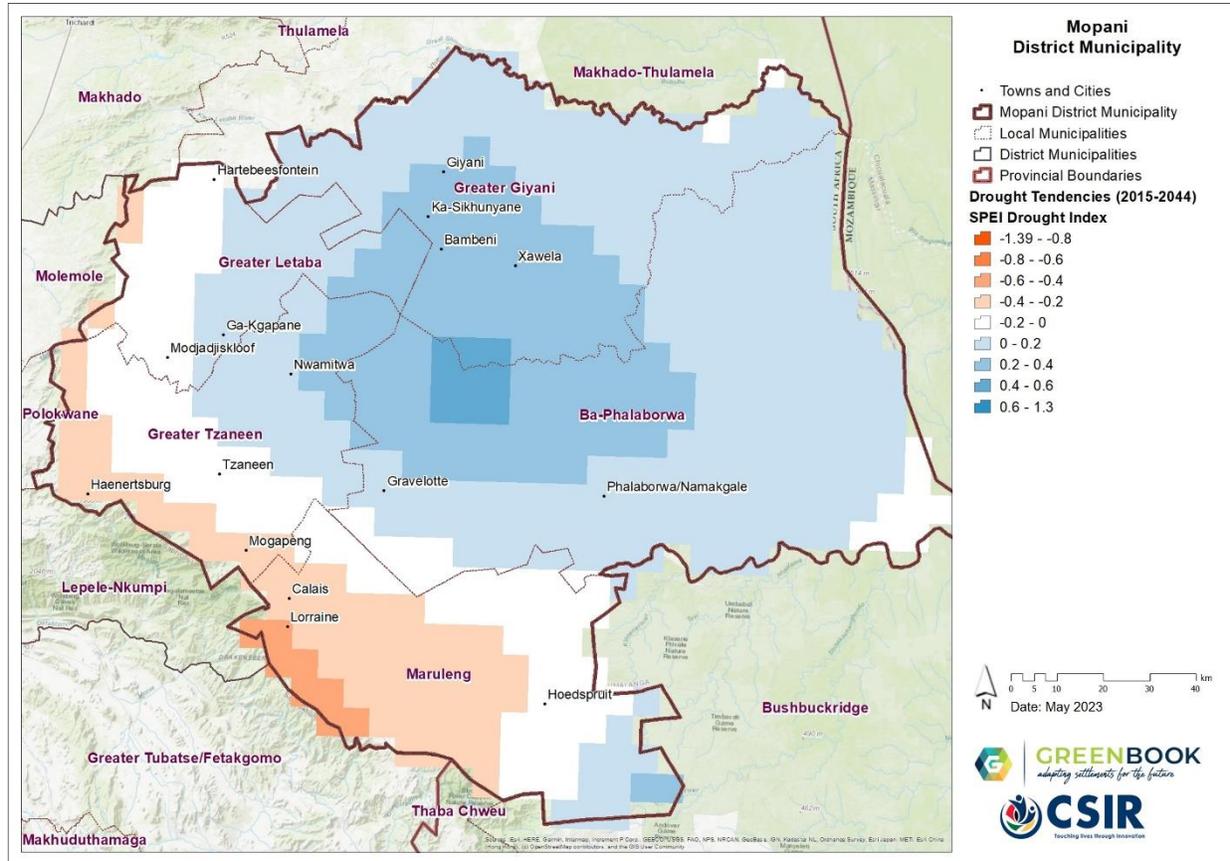


Figure 10: Projected changes in drought tendencies from the baseline period (1986 – 2005) to the future period (2015 –2044) for Mopani District Municipality

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) with a positive value indicative of a decrease in drought tendencies.

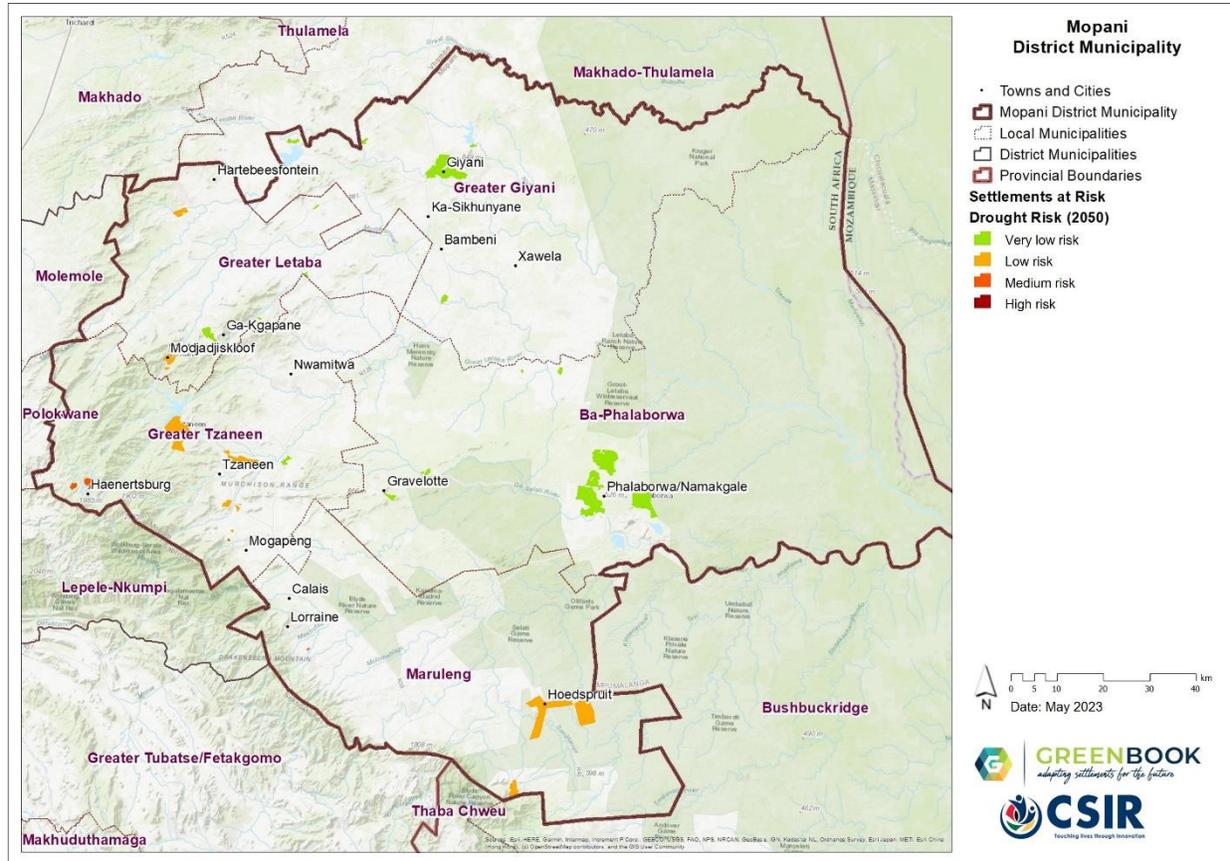


Figure 11: Settlement-level drought risk for Mopani District Municipality

The SPEI index indicates a high tendency for drought in the far north-eastern part of the District, under current climate conditions. However, in future, drought tendencies will decrease over the eastern part, and increase over the western parts of Greater Tzaneen and Maruleng. The settlement of Haenertsburg in Greater Tzaneen will face a medium drought risk towards 2050.

### 2.3.2. Heat

The GCMs were used to simulate bias-corrected, annual average number of very hot days, defined as number of days when the maximum temperature exceeds 35°C GCM grid point for the baseline (current) period of 1961–1990, and the projected change for period 2021–2050.

The annual heatwave days map (Figure 13) under baseline climatic conditions 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, and that for a period of at least three consecutive days.

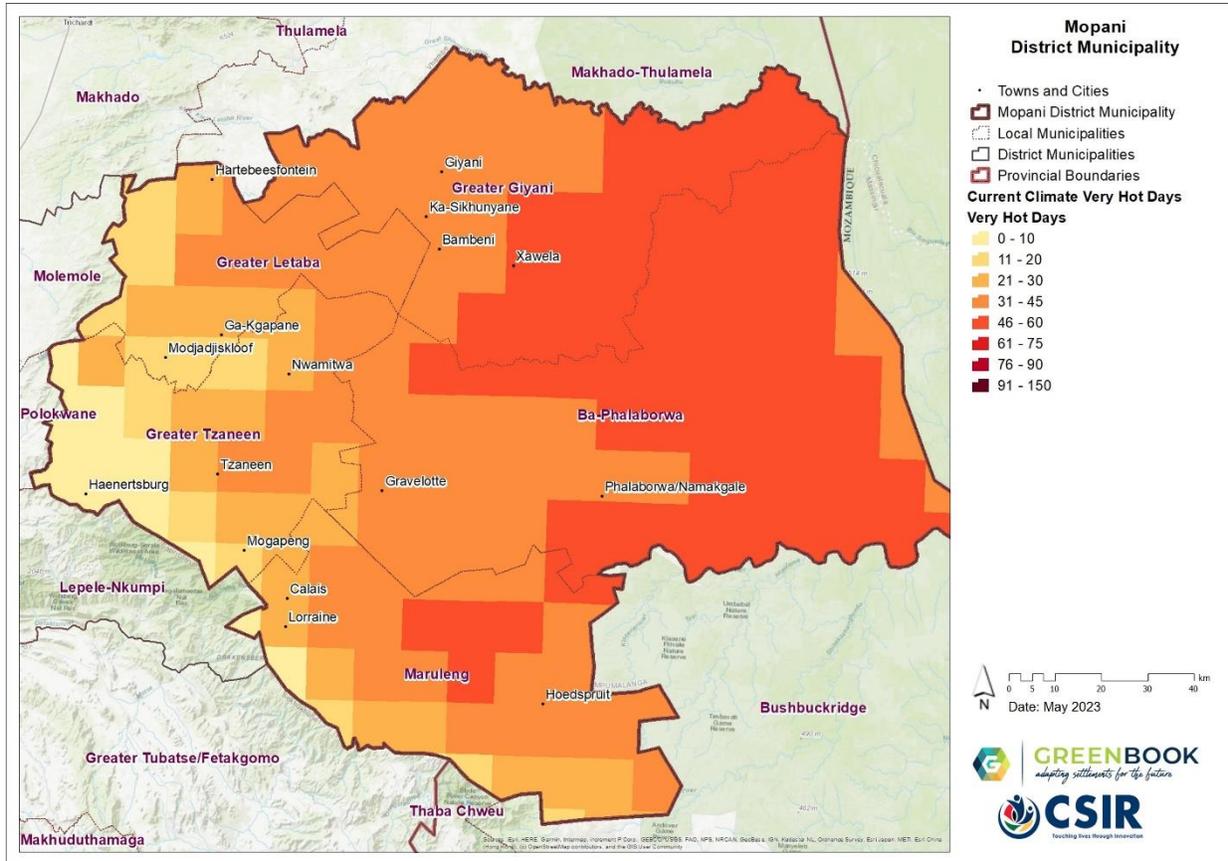


Figure 12: Annual number of baseline annual very hot days across Mopani District Municipality with daily temperature maxim exceeding 35°C

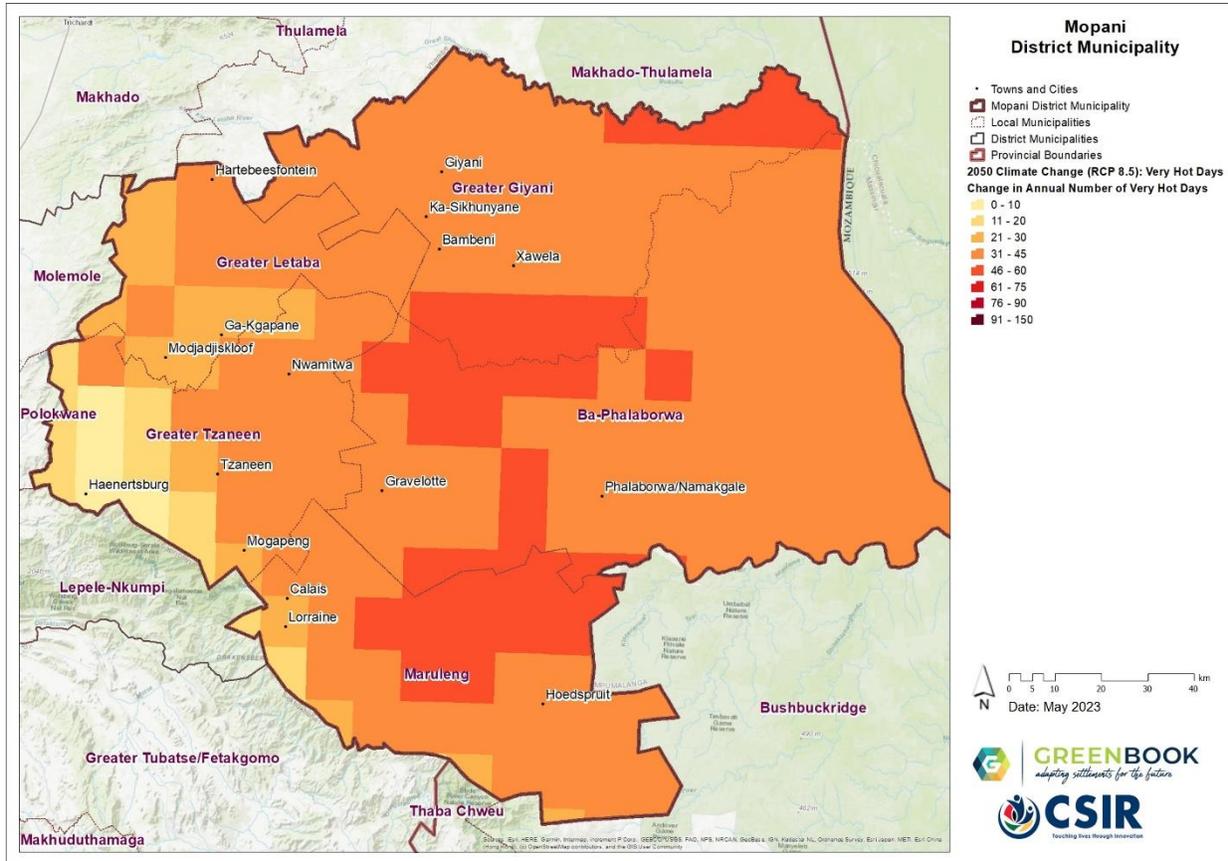


Figure 13: Projected change in average annual number of very hot days with daily temperature maxima exceeding 35°C from 1961-1990 to 2021-2050 for Mopani District Municipality (RCP8.5)

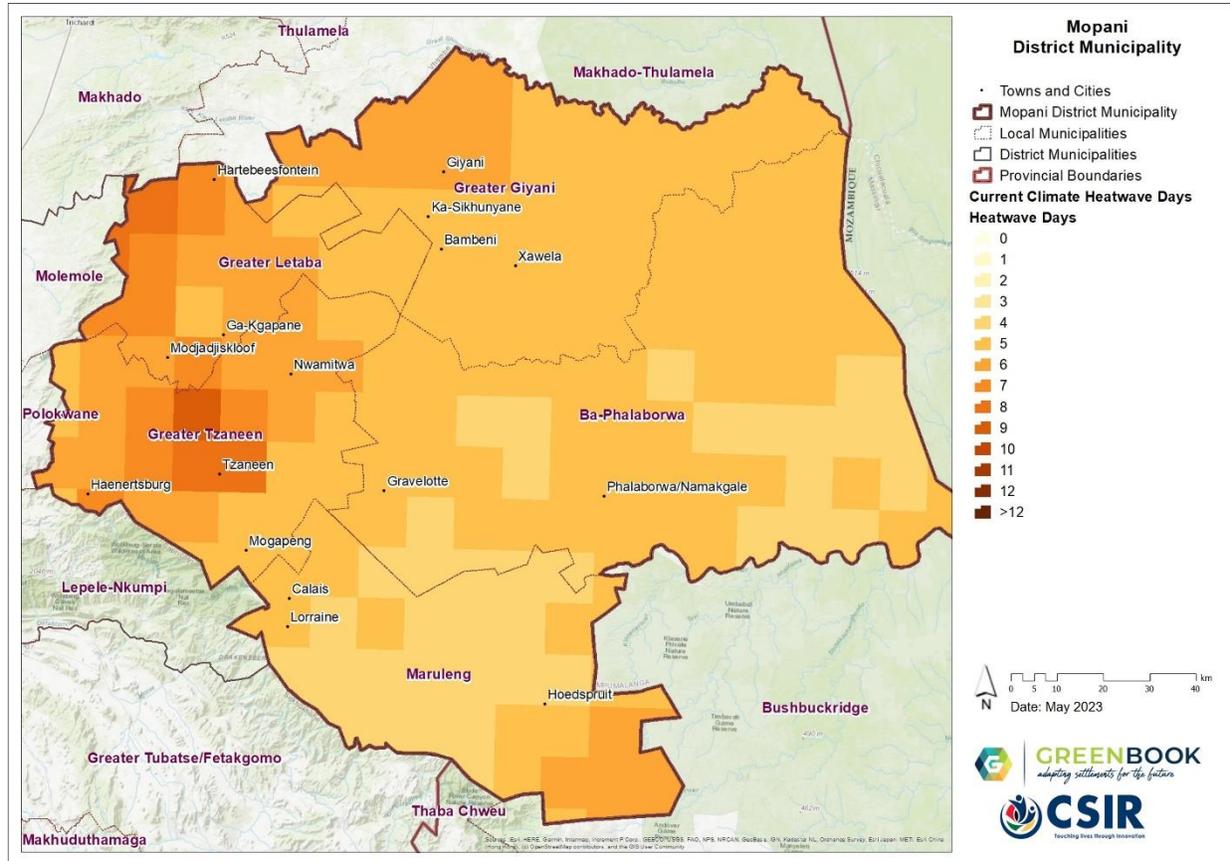


Figure 14: Annual number of heatwave days under baseline climatic conditions across Mopani District Municipality

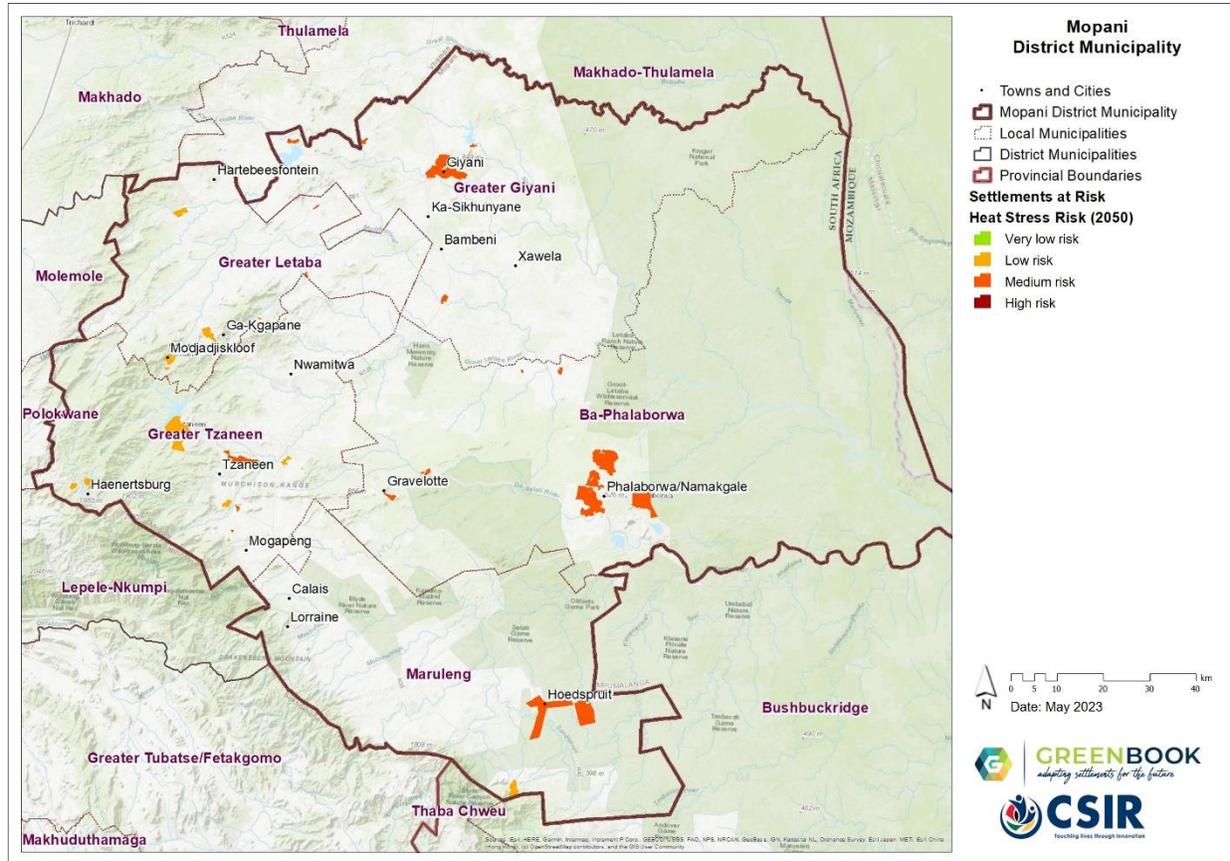


Figure 15: Heat risk across Mopani District Municipality at settlement level in the 2050s

There is significant spatial variation in the number of very hot days experienced across the District. Under baseline climate conditions, there are approximately 60 very hot days experienced in the eastern areas of the DM (Figure 13). From the climate information available, the maps show that the settlements of Phalaborwa and Xawela are located in areas where very hot days are more likely to occur (Figure 15). Heatwave events are however more likely to take place towards the west of the District, affecting Greater Tzaneen and Greater Letaba LMs. The number of very hot days are projected to increase in the areas that are already more likely to experience extreme heat, especially over the central parts of the District.

Figure 15 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. Some of the settlements that would be most exposed to heat stress in the future in MDM include Giyani, Tzaneen, Hoedspruit and Phalaborwa.

### 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 they should not. Much of the natural vegetation requires fires to maintain the ecosystems and keep them 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. A scale was used 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 'very 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.

The projected number of fire danger days for an 8 x 8 km grid-point under an RCP 8.5 “business as usual” low mitigation (worst case) scenario was calculated. A fire danger day is described as a day when the McArthur fire-danger index (McArthur 1967) 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 is informed by the projected change in the number of fire danger days.

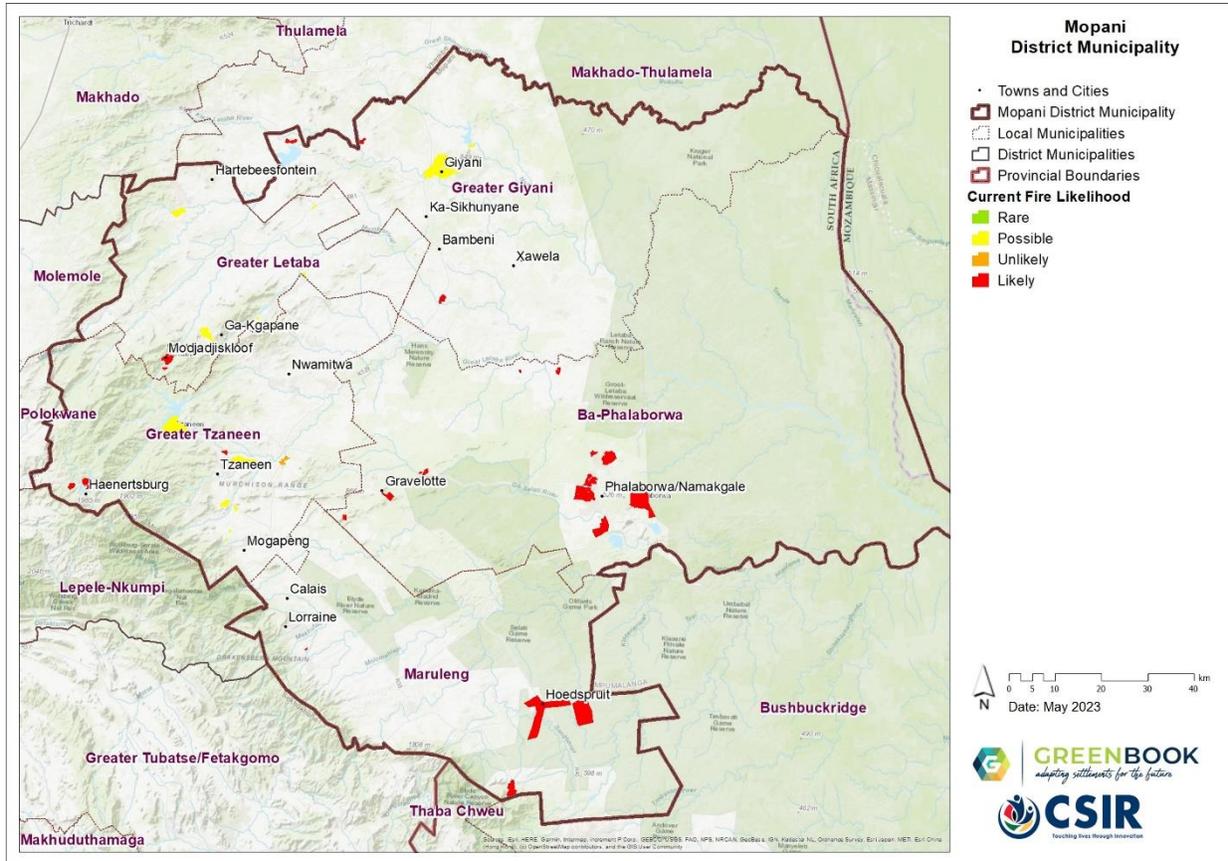


Figure 16: The likelihood of wildfire under current climatic conditions across settlements in Mopani District Municipality

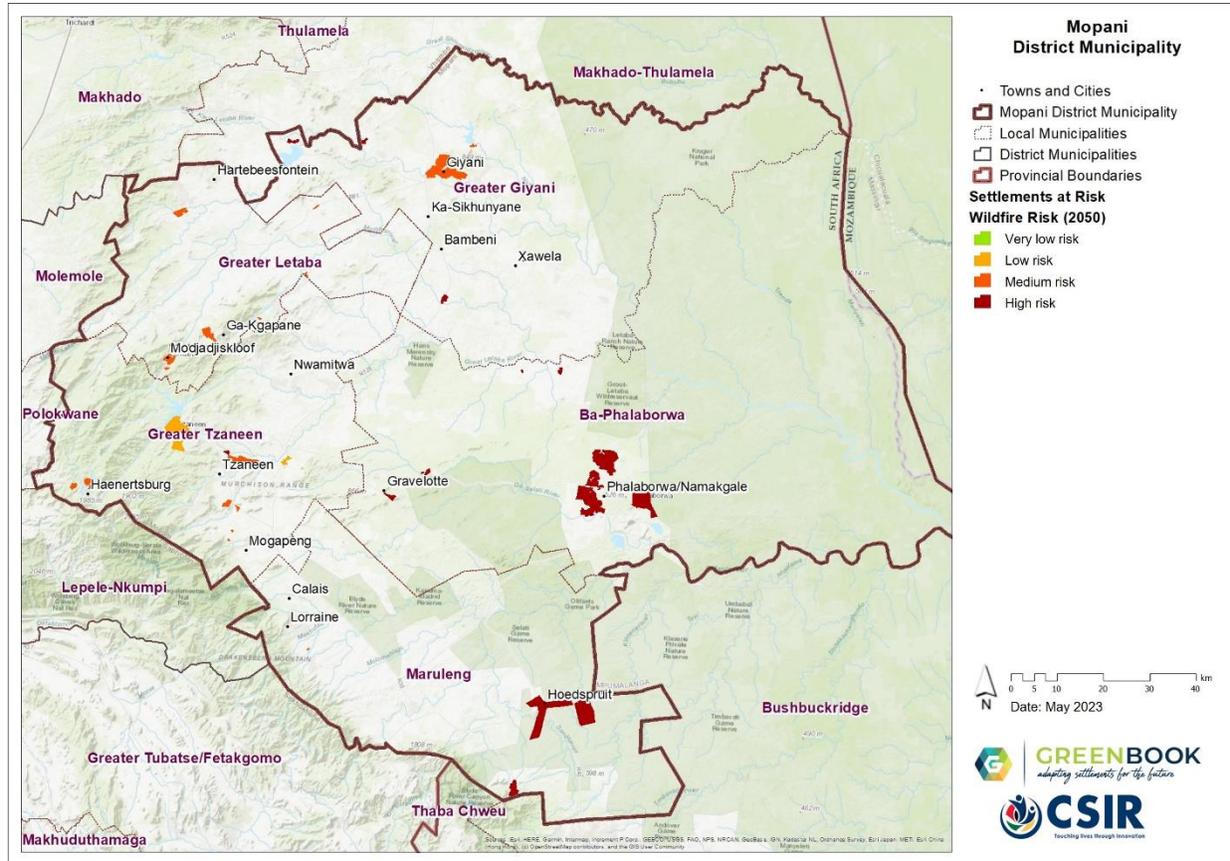


Figure 17: The likelihood of wildfire under future climatic conditions across Mopani District Municipality

Figure 16 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 17 depicts the settlements that could be at risk of increases in wildfires by the year 2050. Settlements which are likely to experience wildfires on their wildland-urban interface include Phalaborwa, Modjadjiskloof, Gravelotte and Hoedspruit. It is projected that of these settlements, Phalaborwa, Hoedspruit and Gravelotte will face a high risk of wildfire in the future.

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 the 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. Additional local and contextual information can be added 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, it is projected that flood events are likely to increase into the future. Estimates of the 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 identified using a risk matrix, that considered the flood hazard index and the projected change in extreme rainfall from 1961 – 1990 to 2050s.

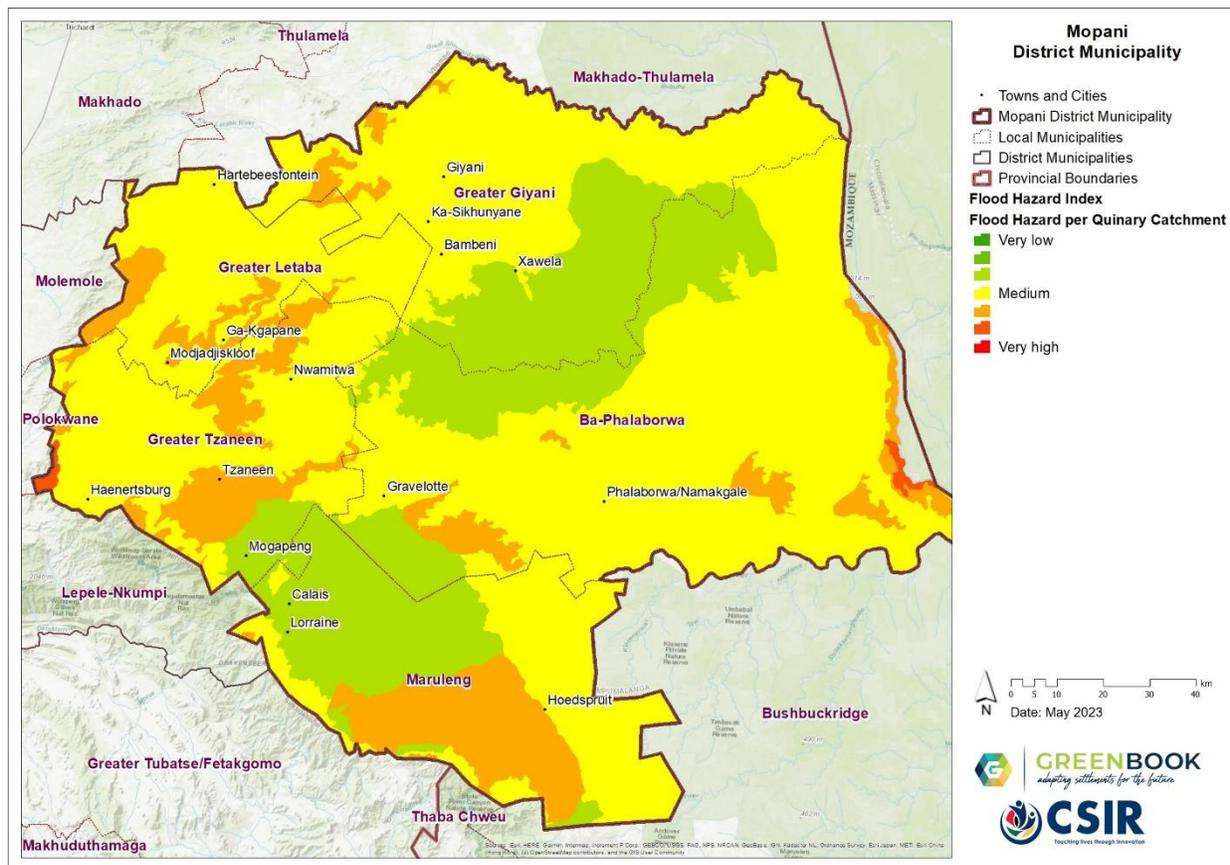


Figure 18: The flood hazard index across Mopani District Municipality under current (baseline) climatic conditions

Figure 18 depicts the flood hazard index of the different quinary catchments present or intersecting with the District 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 District Municipality. Most parts of the DM have a medium flooding hazard, with pockets of medium to very high flooding hazard. Some areas in the central and southwestern parts of the District have a low flood hazard.

Figure 19 depicts the projected change into the future for extreme rainfall days for an 8 x 8 km grid. This was calculated by assessing the degree of change when projected future rainfall extremes (e.g., 95th percentile of daily rainfall) are compared with current rainfall extremes. A value of more than 1 indicates an increase in extreme daily rainfalls. Most parts of the DM will experience slight increases in the number of extreme rainfall days.

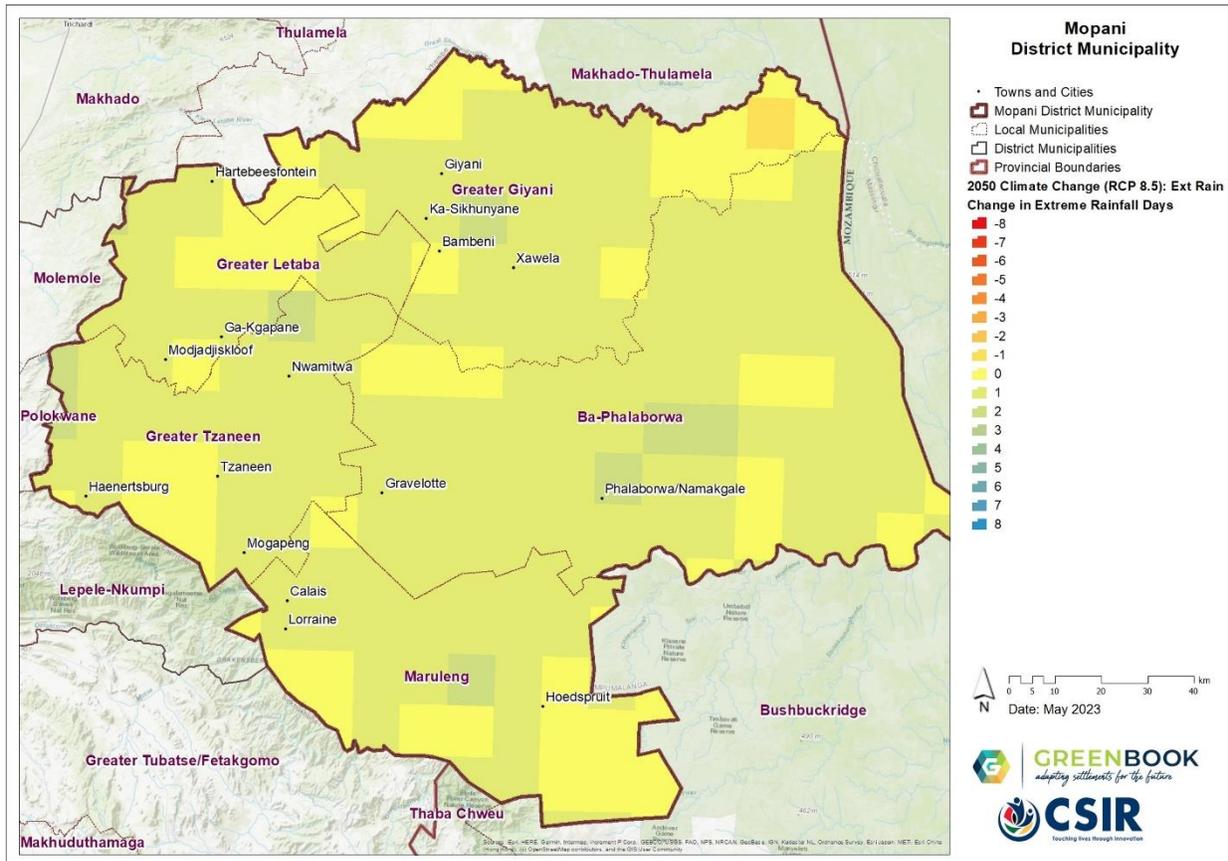


Figure 19: Projected change into the future rainfall days across Mopani District Municipality

Figure 20 depicts the settlements that are at increased risk of flooding under an RCP 8.5 low mitigation (worst case of greenhouse gas emissions) scenario. These include Phalaborwa, Hoedspruit and Ga-Kgapane.

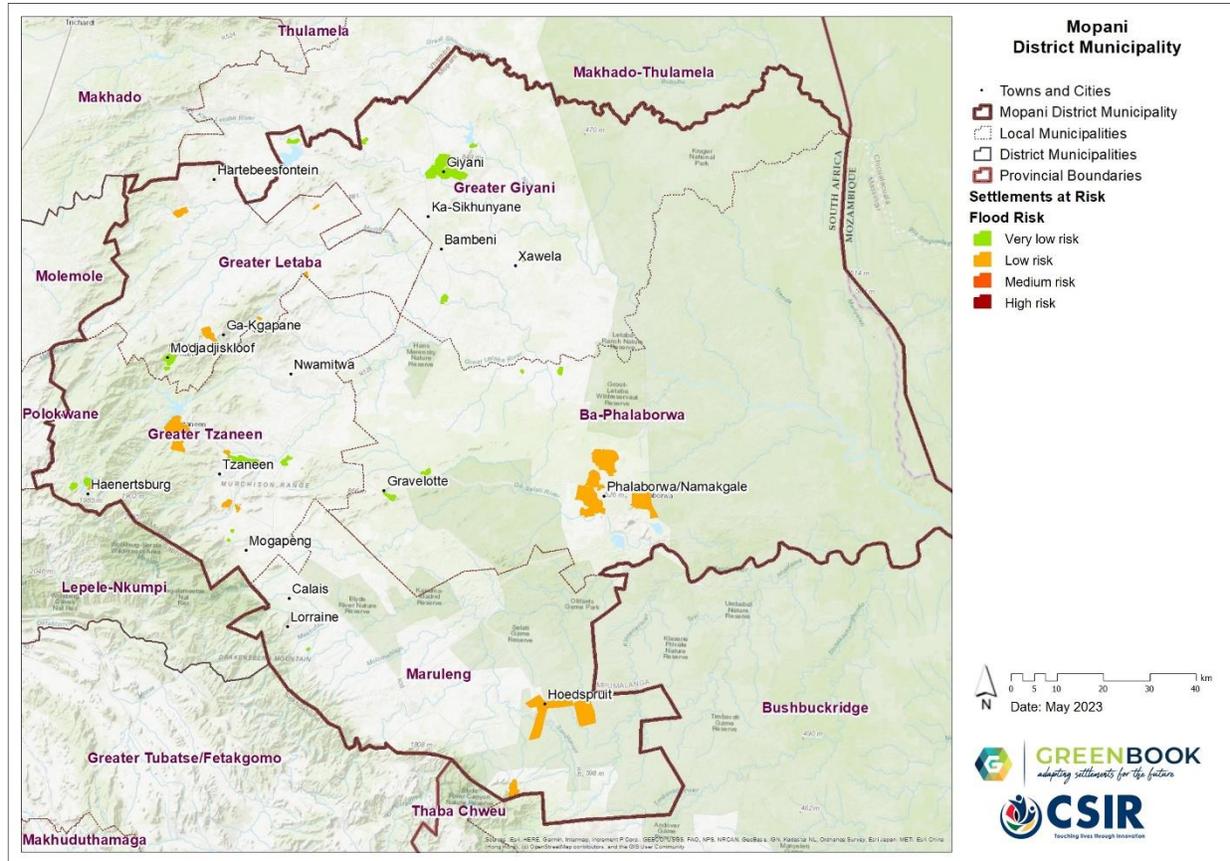


Figure 20: Flood risk into a climate change future at settlement-level flood risk across Mopani District Municipality.

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

This section explores the impact that climate change is likely to have on the resources and economic sectors of the Mopani District Municipality.

#### 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 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 whose 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 Vilholth 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 21 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 Mopani District, most of the

larger settlements are surface water dependent, while others use a combination of surface and groundwater.

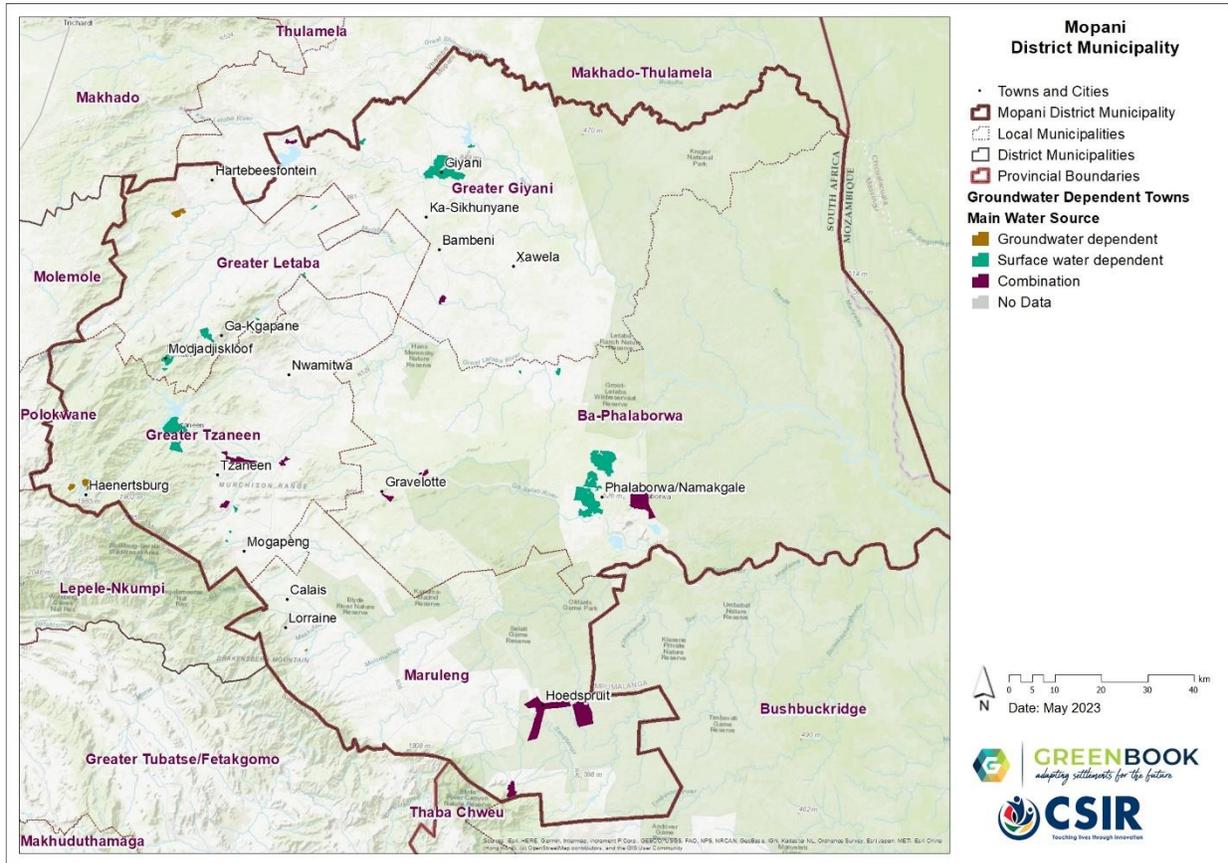


Figure 21: Main water source for settlements in the Mopani District Municipality

Figure 22 indicates the occurrence and distribution of groundwater resources across the District Municipality, showing distinctive recharge potential zones, while Figure 23 indicates the projected change in groundwater recharge potential. Figure 24 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. Groundwater recharge potential is high in the western parts of the DM, especially in the higher rainfall mountain areas of Greater Tzaneen LM, and lower towards the central parts of Ba-Phalaborwa.

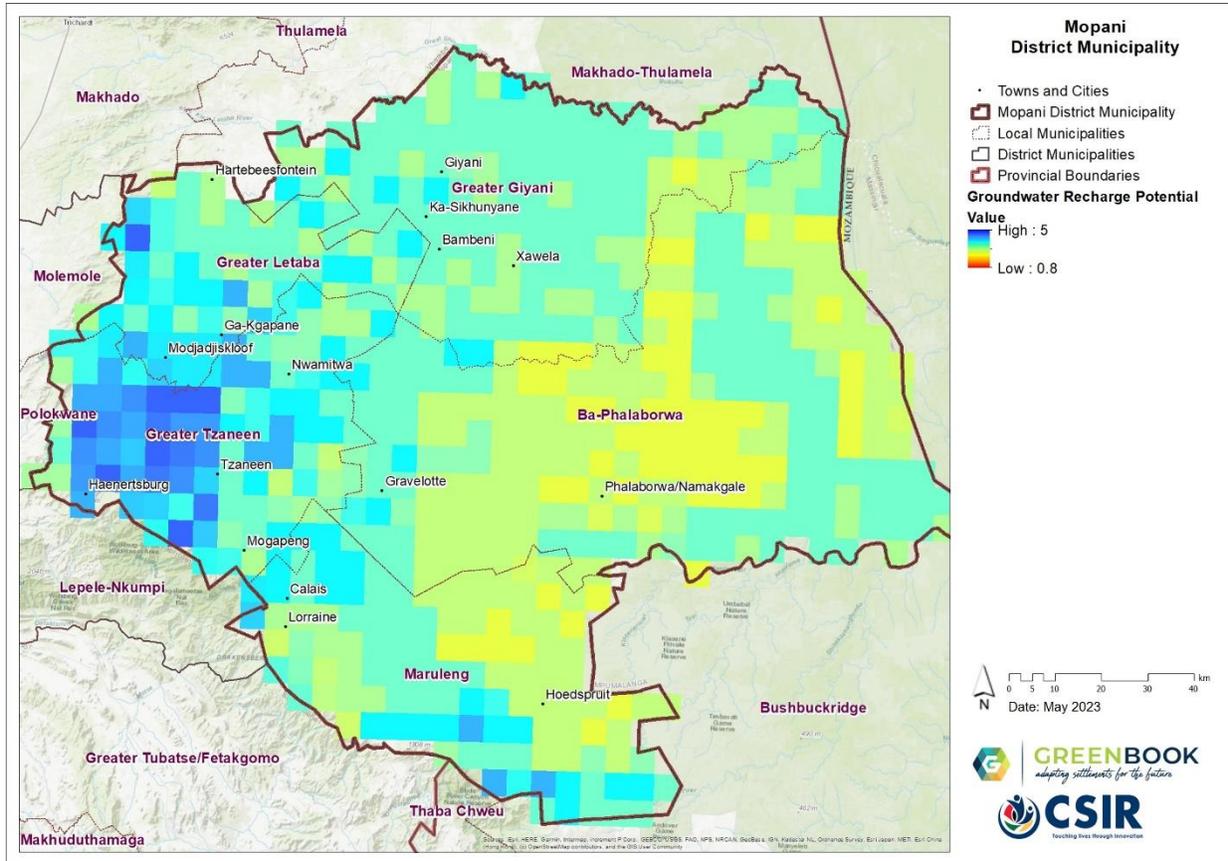


Figure 22: Groundwater recharge potential across Mopani District Municipality under current (baseline) climatic conditions

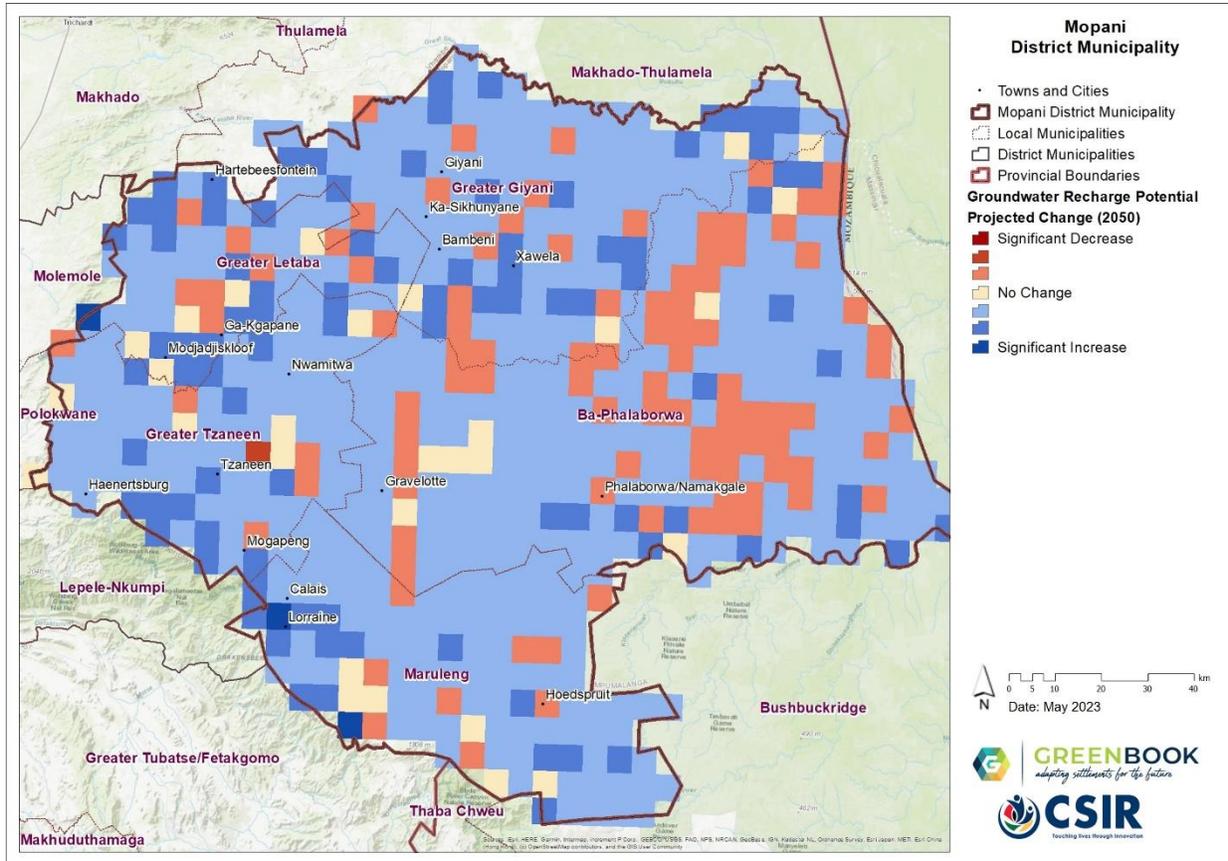


Figure 23: Projected changes in groundwater recharge potential from baseline climatic conditions to the future across Mopani District Municipality

Settlements in the MDM have a low risk of groundwater depletion, except for Phalaborwa which has a medium risk (Figure 24). This is the result of a projected decline in projected groundwater recharge potential into the future, combined with population growth.

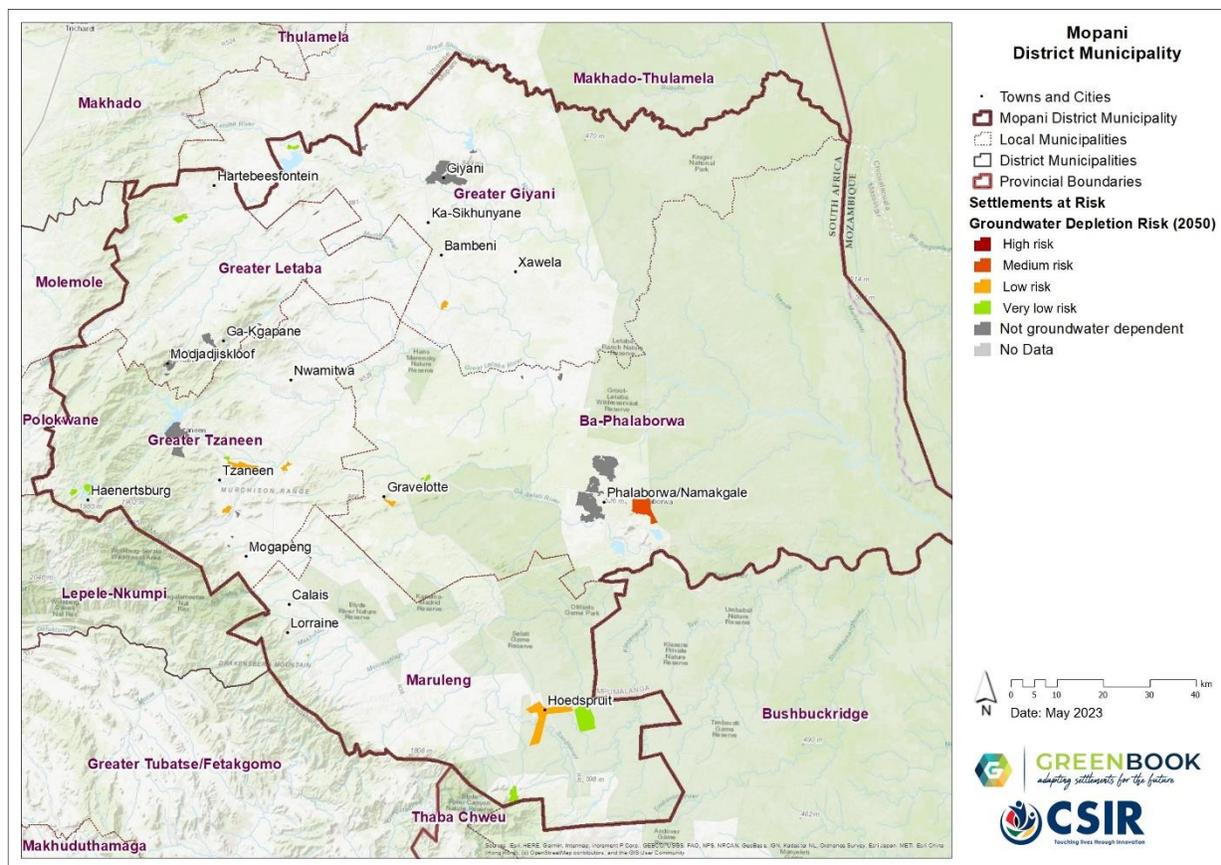


Figure 24: Settlement-level groundwater depletion risk across Mopani District Municipality

Table 3 provides an overview of current water supply vulnerability (i.e., demand versus supply) for the Local Municipalities in the Mopani District Municipality 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 3: Current water supply and vulnerability across Mopani District Municipality

Local Municipality	Water Demand per Capita (l/p/d)	Water Supply per Capita (l/p/d)	Current Water Supply Vulnerability
Ba-Phalaborwa	162.74	430.37	0.38
Greater Giyani	229.68	212.46	1.08
Greater Letaba	71.82	38.36	1.87
Greater Tzaneen	108.36	125.09	0.87
Maruleng	161.32	128.91	1.25

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 the current state of water supply and reticulation infrastructure. The current context and conditions within each of the local municipalities need to be considered when interpreting the information provided in this report. See the GreenBook Municipal Risk Profile Tool for more information on surface water, change in precipitation, runoff, and evaporation. Water supply vulnerability per local municipality is discussed below.

#### Ba-Phalaborwa

Water supply in this LM is currently much higher than demand, but because of the projected increase in the population in Ba-Phalaborwa, water supply vulnerability is projected to increase into the future.

#### Greater Giyani

Water demand is slightly higher than water supply. Because of the projected population decrease, combined with a projected slight increase in mean annual rainfall, water supply vulnerability is expected to decrease in the future.

#### Greater Letaba

Water supply is vulnerable under baseline conditions but is expected to improve in the future. This is due to a decrease in population growth and an increase in mean annual rainfall.

#### Greater Tzaneen

In Greater Tzaneen LM, current water supply vulnerability is low but is expected to increase slightly by 2050 due to projected population growth pressure, a projected decrease in average annual rainfall and increased evaporation.

#### Maruleng

Water supply vulnerability is relatively high and is expected to decline from 1.25 to 1.1 by 2050. Decreased vulnerability is driven by declining population growth pressure, and an increase in mean annual rainfall.

### 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 with regard to the industries served, and also 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 has been done in the past.

The methodological approach to understanding the impact of climate and climate change on agriculture, forestry, and fisheries, consisted of four components. Firstly, the most important areas in terms of Gross Value Added (GVA) and employment for the agriculture, forestry and fisheries 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.

The AFF sector contributes 3.20 % to the local GVA of the Mopani District Municipality. It is the fourth largest economic contributor after Mining, Government and Community Services, Wholesale and Retail. There are several high-value pine and eucalyptus plantations, particularly within the Greater Tzaneen and Greater Letaba Local Municipalities. The Tzaneen and Letsitele regions support citrus, avocados, mangoes and bananas, while the Mooketsi area is the biggest producer of tomatoes in Limpopo and South Africa. The Limpopo province stands as the leading grower of citrus in South Africa, producing 42 % of the total national citrus output. Agriculture and forestry sector is also an important source of employment in the District Municipality, especially in the Greater Tzaneen and Letaba municipalities where most of the labour force is employed in this sector (CoGTA, 2020).

Below, the main agricultural commodities for each Local Municipality within the Mopani District is discussed below in terms of what the impact of climate change might be on those commodities under an RCP 8.5 low-mitigation “business as usual” GHG emissions scenario.

### Ba-Phalaborwa

In Ba-Phalaborwa LM, the AFF sector contributes 1.03 % to the local GVA, which is a contribution of 0.21 % to the national GVA for the AFF sector. Of the total employment, 8.82 % is within the AFF sector. The main agricultural commodities are citrus, game and beef cattle farming. Climate projections show a hotter and wetter climate with more extreme rainfall events. Higher temperatures and humidity will create conditions that are more suitable for the development and distribution of fungal diseases in citrus while leading to reduced growth and reproduction performance in beef cattle.

### Greater Giyani

In Greater Giyani LM, the AFF sector contributes 2.94 % to the local GVA, which is a contribution of 0.18 % to the national GVA for the AFF sector. Of the total employment, 9.16 % is within the AFF sector. The main agricultural commodities are citrus, beef cattle and tomatoes. Climate projections show a generally hotter and wetter climate, becoming drier towards the end of the century. Higher temperatures and humidity will create conditions that are more suitable for the development and distribution of fungal diseases in citrus while leading to reduced growth and reproduction performance in beef cattle. In tomatoes, these conditions are conducive to the spread of the leafminer (*Agromyzid*) pest and the red spider mite (*Tetranychidae*).

### Greater Letaba

In Greater Letaba LM, the AFF sector contributes 7.62 % to the local GVA, which is a contribution of 0.47 % to the national GVA for the AFF sector. Of the total employment, 25.60 % is within the AFF sector. The main agricultural commodities are sub-tropical fruit such as tomatoes, bananas, mangoes, oranges and pineapples as well as beef cattle. Climate projections show a generally hotter and wetter climate, becoming drier towards the end of the century. Higher temperatures and humidity will create conditions that are more suitable for the development and distribution of fungal diseases in citrus, while leading to reduced growth and reproduction performance in beef cattle. In tomatoes, these conditions are conducive to the spread of the leafminer (*Agromyzid*) pest and the red spider mite (*Tetranychidae*).

### Greater Tzaneen

In Greater Tzaneen LM, the AFF sector contributes 7.10% to the local GVA, which is a contribution of 1.13 % to the national GVA for the AFF sector. Of the total employment, 22.60 % is within the AFF sector. The main agricultural commodities are citrus fruit, sub-tropical fruit and vegetables. Climate projections show a generally hotter and wetter climate, becoming drier towards the end of the century. Higher temperatures and humidity will create conditions that are more suitable for the development and distribution of fungal diseases in citrus while in tomatoes, these conditions are conducive to the spread of the leafminer (*Agromyzid*) pest and the red spider mite (*Tetranychidae*).

## Maruleng

In Maruleng LM, the AFF sector contributes 10.35 % to the local GVA, which is a contribution of 0.36 % to the national GVA for the AFF sector. Of the total employment, 34.80 % is within the AFF sector. The main agricultural commodities are mangoes, citrus, and beef cattle or game farming. Climate projections show hotter and drier, but wetter conditions towards the end of century. Higher temperatures are likely to cause increased evapotranspiration and irrigation requirements for citrus while heat stress will lead to reduced growth and reproduction performance in beef cattle.

### 3. Recommendations

The greatest risks faced across MDM are the potential increase in exposure to heat extremes and veld fire, combined with population growth pressure in the Ba-Phalaborwa region. The towns that are seeing significant population growth are already experiencing service access pressure, and larger groups of people will become vulnerable and exposed to climate-related hazards. Economic vulnerability is relatively high, especially in the Ba-Phalaborwa and Maruleng LMs. This indicates the susceptibility of the Municipalities' economies to external shocks, including the impacts of climate change, particularly when considering the diversity of the District's economy, its GDP growth/decline rate, labour force and the level of inequality in the District.

Environmental vulnerability is relatively high across the entire DM, indicating that there is conflict between preserving the natural environment and accommodating pressure associated with population growth, urbanisation and economic development. From a biodiversity perspective, the loss of grasslands was identified as a particular area of concern since the grasslands are vulnerable to climate change and form a vital role in water production.

The dense vegetation and hotter climate over the DM will also lead to increased risk of wildfire. The proliferation of invasive alien plant species, such as pines, eucalyptus, lantana and wattle, under changing climate conditions, contribute to the risk of veld fires. Increase in wildfires not only threaten human settlements but also pose serious risks to rangelands, biodiversity and protected areas. The grassland and savannah biomes, in particular, are vulnerable to fire during the dry late winter / early spring months.

Additionally, certain parts of the DM could experience more extreme rainfall events that could lead to flooding. Increase in intensity of rainfall and flooding could lead to increased surface runoff, resulting in increased soil erosion, soil loss and degradation, especially after drought and fires. The mentioned risks should therefore not be viewed in isolation, but cognizance should be taken of the likelihood of overlapping risks such as increased heat stress, drought, fire and flood risk. These compounding risks significantly increase the vulnerability of settlements to climate change.

Large areas of land in the Mopani District are rural of nature and traditional villages make up most of this land. These traditional villages experience very high socio-economic, economic and environmental vulnerabilities. Subsistence farming is an important livelihood strategy and farming practices are highly reliant on rainfall. Drought and heat stress are expected to worsen challenges of water accessibility in future, especially in the western part District.

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

1. To ensure water security for human consumption and irrigation under a changing climate: Given the water scarcity challenges in the country, developing comprehensive strategies for water resource management is crucial. Moreover, the temperature increases, as well as increases in drought tendencies and water supply vulnerability that the District will likely encounter into the future (at least up to 2050), are likely to result in adverse consequences such as water shortage, which thus, makes it necessary for the District to take the necessary actions to ensure water security for consumption and irrigation purposes in the face of climate change. Some of the actions that the District could take include prioritising infrastructure maintenance; investing in efficient water supply infrastructure to meet future demand; promoting water conservation practices by implementing strategies such as public awareness campaigns, leak detection and repairs, and water metering and billing; and exploring measures to secure alternative water sources such as rainwater (harvesting), groundwater (recharge and extraction) and wastewater (reuse).
2. To protect biodiversity and improve sustainable use of natural resources: As noted earlier, the District's natural environment is under severe pressure due to rapid urbanisation, agricultural expansion and land-use change. This therefore makes the District's natural environment and resources, as well as biodiversity, very vulnerable to extreme climate-related events. Moreover, the loss of grasslands in the DM, which play a vital role in water production, is of particular concern. It is therefore necessary to protect and restore these natural environments in order to maintain their key functions. The protection and restoration of natural ecosystems, like high-priority biomes, wetlands, river ecosystems and riparian areas, are integral to maintaining biodiversity, supporting water resource management, and providing natural buffers against climate-related hazards like wildfires and floods. Some of the actions that the District could take to realise this goal include establishing or expanding protected areas, enforcing regulations against harmful practices in such areas, and promoting the sustainable use of natural resources.
3. To increase resilience of the agricultural sector to more extreme events such as storms and drought, as well as indirect risks such as pests and diseases: The District's agricultural sector contributes to food security and supports the livelihoods of many local residents. Moreover, because agriculture is arguably one of the most vulnerable sectors to the impacts of climate change, at least in South Africa, it is essential to increase its resilience to the various impacts in an effort to maintain food- and (improve) social security. This can be done by, for instance, 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 pests.

4. To increase the adaptive capacity of human settlements to climate change and extreme events: To reduce the vulnerability of human settlements to climate-related hazards and extreme events, it is essential to increase their capacity to adapt to such impacts and events. The District could therefore increase the adaptive capacity of human settlements by adopting design standards and practices that take into account future climate change impacts, to ensure that the District's urban and settlement fabric are resilient to such events (e.g., climate proofing infrastructure and buildings).

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

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