Waterberg District Municipality

GreenBook Risk Profile Report

Draft

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Acronyms

°C	Degree Celsius
AFF	Agriculture, Forestry and Fisheries
AR5	Fifth Assessment Report
CABLE	CSIRO Atmosphere Biosphere Land Exchange model
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
EnV	Environmental Vulnerability Index
GCM	General circulation model
GDP	Gross Domestic Product
GRiMMS	Groundwater Drought Risk Mapping and Management System
GVA	Gross Value Added
IDP	Integrated Development Plan
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
km	kilometre
l/p/d	Litres Per Person Per Day
MAR	Mean Annual Runoff

mm	millimetre
NDMC	National Disaster Management Centre
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
THI	Temperature Humidity Index
WDM	Waterberg District Municipality
WMAs	Water Management Areas
WMO	World Meteorological Organisation
WRYM	Water Resources Yield Model
WUI	Wildland-Urban Interface

Glossary

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 (GreenBook, 2021).
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	"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).
Sensitivity	"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).
Vulnerability	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).

1. Introduction

This Climate Risk Profile report, as well as the accompanying draft Climate Change Adaptation Plan, were developed specifically for Waterberg District Municipality (WDM), 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 l 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 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 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.

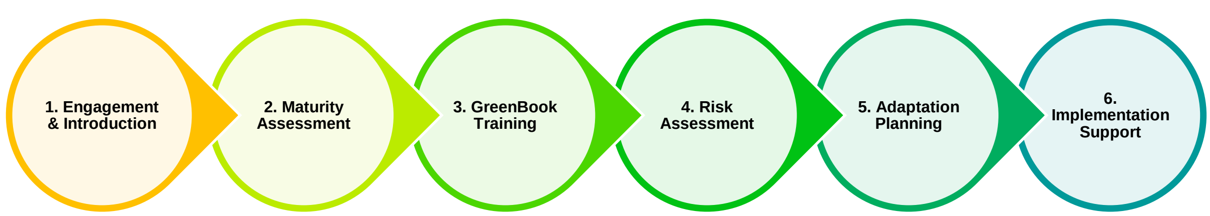

Figure 1: The Value-chain towards the implementation of climate change response and adaptation in municipalities

The purpose and strategic objectives of the Climate Risk Profile report 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 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 2). "Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, 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.

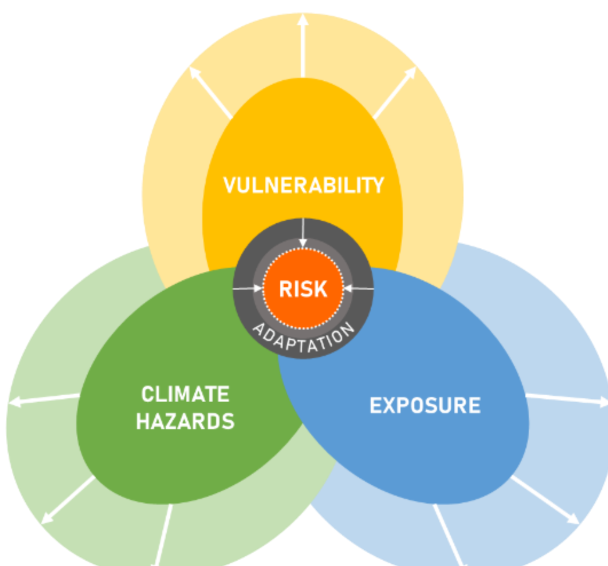

Figure 2: The interaction between the various components of risk, indicating the opportunity to reduce risk through adaptation (based on IPCC, 2014 and IPCC, 2021)

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 and the impact of climate change 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.

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 (SPLUMA) of 2013 outlines five principles intended to guide spatial planning, land development and land use management at 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 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 Waterberg District Municipality (WDM) is located in the south western part of the province of Limpopo, South Africa's most northern province. The District is one of five District Municipalities in Limpopo, and shares borders with Capricorn District in the north and north east, Sekhukhune District Municipality and Gauteng province in the south east, as well as the North West province in the south west. Waterberg is the largest (44 913 km^2) of the five District Municipalities in Limpopo (CoGTA, 2020; WDM, 2023).

Waterberg is a largely rural District, with five local municipalities, namely Bela-Bela, which is located in the most southern part of the District; Lephalale, located on the north western part of the District; Mogalakwena, located on the north-eastern part of the District; Modimolle-Mookgophong, which serves as the administrative centre of the District and is located on the south-eastern part of the Municipality; as well as Thabazimbi, which is situated in the south-western part of the District (CoGTA, 2020; WDM, 2023).

The District has a total population of about 761 590 (WDM, 2023), with 679 133 located in settlements. The settlement-based population grew by 22.7% between 2001 and 2011 and is projected to grow by 36% between 2011 and 2030. Waterberg's leading economic sectors include Mining, Agriculture and Tourism, all of which cumulatively account for 56% of the District's Gross Value Added (GVA). The District's major employing sectors are Mining, which employs 33% of the District's working population, as well as Trade and Personal Services, both of which employ 17% and 12.5% of the District's working population, respectively (CoGTA, 2020; DEA,2018; WDM, 2023).

Waterberg District is home to several major dams, rivers and wetlands, as well as internationally recognised protected areas. These include the Mokolo, Doorndraai and Glen Alpine Dams; Mokolo, Limpopo, Lephalale, Mogalakwena, Sterk, Olifants and Nyl Rivers; as well as Marakele National Park, Entabeni Nature Reserve, and Dnyala Nature Reserve, which forms part of Waterberg's Biosphere Reserve that is recognised by the United Nations Educational, Scientific and Cultural Organisation (UNESCO). The District's Biosphere Reserve covers an area of 654 033 hectares and represents a considerable area of the country's Savanna Biome, with a high level of biological diversity, including red and orange listed species of conservation concern, as well as endemic species (DEA, 2018). The Savanna Biome covers 98.2% of the District; Azonal Vegetation (0.5%), Forests (0.1%) and Grasslands (1.24%) make up the rest of the District's biophysical environment (DEA, 2018).

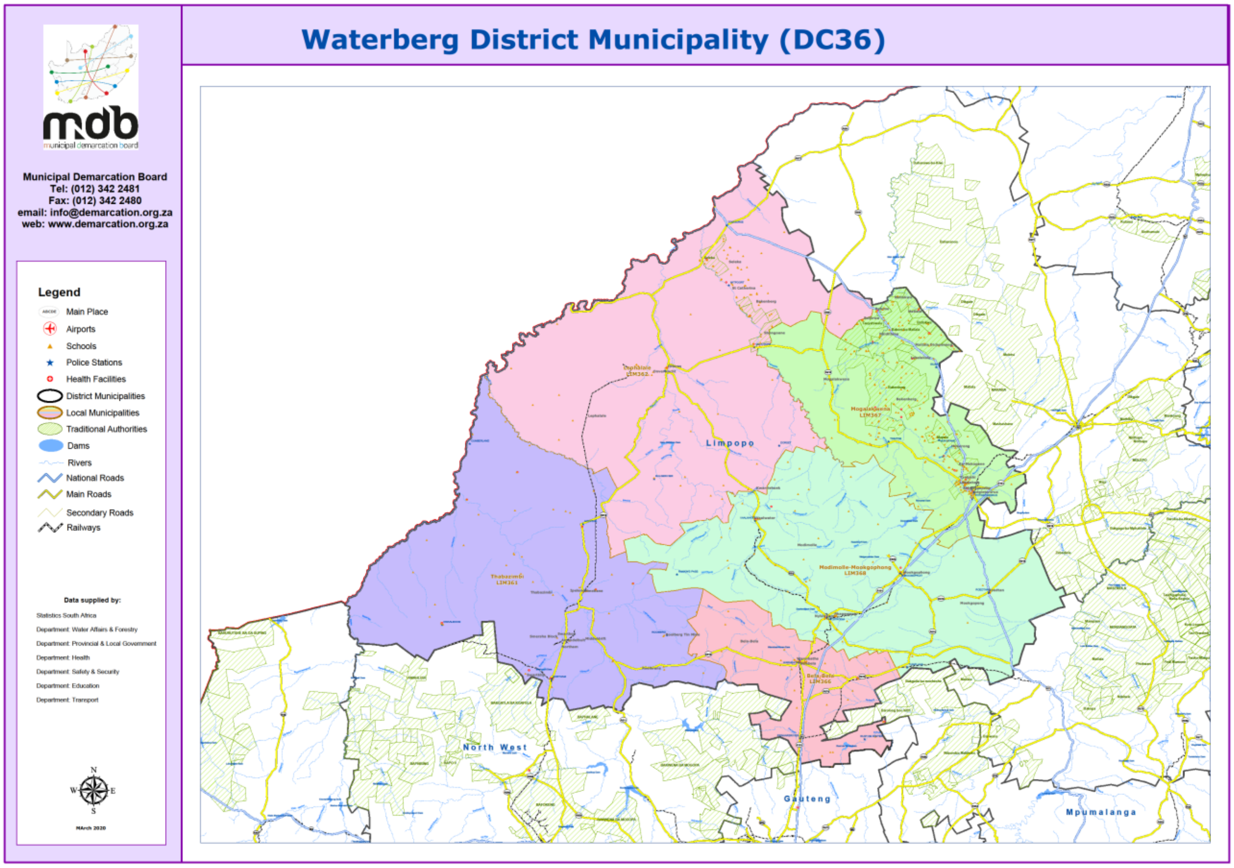

Figure 3: Waterberg District Municipality (Municipal Demarcation Board, 2022)

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 Waterberg 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 Waterberg 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 drives 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 Waterberg 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, 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.

Each local municipality in the Waterberg District is 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 Waterberg District Municipality

LOCAL MUNICIPALITY	SEVI 96	SEV 11	Trend	EcVI 96	EcVI 11	Trend	PVI	Trend	EnVI	Trend
Bela-Bela	3.6	3.2	↘	3.7	3.9	↗	6.0	N/A	3.6	N/A
Lephalale	4.6	3.0	↘	7.1	9.2	↗	7.1	N/A	3.4	N/A
Modimolle-Mookgophong	4.5	3.8	↘	2.7	2.5	↘	6.1	N/A	4.6	N/A
Mogalakwena	4.9	4.7	↘	5.5	7.6	↗	5.9	N/A	3.9	N/A
Thabazimbi	4.3	2.3	↘	5.1	6.8	↗	7.4	N/A	4.4	N/A

Socio-economic vulnerability has decreased (improved) across all local municipalities in the District between 1996 and 2011. However, economic vulnerability has increased (worsened) across all local municipalities in the District, with the exception of Modimolle-Mookgophong, between 1996 and 2011. Lephalale Local Municipality had the highest economic vulnerability in the District and the fourth highest in the Province, i.e., in 2011. Interestingly, Mogalakwena Local Municipality recorded the highest unemployment rate at 22.1% in 2018, while Lephalale Local Municipality recorded the lowest unemployment rate of 11.6% in the same year (WDM, 2023), thus indicating changes in the District's economic dynamics for the last decade. Thabazimbi Local Municipality had the highest physical vulnerability score in 2011, thus alluding to the District's physical remoteness and the vulnerable characteristics of its physical assets and structure.

2.1.2. Settlement vulnerability

The unique set of indicators outlined below highlight the multi-dimensional vulnerabilities of the settlements within the Waterberg 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 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 indictors, 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.

Bela-Bela

The major settlements in this municipality are Kalkheuwel Mine, Welgegund Village, Settlers, Bela-Bela and several traditional areas. Bela-Bela faces the highest growth- and environmental pressure. Welgegund Village has very high socio-economic and economic vulnerability, while traditional areas in the local municipality have very high service access and regional connectivity vulnerability.

Lephalale

The major settlements in this municipality are Lephalale, Marapong, Thabo Mbeki and several traditional areas. The settlement of Marapong faces the greatest growth- and environmental pressure, as has the highest economic vulnerability in the local municipality. Parts of Marapong are some of the most remote areas in the local municipality, with very high service access vulnerability. Traditional areas are home to the most socio-economically vulnerable populations in the municipality.

Modimolle-Mookgophong

The major settlements in this municipality are Modimolle, Thusang, Roedtan, Mookgopong, Alma, Vaalwater and several traditional areas. Modimolle faces the highest growth pressure in the District, while Vaalwater has the District's highest service access vulnerability. Thusang has the most vulnerable natural environment in the local municipality. The District's most remote settlements (with very high regional connectivity vulnerability) are Alma, Vaalwater, as well as several traditional areas. In addition to high regional connectivity vulnerability, traditional areas also have the highest economic vulnerability, with highly socio-economically vulnerable populations.

Mogalakwena

The major settlements in this municipality are Mokopane, GaPila, Rooibokfontein, Mapela, GaSekhaolelo, Mabula, Babirwa, as well as several traditional areas. Mokopane has the highest growth pressure. GaPila and Rooibokfontein have the most vulnerable natural environments, as well as the most socio-economically vulnerable populations, while Babirwa is the most remote settlement in the local municipality. GaSekhaolelo has the highest economic vulnerability in the municipality, and both Mabula and traditional areas have very high service access vulnerability.

Thabazimbi

The major settlements in this municipality are Swartklip Mine, Northam, Northam Platinum Mine, Leeupoort, Middeldrift, Smersha Block, Rooiberg, Amandelbult, Dwaalboom, and Thabazimbi. Thabazimbi and parts of Northam face the highest population growth pressure, while Rooiberg and Smersha Block are home to the municipality's most socio-economically vulnerable populations. Smersha Block also has Thabazimbi's highest environmental-, economic-, and service access vulnerability. Dwaalboom is the most remote settlement in the local municipality.

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 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 Waterberg District Municipality

Population per municipality	2011	Medium Growth Scenario	
		2030	2050
Bela-Bela	66 489	101 009	133 786
Lephalale	118 805	200 411	298 684
Modimolle-Mookgophong	104 159	126 637	137 170
Mogalakwena	304 474	343 260	326 113
Thabazimbi	85 206	127 328	166 017
Waterberg DM Total	679 133	898 645	1 061 770

The District's population will increase by 60.7% between 2011 and 2050, under a medium growth scenario. Most of this growth will take place in the settlements within Lephalale local municipality. Parts of Mogalakwena are likely to experience a decline in population between 2030 and 2050. Figure 4 depicts the growth pressures that the settlements across the Waterberg District Municipality will likely experience. The settlements that will see extreme growth pressures up to 2050, include Lephalale, Letlora, Thabazimbi, Northam, Bela-Bela, Amandebult, Leeupoort and parts of Swaartklip.

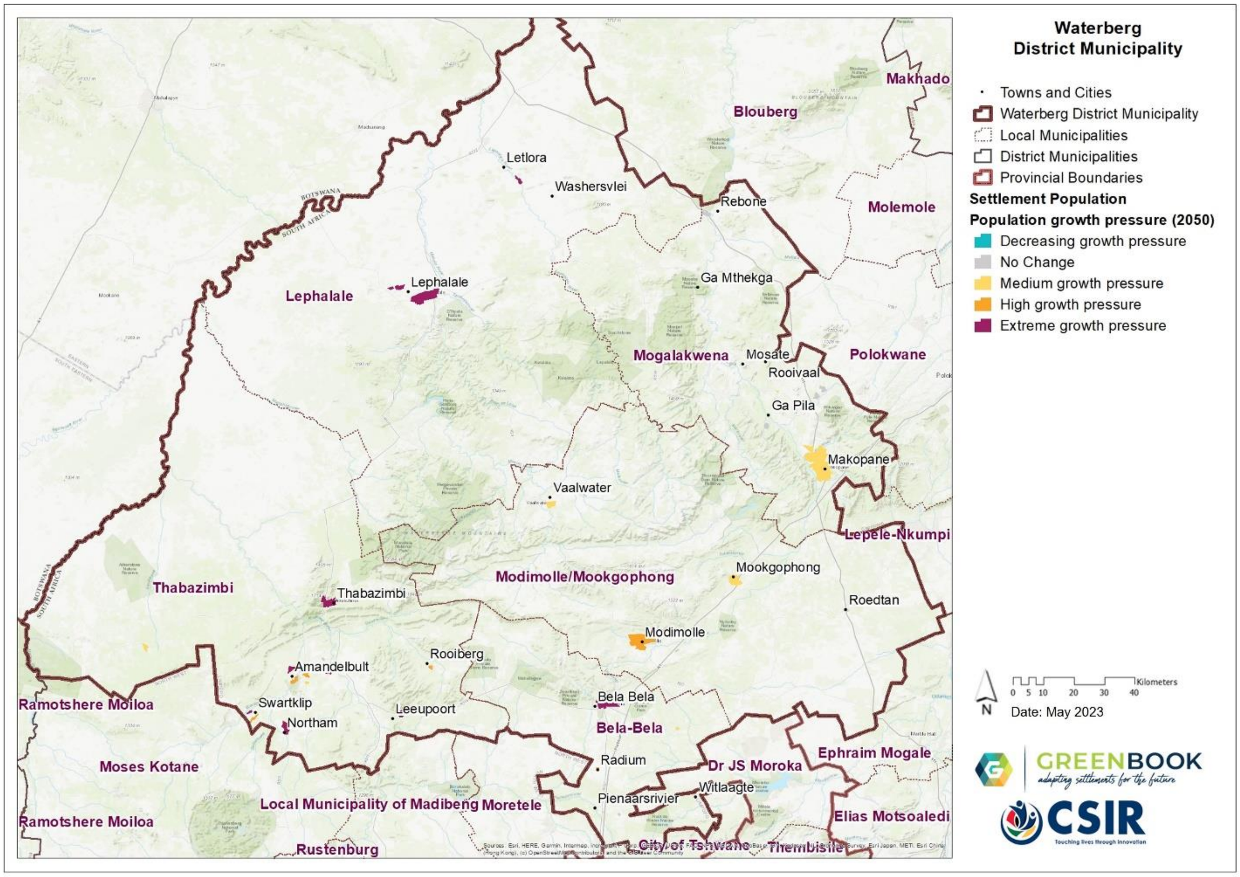

Figure 4: Settlement-level population growth pressure across Waterberg District Municipality

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 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 CMIP5 and AR5 of the 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, whilst RCP 8.5 is a low mitigation scenario.

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 (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 (climatological) state over South Africa calculated for the period 1961–1990 is shown (note that the median of the six downscalings is 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 1961-2000.
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.

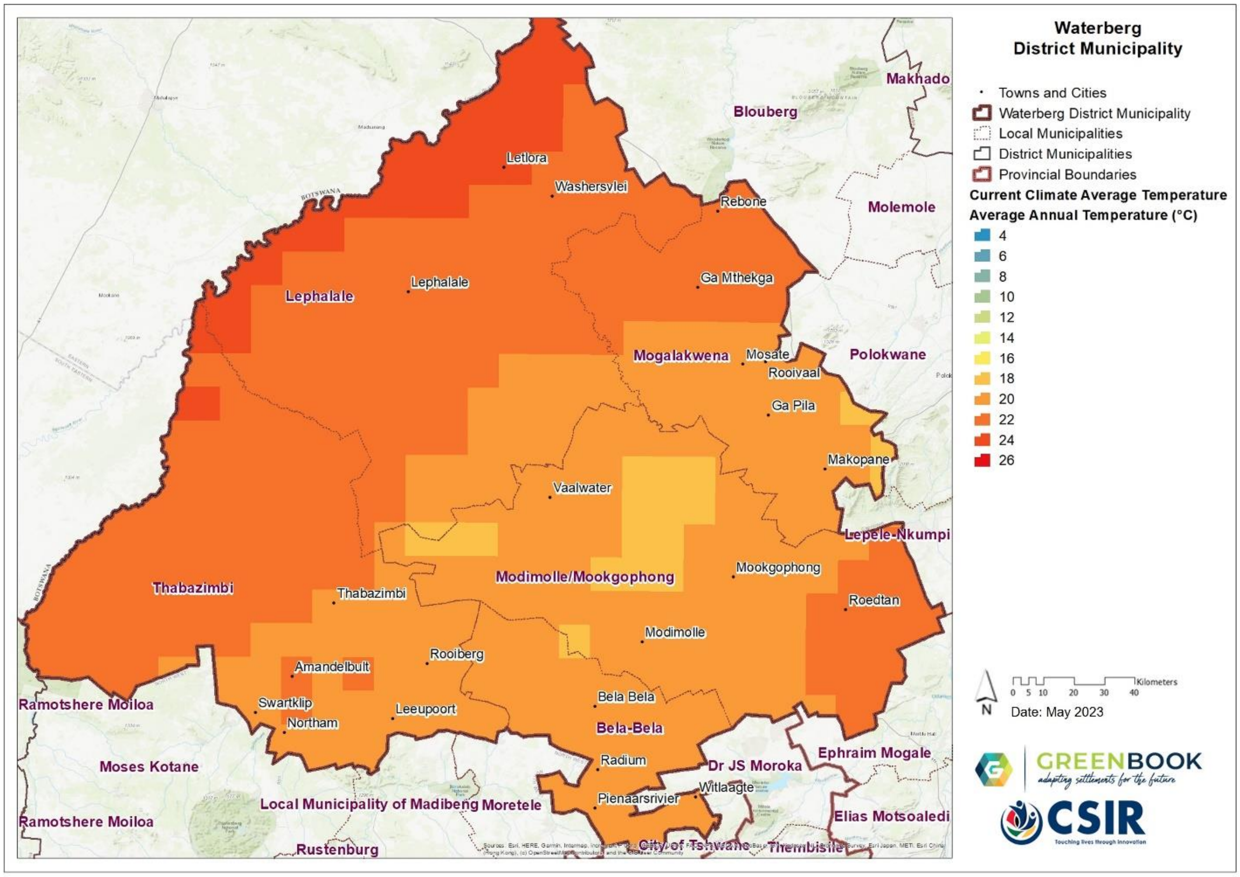

Figure 5: Baseline average annual temperature (°C) for the period 1961-1990 for Waterberg District Municipality

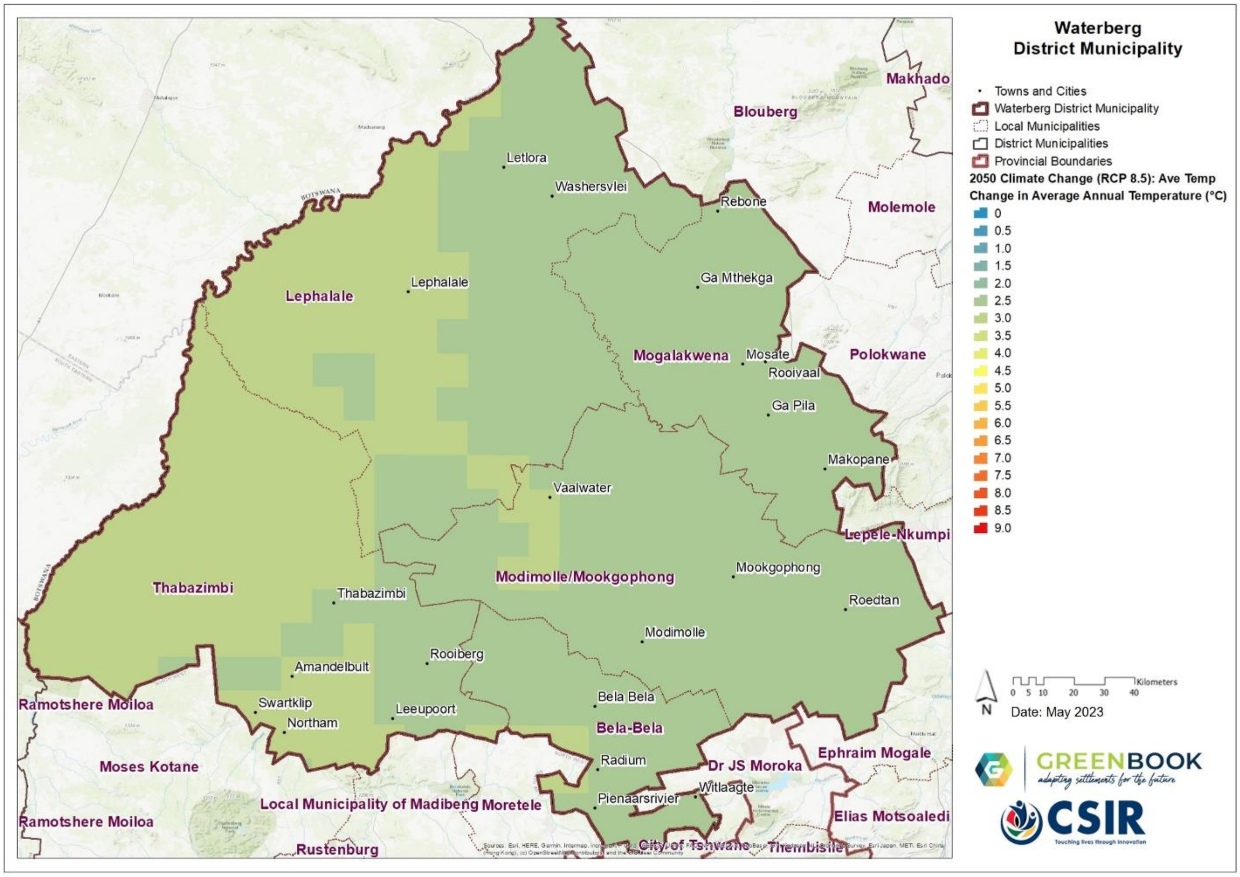

Figure 6: Projected change in average annual temperature (°C) for the period 2021-2050 for Waterberg District Municipality (RCP 8.5)

At the baseline, Waterberg experiences average annual temperatures of between 17 and 22 °C, with higher averages found along the north western border of the District, especially in Lephalale local municipality. The projections show average annual temperature increases of between 2.69°C and 3.13°C by across the district by 2050, under a low mitigation scenario (RCP 8.5). The greatest increases are expected in the west of the District, mostly in the local municipalities of Lephalale and Thabazimbi.

2.2.2. Rainfall

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

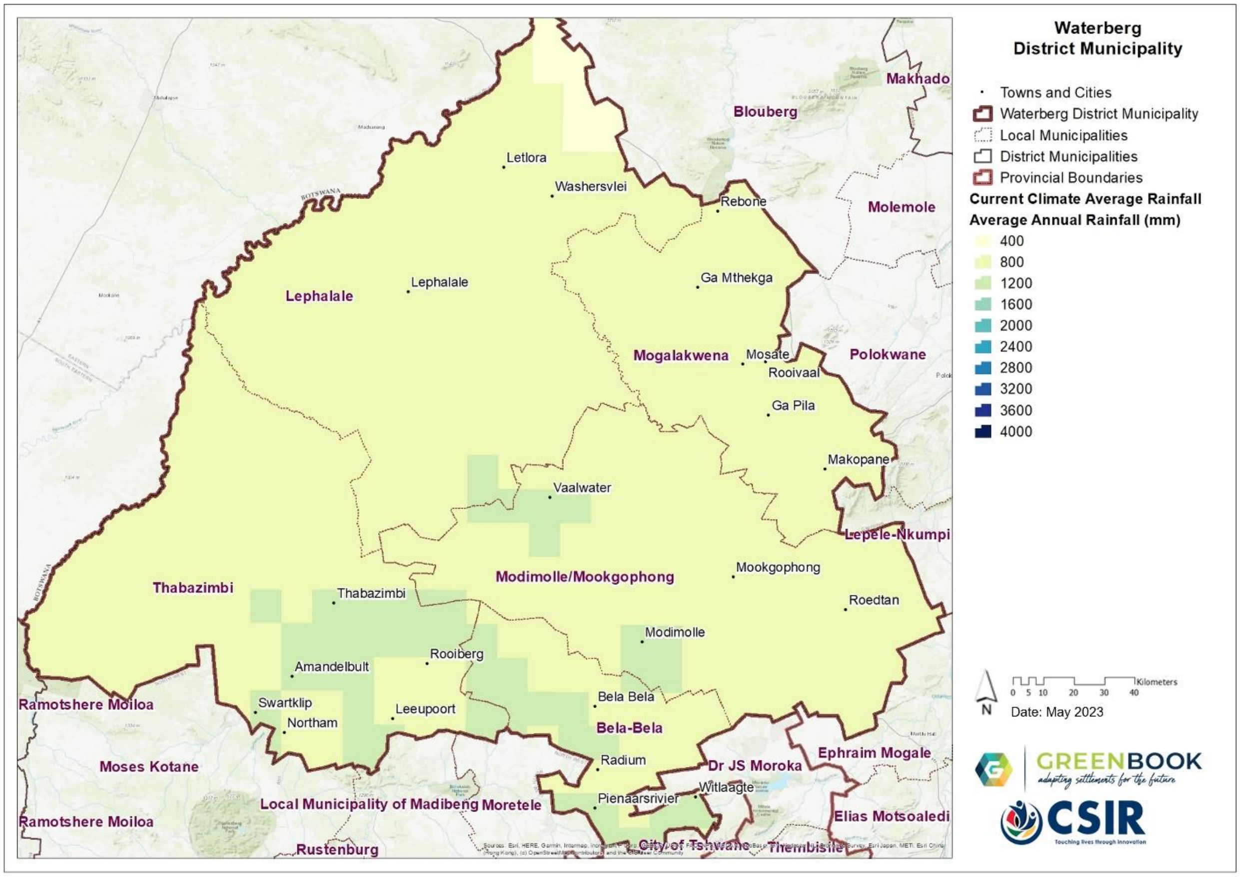

Figure 7: Baseline average annual rainfall (mm) for the period 1961-1990 for Waterberg District Municipality

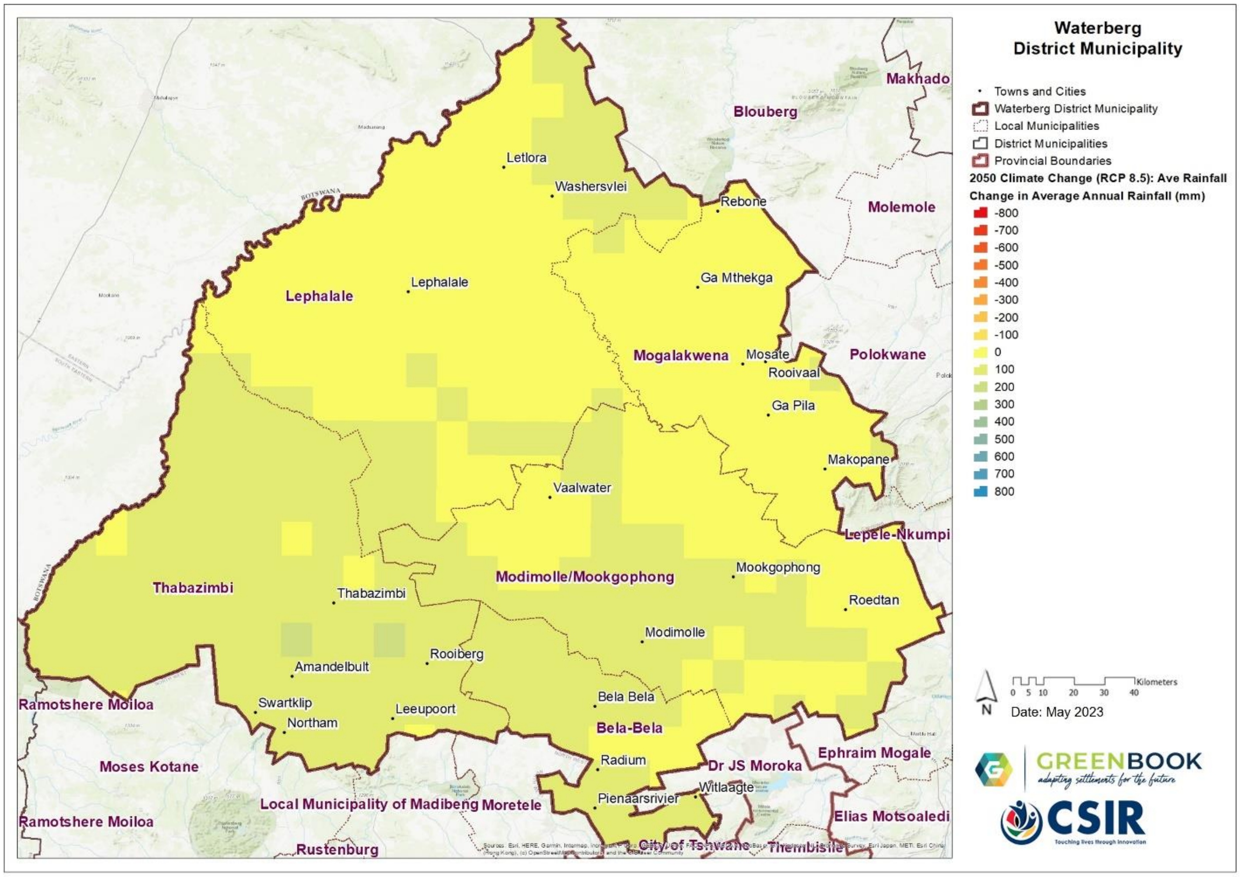

Figure 8: Projected change in annual average rainfall (mm) for the period 2021-2050 for Waterberg District Municipality (RCP8.5)

At the baseline, Waterberg District Municipality experiences average annual rainfall of between 301 and 937mm, with higher averages found across the south-central parts of the District. The projections show average annual rainfall changes of between 17mm less and 91 mm more across the District by 2050, under a low mitigation scenario (RCP 8.5). Relatively higher increases in average annual rainfall are expected across the southern parts of the District, with another pocket located in the most northern part of Waterberg. The rest of the District will generally experience no changes to slight increases in average annual rainfall.

2.3. Climate Hazards

This section showcases information with regards to Waterberg 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).

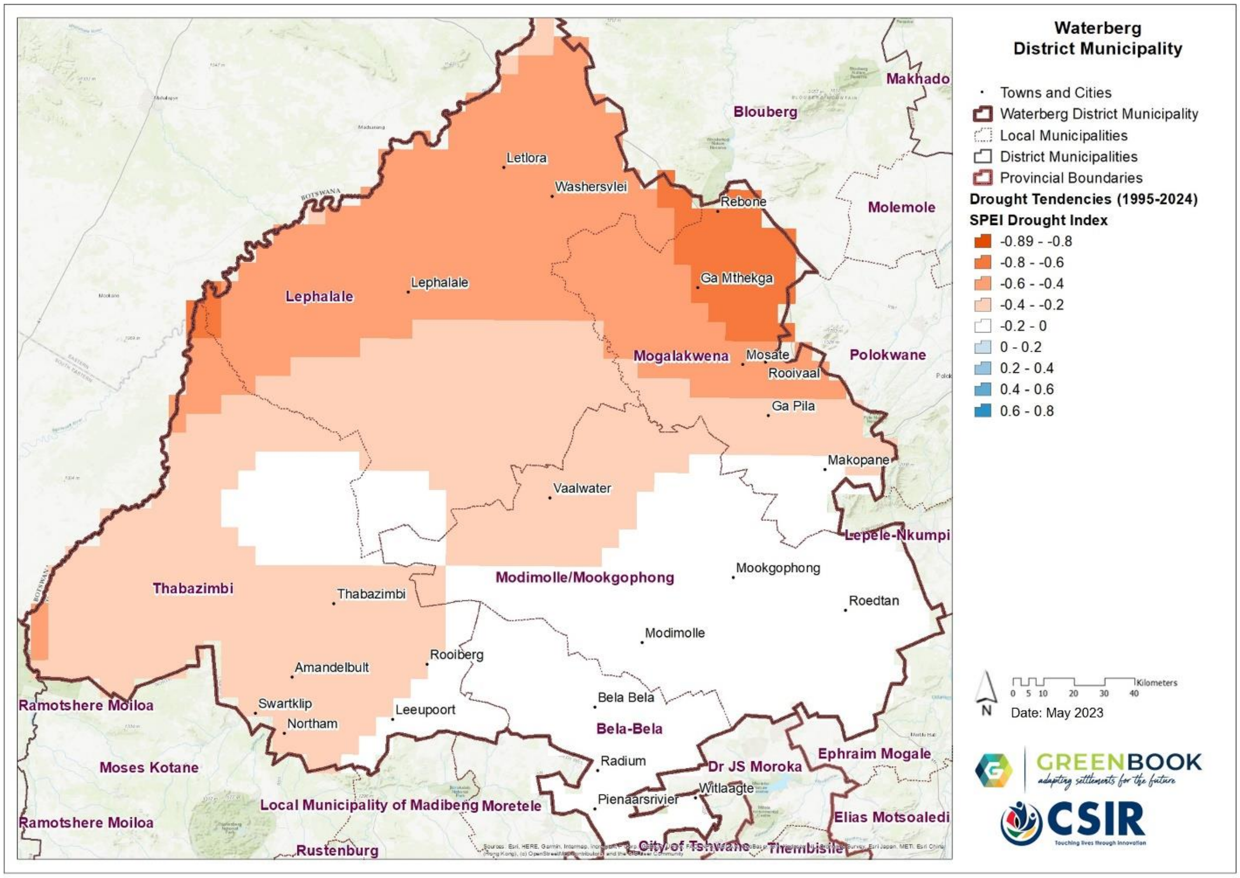

Figure 9: Drought tendencies for the period 1995-2024 relative to the baseline period Waterberg District Municipality

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).

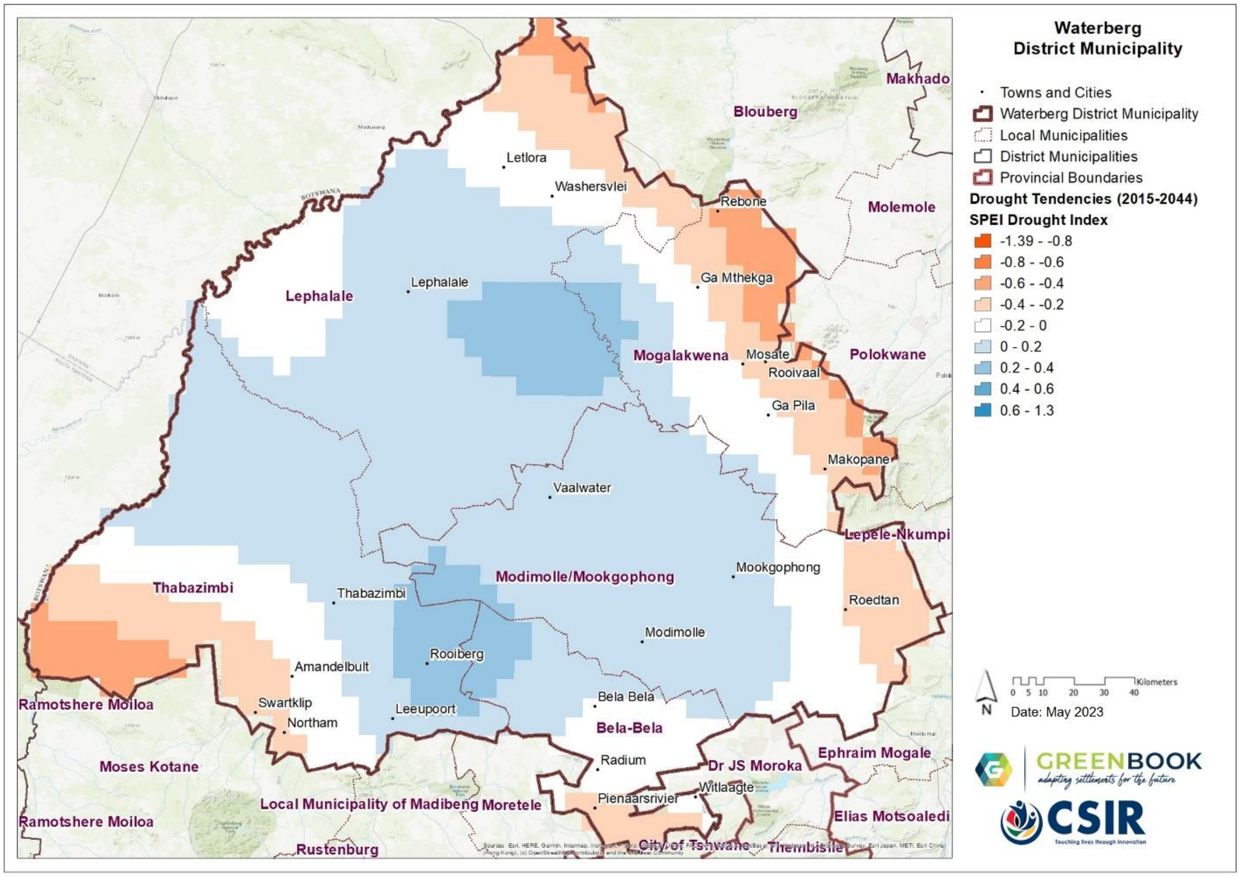

Figure 10: Projected drought tendencies for the period 2015-2044 relative to the baseline period for Waterberg District Municipality

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

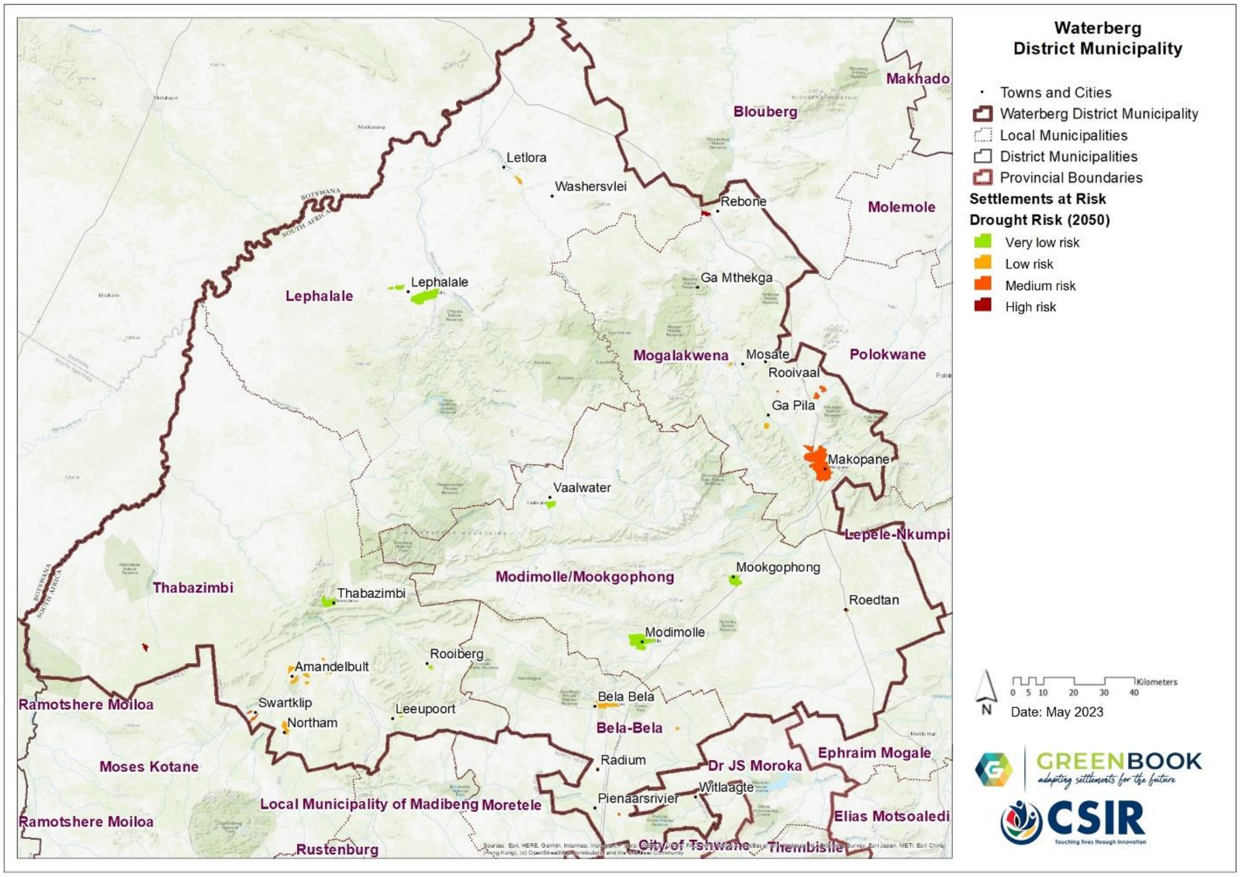

Figure 11: Settlement-level drought risk for Waterberg District Municipality

At the baseline (Figure 9), northern parts of the District, and parts of the south west, are exposed are exposed to higher drought tendencies, with the rest of the District experiencing near-normal conditions. Most of the District, particularly in the central parts, is expected to experience more periods of rainfall into the future (See Figure 10). Few settlements, including Rebone in Mogalakwena and Dwaalboom in Thabazimbi, face a high risk of drought into the future (Figure 11).

2.3.2. Heat

The climate model was used to simulate bias-corrected, annual average number of very hot days, which are days when the maximum temperature exceeds 35°C (units are the number of days per model grid point) for the baseline (current)period of 1961–1990, and the projected change for period 2021–2050.

The very hot days map (Figure 12) depicts the number of days (per 8 x 8 km grid point) where the maximum temperature exceeds 35°C. The annual heatwave days map (Figure 13) 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 5°C, for a period of at least three consecutive days.

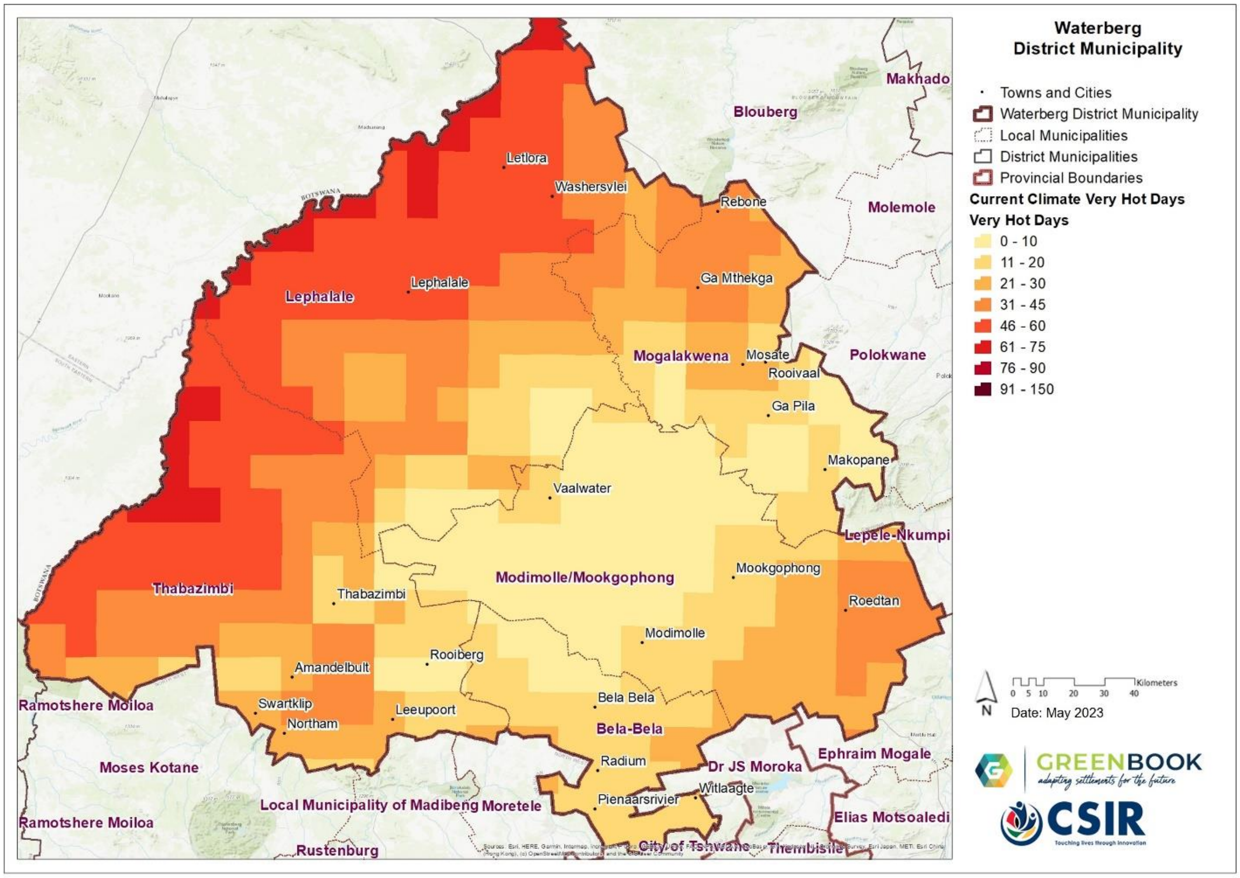

Figure 12: Number of baseline annual very hot days across Waterberg District Municipality

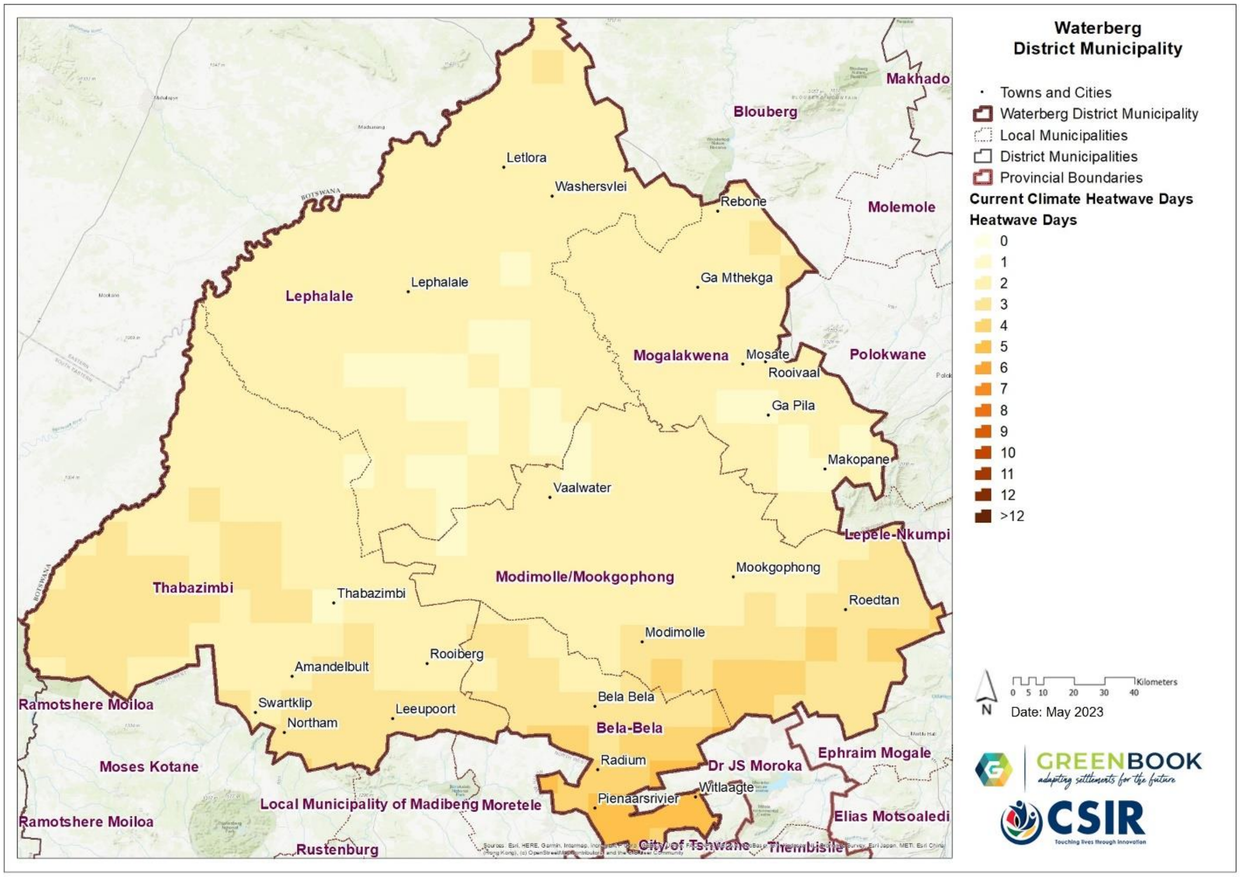

Figure 13: Number of baseline annual heatwave days across Waterberg District Municipality

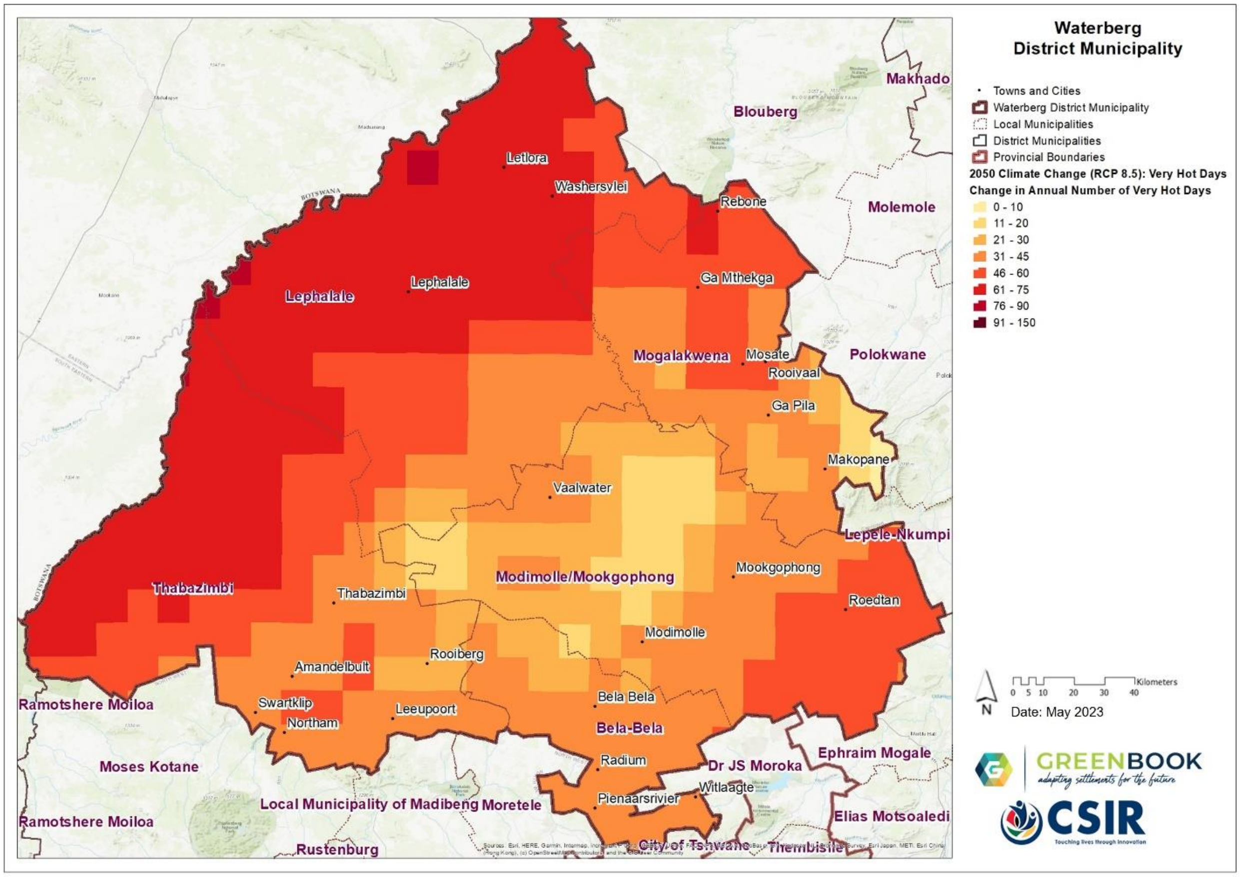

Figure 14: Projected change in annual average number of very hot days for the period 2021-2050 for Waterberg District Municipality

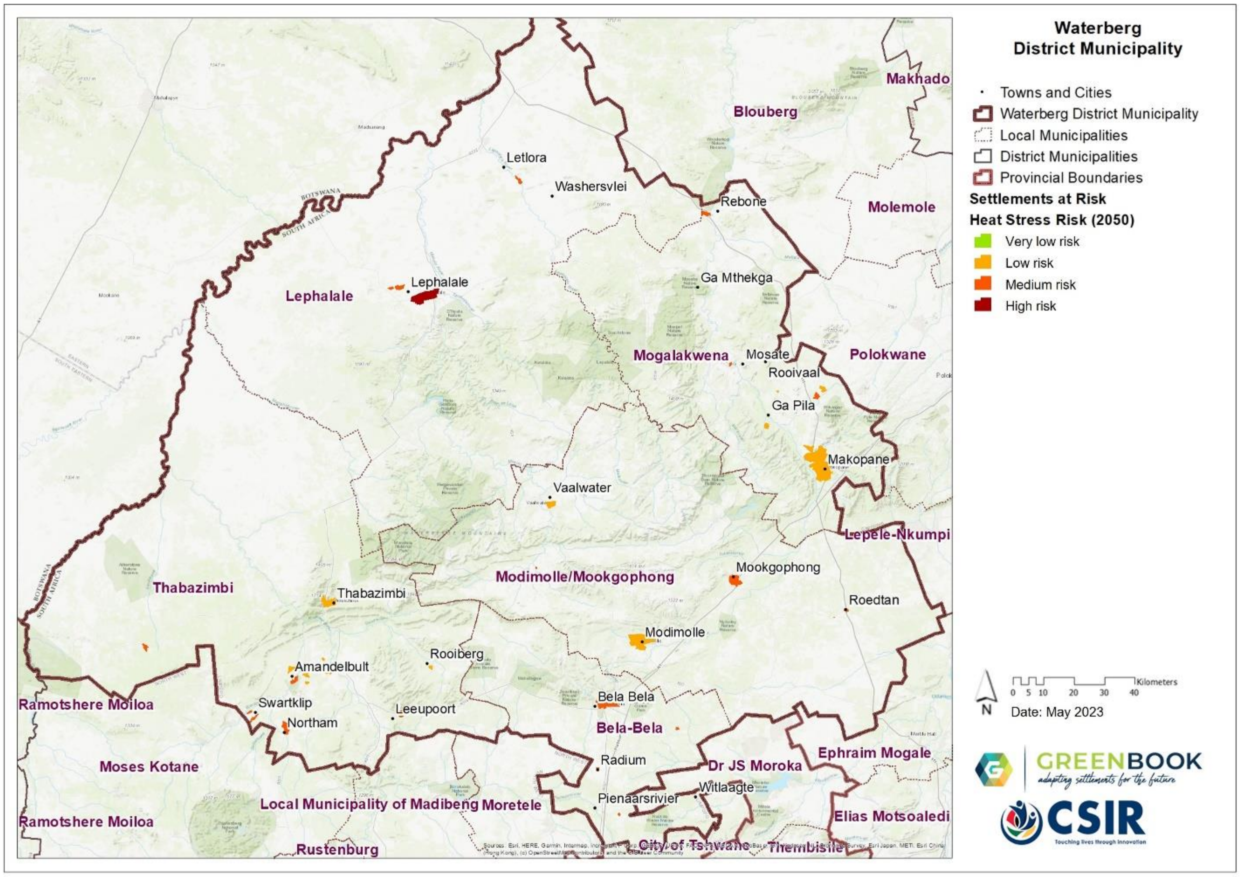

Figure 15: Settlement-level heat stress risk across Waterberg District Municipality

At the baseline, the greatest annual number of very hot days, ranging from 61 to75, are more likely to be experienced in areas along the west and north western border of the District, particularly along and near the western borders of Lephalale and Thabazimbi local municipalities, with most parts of Modimolle experiencing the lowest number of hot days in Waterberg (Figure 12). Heatwave events are currently more likely to take place in the most southern parts of the District, particularly in the municipality of Bela-Bela (Figure 13). The number of very hot days are projected to increase significantly in the areas that are already more likely to experience extreme heat (Figures 12 and 14).

Figure 15 depicts the settlements that are at risk of increases in heat stress. 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. Lephalale constitutes the District's settlement that could be most at risk to heat stress by 2050 (Figure 15).

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 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 '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 low mitigation (worst case) 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 is informed by the projected change in the number of fire danger days.

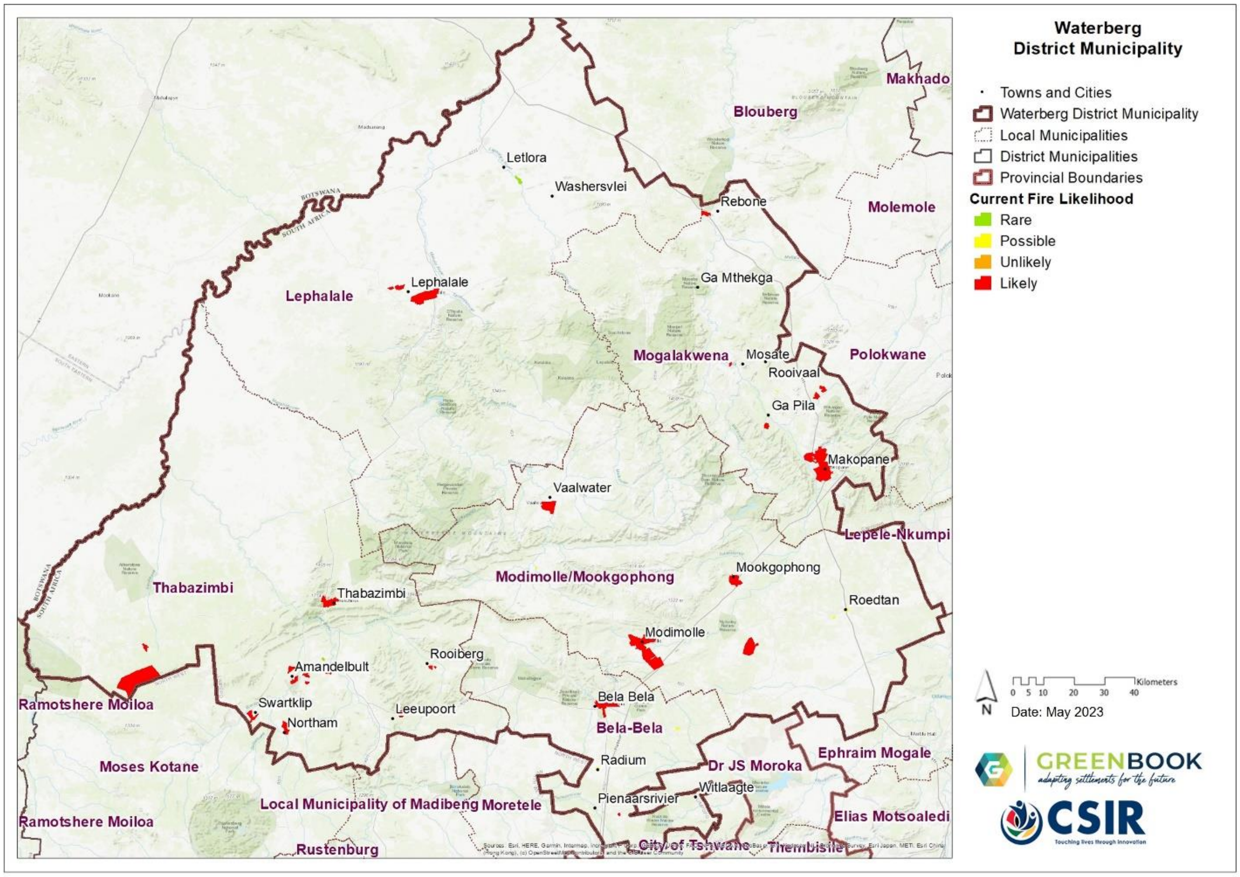

Figure 16: Current wildfire likelihood across settlements in Waterberg District Municipality

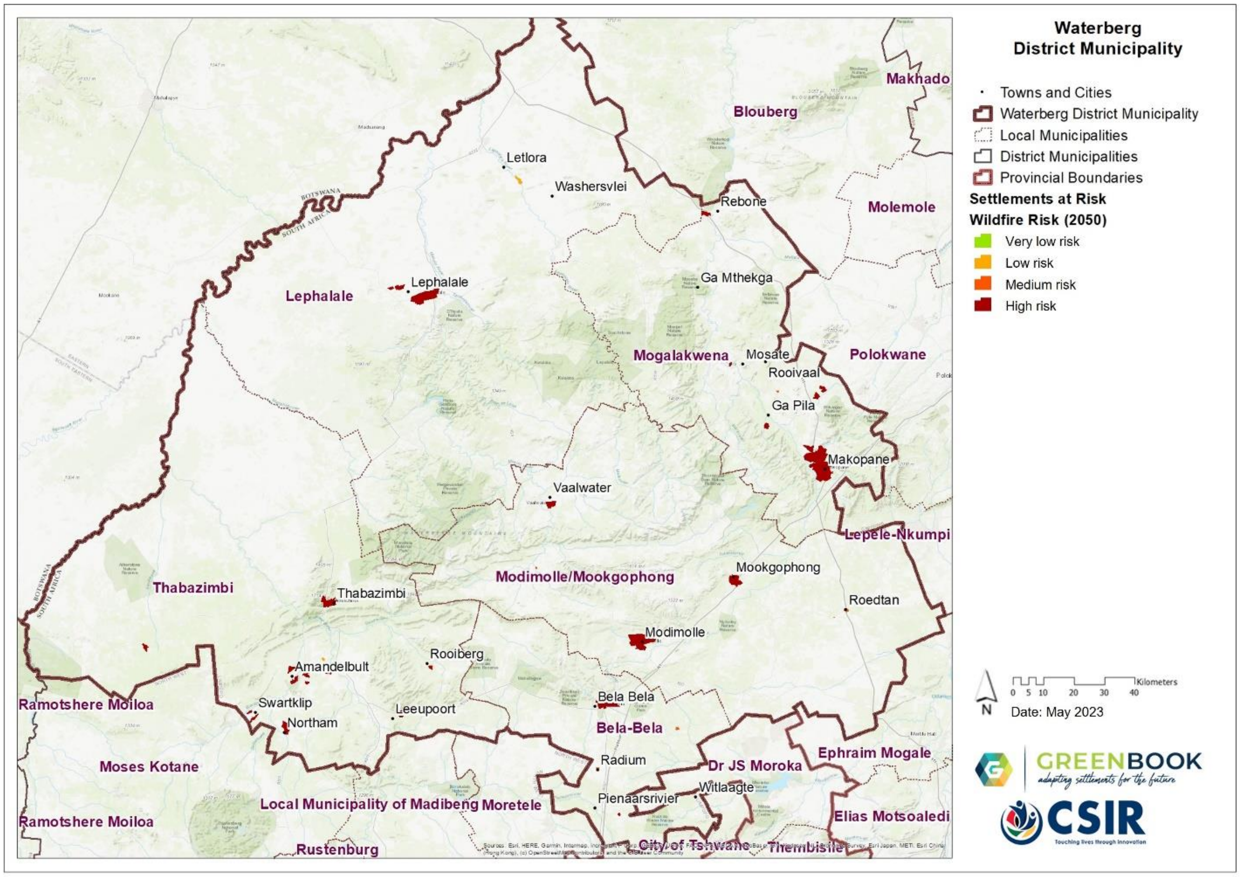

Figure 17: Settlement-level future wildfire risk across Waterberg District Municipality

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. Most of the settlements in Waterberg are very likely to experience wildfires on their wildland-urban interface. These include Bela-Bela, Modimolle, Lephalale, Leeupoort/Rooikrans, Rooiberg, Thabazimbi, Amandebult, Smersha Block, Setaria, Northam, Swartklip, Makopane, Ga Pila, Rooivaal, Mosate, Vaalwater, and Marapong, amongst others. It is projected that the same settlements face a high risk of wildfire in the future (i.e., by 2050).

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. 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, such as for example, recent informal settlement that may increase exposure and risk. Additional local and contextual information should be considered to further enrich the information provided here.

Since intense rainfall is the main driver of floods and rainfall intensity is likely to increase, estimates of the extreme daily rainfall in 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 for 2050.

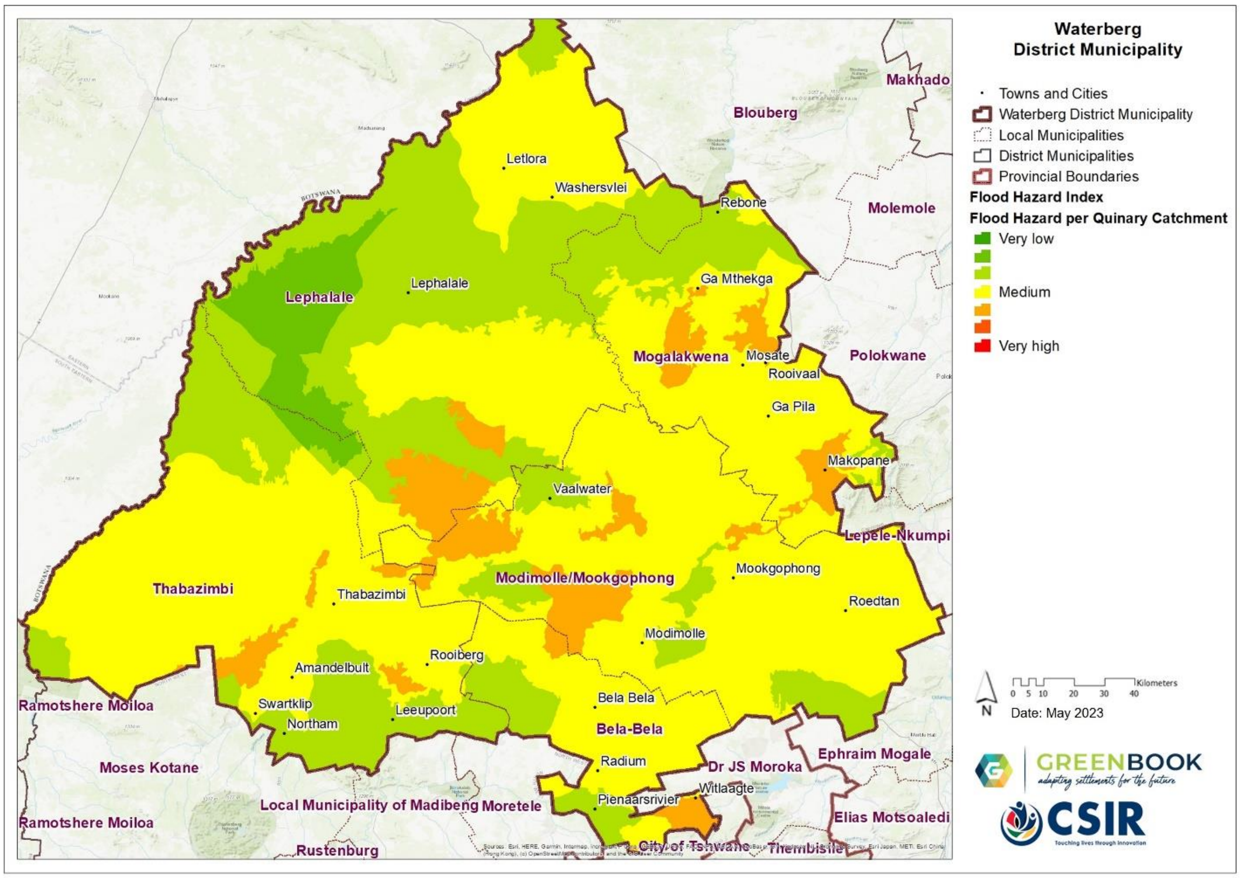

Figure 18: The current flood hazard index across Waterberg District Municipality

Figure 18 depicts the flood hazard index of the different quinary catchments present or intersecting with the District. 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, ranging from very low to slightly above medium flooding hazard, pockets of slightly above medium flooding hazard are scattered mostly across the central parts of the District (orange).

Figure 19 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., 95th percentile of daily rainfall) are compared with those under the current rainfall. A value of more than 1 indicates an increase in extreme daily rainfalls. Moderate decreases to significant increases in the number of extreme rainfall days are expected across the District, with decreases expected mostly in the north to central parts of the District, particularly in Lephalale and northern parts of Mogalakwena, and increases expected mostly across the southern and south-eastern parts of the District, especially in Thabazimbi, Modimolle-Mookgophong, as well as northern parts of Bela-Bela and southern parts of Mogalakwena.

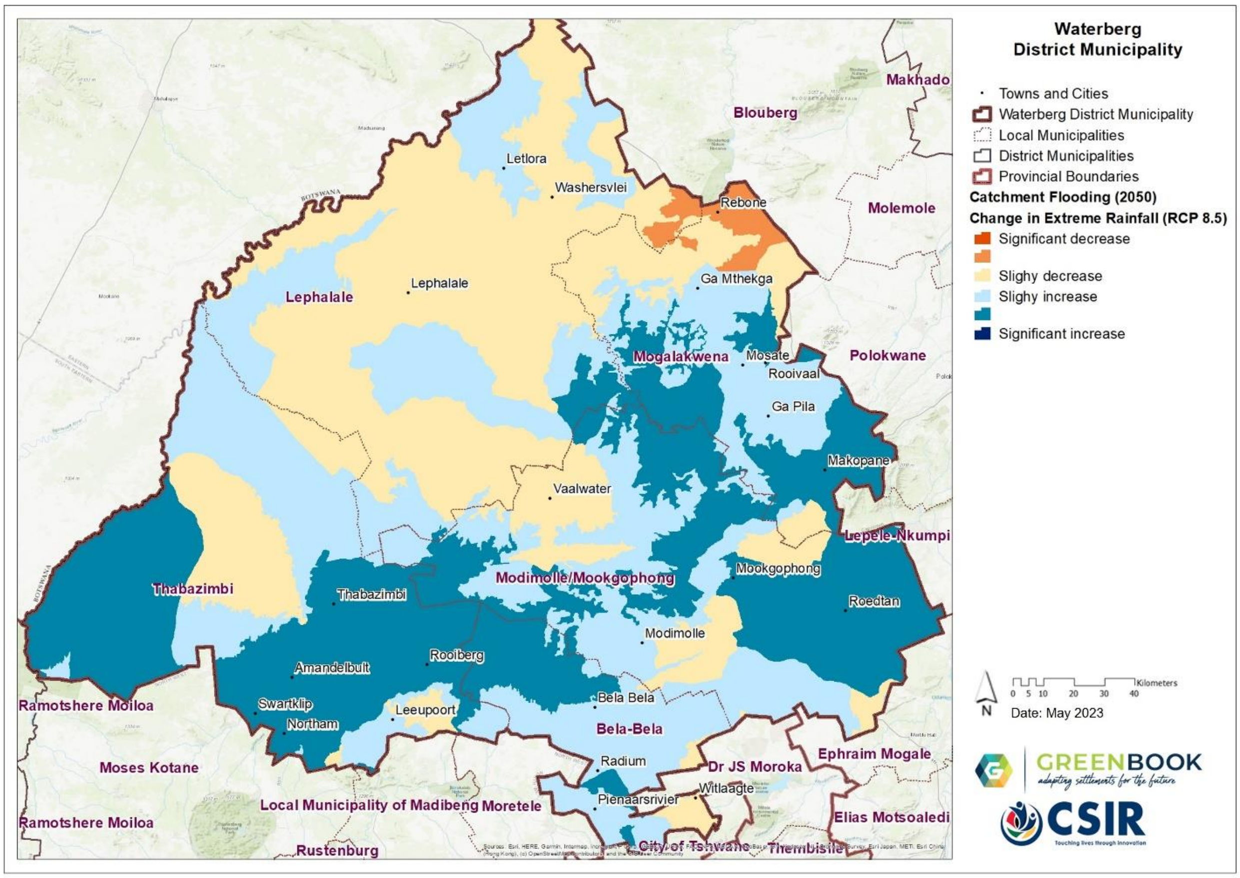

Figure 19: Change in extreme rainfall days across Waterberg District Municipality

Figure 20 depicts the settlements that are at increased risk of flooding under an RCP 8.5 low mitigation (worst case) scenario. Amandebult and surrounding areas, as well as Thabazimbi, Rooiberg, Rooival, GaPila and Mokopane are some of the settlements projected to be at medium risk to flooding in the future. No settlements in Waterberg are projected to face a high flood risk in the future, this may be a result of reduced exposure and moderate vulnerability to flooding.

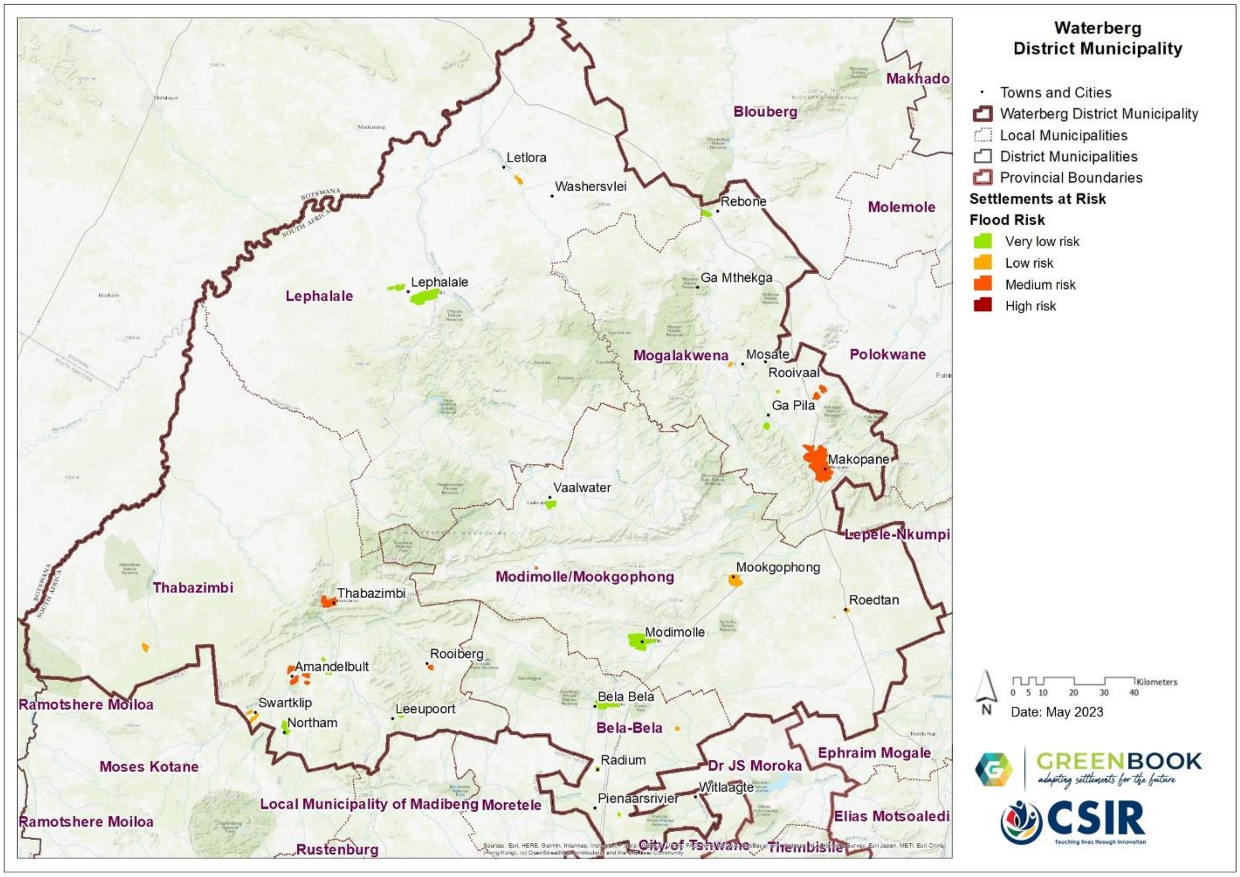

Figure 20: Settlement-level flood risk across Waterberg District Municipality.

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 Waterberg District Municipality.

2.4.1. Water resources and supply vulnerability

South Africa is a water-scarce country with an average rainfall of only about 450 mm per year, and 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. Like precipitation, runoff is highly variable both in space and time. 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 to move 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 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 temperatures will also increase pollution and water quality risks.

To get 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. 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. Firstly 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 19 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 is 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, 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 Waterberg District, there is a mix of surface water and groundwater dependent towns.

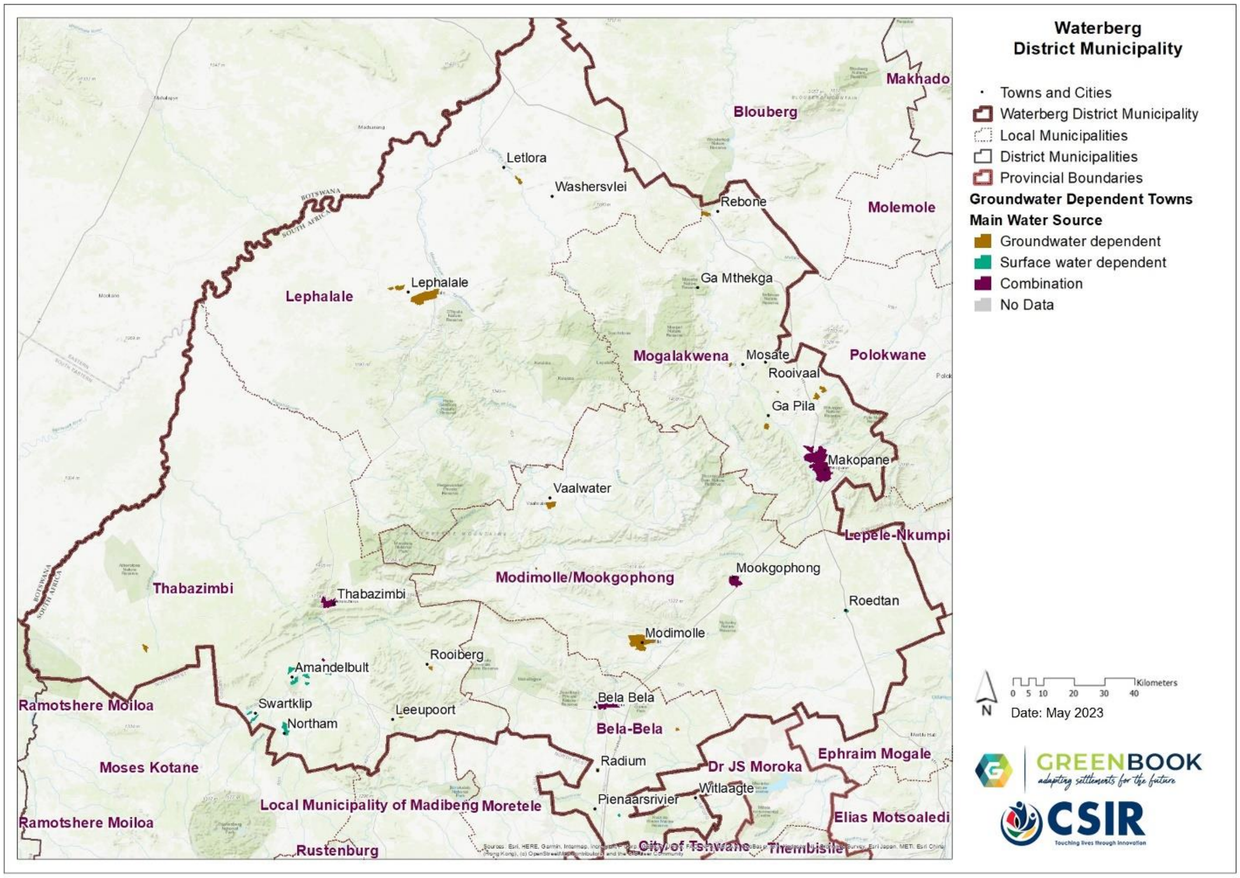

Figure 21: Main water source for settlements in the Waterberg District Municipality

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 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 most parts of the District, particularly across the central to southern parts of the Municipality. Recharge potential is lower in the northern parts of the District, especially in the most northern parts of Lephalale and Mogalakwena. Areas with a high recharge potential, at the baseline, are also projected to have an increase in groundwater recharge potential, by 2050.

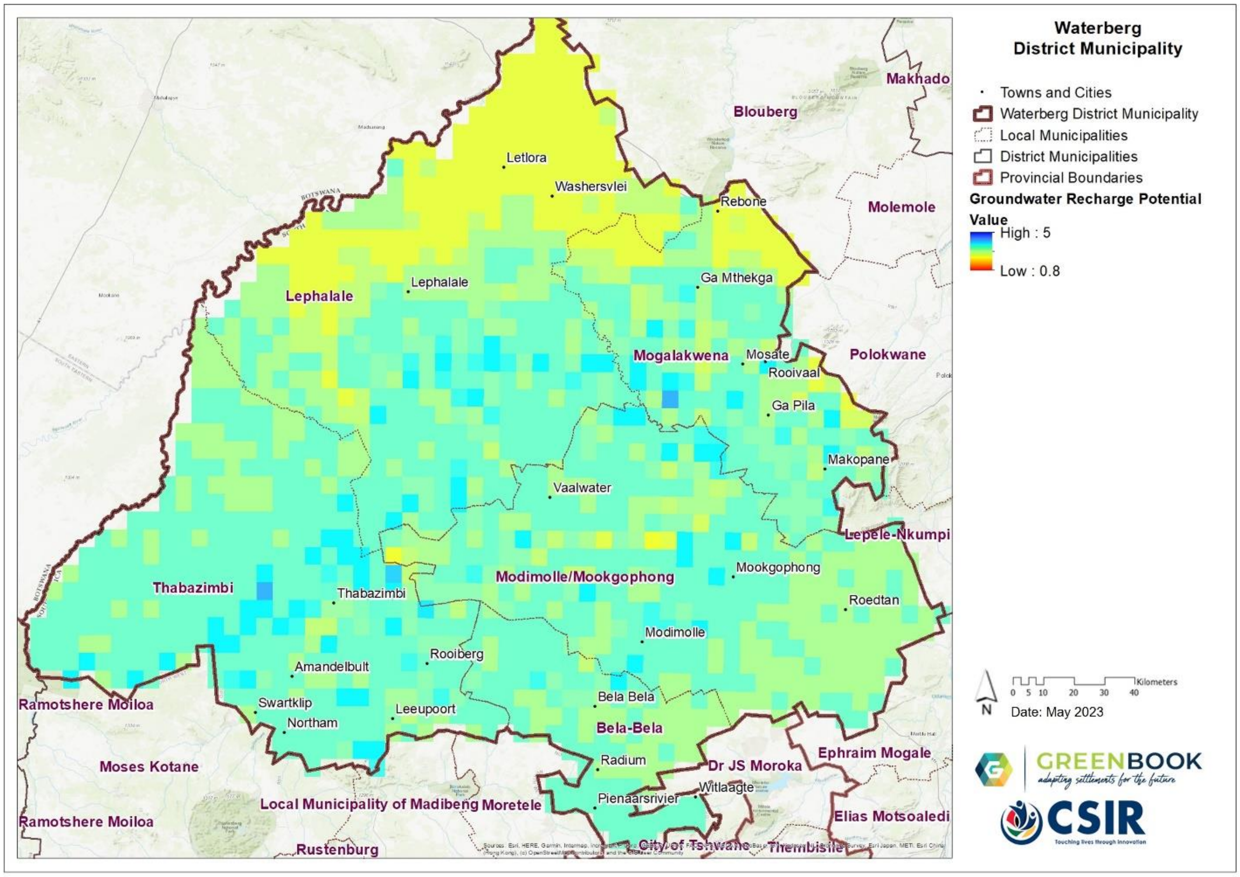

Figure 22: Current groundwater recharge potential across Waterberg District Municipality

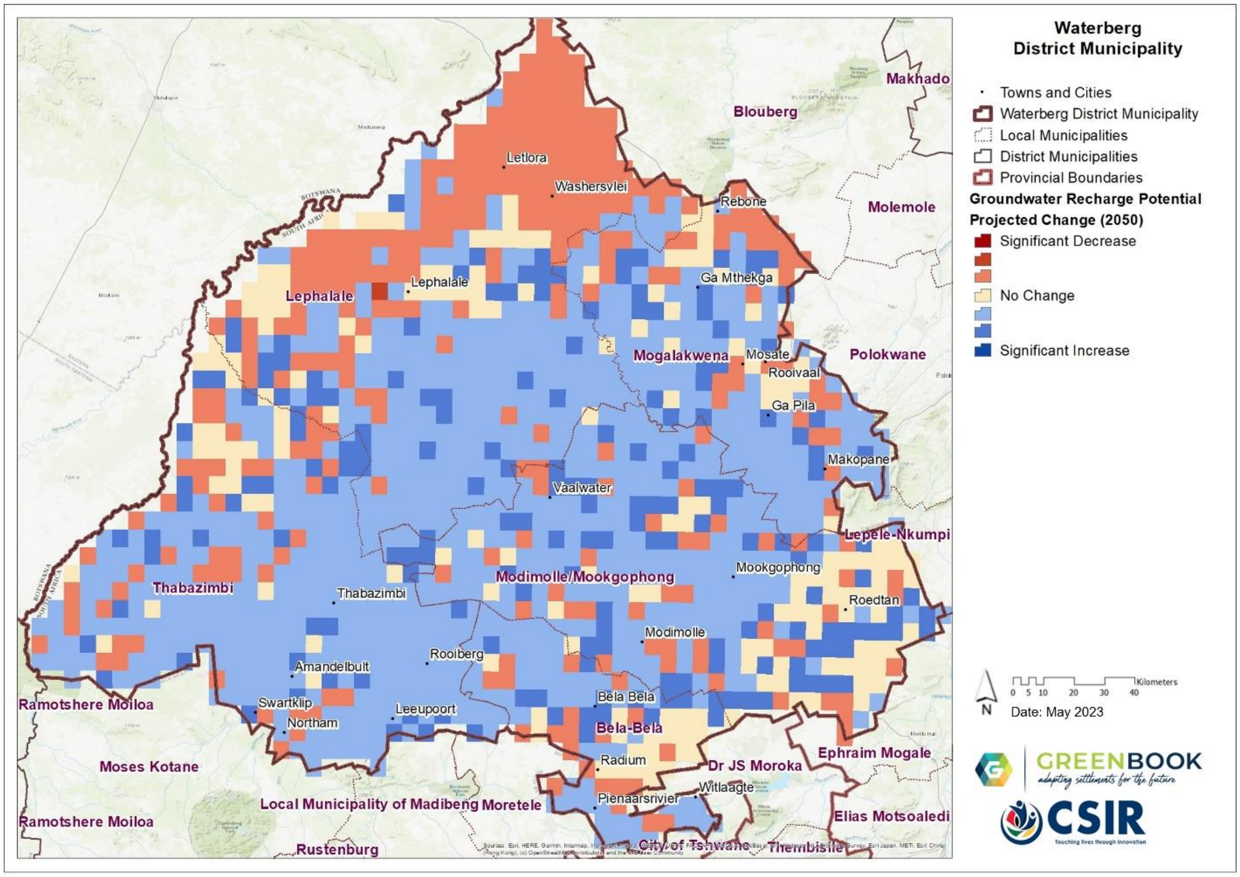

Figure 23: Projected change groundwater recharge potential across Waterberg District Municipality

The settlement of St Catherina, located south of Letlora, in Lephalale local municipality, has the highest risk of groundwater depletion, considering projected groundwater recharge potential combined with population growth (Figure 24). Other settlements that rely on groundwater (or a combination of ground- and surface water), that face a medium risk of groundwater depletion include Lephalale, Modimolle, Bela-Bela, Thabazmbi, and Rooiberg.

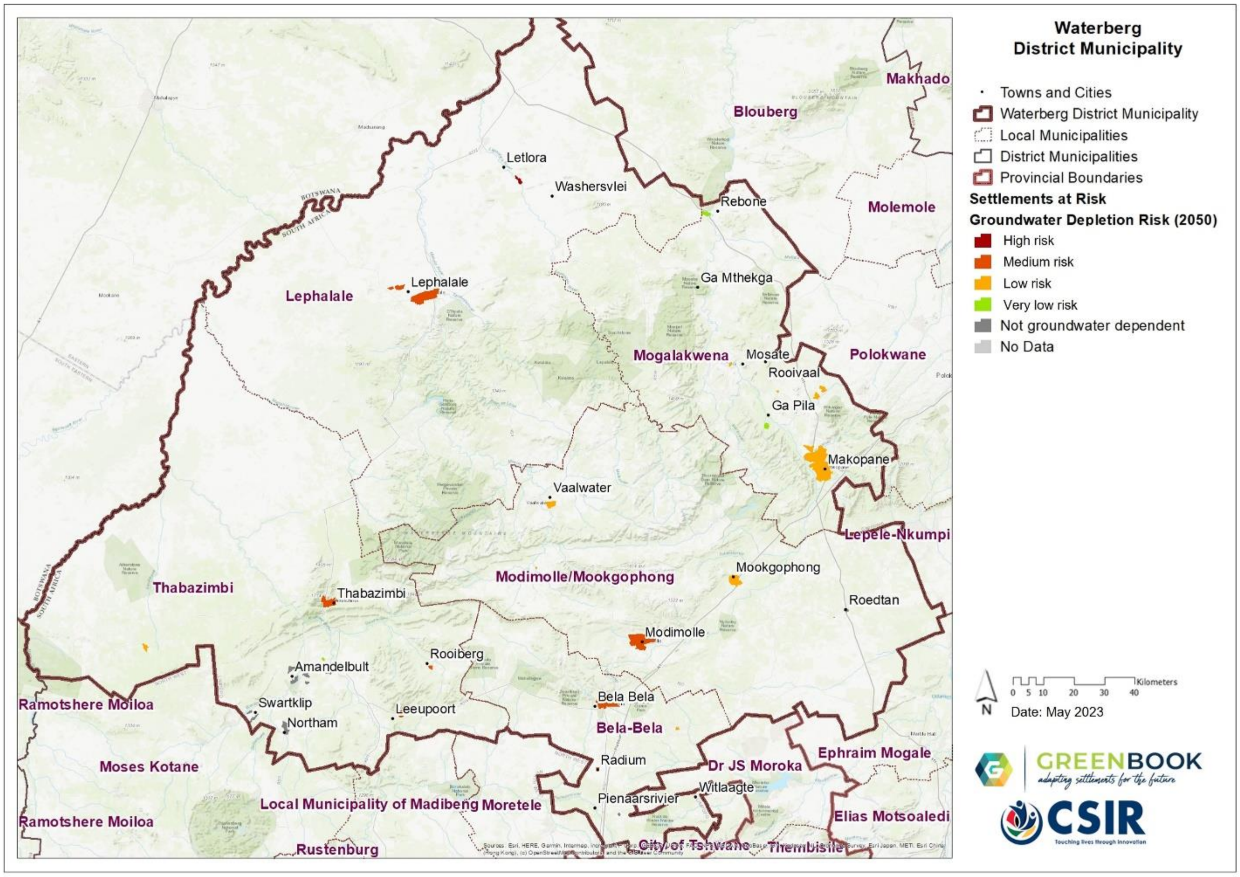

Figure 24: Settlement-level groundwater depletion risk across Waterberg District Municipality

Table 3 provides and overview of current water supply vulnerability (i.e., demand versus supply) for the local municipalities in the Waterberg District Municipality based on the data compiled for the Department of Water and Sanitation (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 Waterberg District Municipality

Local Municipality	Water Demand per Capita (l/p/d)	Water Supply per Capita (l/p/d)	Current Water Supply Vulnerability
Bela-Bela	118.1	117.52	1
Lephalale	93.3	209.3	0.45
Modimolle-Mookgophong	113.21	126.15	0.9
Mogalakwena	119.47	116.78	1.02
Thabazimbi	43.25	184.92	0.23

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 each of the local municipalities need to be considered when interpreting the information provided in this report. Water supply vulnerability per local municipality is discussed below.

Bela-Bela

Bela-Bela's water demand is currently almost equivalent to its supply, but because of the projected increase in mean annual evaporation and population growth, water supply vulnerability is projected to increase to between 1.6 and 2.03 in the future.

Lephalale

Water supply vulnerability is currently very low, with water supply significantly higher than demand, and because of the projected increase in population growth and mean annual evaporation, as well as the projected decrease in mean annual precipitation and runoff, water supply vulnerability is projected to increase to between 1.04 and 1.4 by 2050.

Modimolle-Mookgophong

Water supply vulnerability is currently low, with current water demand moderately higher than supply. The municipality's water supply vulnerability is projected to increase to between 1.03 and 1.3 by 2050, due to an increase in population growth and mean annual evaporation, as well as a decrease in mean annual runoff.

Mogalakwena

Water supply vulnerability is currently high, as water demand is slightly higher than supply. Water supply vulnerability is projected to range between 1 and 1.28 by 2050, as a result of the projected decreases in mean annual precipitation and runoff.

Thabazimbi

At the baseline, water supply vulnerability is very low and is expected to remain low, ranging between 0.38 and 0.52, by 2050. The municipality's water supply vulnerability is driven by projected increases in regional urban water supply and mean annual runoff.

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 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 we have 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.

Waterberg's agricultural sector contributes 3% to District's GVA and makes up 30% of the province's agricultural activity. The potential impact of climate change and climate hazards on agriculture is notable considering that sector employs around 21% of the District's labour force (CoGTA, 2020; WDM, 2023). Furthermore, Waterberg has the biggest extent of agricultural area (4.3 million hectares) in Limpopo, which translates to approximately 38.5% of the province's agricultural area (WDM, 2023). There is potential to expand the areas under production, in Waterberg, to areas with suitable agro-climatic conditions, thus providing opportunities for value chain development, and further job creation (CoGTA, 2020, p. 26).

Below the main agricultural commodities for each municipality within the Waterberg District is discussed in terms of what the impact of climate change might be on those commodities under an RCP 8.5 low-mitigation scenario.

Bela-Bela

In Bela-Bela the Agriculture, Forestry and Fisheries sector contributes 5.44% to the local municipality's GVA, which is a contribution of 0.24% to the national GVA for the Agriculture, Forestry and Fisheries sector. Of the total employment, 15.52% is within the Agriculture, Forestry and Fisheries sector. The main commodities are sunflower seeds, tobacco and pigs. Climate projections show a generally hotter and wetter climate, which could result in increased sunflower seed yields. However, projected increases in heat stress could result in lower seed weight and lower oil content, as well as an altered fatty acid composition. Furthermore, heat stress could also decrease sunflower yield as it affects pollen production and floret fertility, even under well-watered, or wet, conditions. And although warm and humid conditions negatively affect reproductive efficiency and health of pigs, the production of tobacco remains viable as long as heat stress is managed.

Lephalale

In Lephalale the Agriculture, Forestry and Fisheries sector contributes 3.31% to the local municipality's GVA, which is a contribution of 0.4% to the national GVA for the Agriculture, Forestry and Fisheries sector. Of the total employment, 19.77% is within the Agriculture, Forestry and Fisheries sector. The main commodities are beef cattle and tobacco. Climate projections show a generally hotter and wetter climate, becoming drier towards the end of the century. Increased heat stress on livestock can lead to reduced growth & reproductive efficiency, while hot and moist conditions could result in increased spread of disease and parasites. Tobacco production remains viable under projected climate conditions, as long as heat stress is managed.

Modimolle-Mookgophong

In Modimolle-Mookgophong the Agriculture, Forestry and Fisheries sector contributes 9.73% to the local GVA, which is a contribution of 0.66% to the national GVA for the Agriculture, Forestry and Fisheries sector. Of the total employment, 28.54% is within the Agriculture, Forestry and Fisheries sector. The main commodities are tobacco, maize and beef cattle. Climate projections show a generally hotter and wetter climate, becoming drier towards the end of the century. Wetter conditions could result in increases in maize yield for near future. However, unmanaged heat stress could negatively affect maize production and tobacco crop quality.

Mogalakwena

In Mogalakwena the Agriculture, Forestry and Fisheries sector contributes 1.78% to the local municipality's GVA, which is a contribution of 0.23% to the national GVA for the Agriculture, Forestry and Fisheries sector. Of the total employment, 6.88% is within the Agriculture, Forestry and Fisheries sector. The main commodities are maize, beef cattle and chickens. Climate projections show a generally hotter and drier climate. Hot and dry conditions could result in potential maize yield reductions, as well as deterioration of veld/forage quality and quantity for cattle. The same conditions could result in increased production costs (through increased investment in ventilation and cooling) to maintain optimal seasonal temperatures and reduce the risk of heat stress for chickens. The impacts of heat stress on birds include reductions in body weight gain, reproduction efficiency and egg quality.

Thabazimbi

In Thabazimbi the Agriculture, Forestry and Fisheries sector contributes 0.9% to the local GVA, which is a contribution of 0.37% to the national GVA for the Agriculture, Forestry and Fisheries sector. Of the total employment, 12.33% is within the Agriculture, Forestry and Fisheries sector. The main commodities are wheat, sunflower seed and beef cattle. Climate projections show a generally hotter and wetter climate. Hot and moist conditions are likely to result in increased wheat yields for the near future. However, yield and crop suitability could decline over time as temperatures start to exceed critical crop thresholds. For the impact of hot and moist climate conditions on the production of sunflower seeds and beef cattle, please see earlier sections on the impacts of projected climate conditions on Bela-Bela's and Lephalale's AFF sectors.

3. Recommendations

The greatest risks faced across Waterberg District are increased temperatures, heat stress, as well as increased rainfall (and rainfall tendencies), with the latter likely to lead to increases in flooding and/or storm events. Increases in rainfall is also likely to increase the risk (or spread) of water- and vector-borne diseases, thus threatening the health of humans and animals (WDM, 2016). Increase in rainfall and storm events could also compromise key infrastructure and resources, as well as disrupt essential operations and the the provision of basic services such as electricity, water and healthcare. Wildfire constitutes another risk to settlements across Waterberg, and in settlements like Northam, Thabazimbi and Lephalale, this risk is combined with extremely high population growth, thus indicating the increasing exposure of people and their assets to the risk of wildfire in the future.

Although the District's groundwater recharge potential is projected to increase into the future, water supply vulnerability, where demand will outstrip supply, is expected to increase in all local municipalities within Waterberg, except Thabazimbi, thus indicating the need for local municipalities in Waterberg to diversify freshwater sources by tapping into groundwater reserves and conserving available potable water. Furthermore, most of the local municipalities in the District experienced a downward trend in economic vulnerability, particularly between 1996 and 2011, with high unemployment rates, thus alluding to the need to create more resilient and diverse local economies, which will also build the adaptative capacity of the District's local municipalities, to the impacts of climate change.

In response to these climate risks and impacts the following adaptation goals are recommended:

1. To prioritise the health and safety of communities in the face of a changing climate.
2. To reduce the vulnerability and exposure of human and natural systems to climate change and extreme events such as flooding, wildfire and heat extremes.
3. To ensure water security under a changing climate.
4. To develop climate-resilient, low-carbon, diverse and inclusive local economies that are socially responsible, environmentally sustainable and provide opportunities for marginalised residents.

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