Sedibeng District Municipality

Risk Profile Report based on the GreenBook

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Report compiled by the CSIR
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List of Acronyms and Abbreviations

°C	Degree Celsius
AFF	Agriculture, Forestry, and Fisheries
AR5	Fifth Assessment Report
CABLE	CSIRO Atmosphere Biosphere Land Exchange model
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
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
SDM	Sedibeng District Municipality
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	“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 Sedibeng District Municipality (DM), 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 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 fulfilment 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.

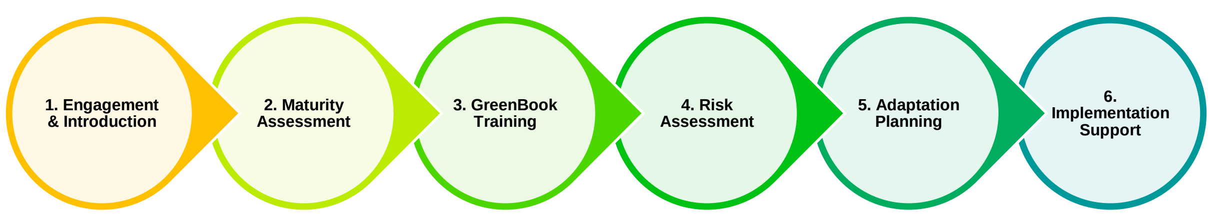

Figure 1: The Value-chain towards the implementation of climate change response and adaptation in municipalities

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, and services (including ecosystem services, ecosystems and species)" (Chen, et al., 2021, p. 64). The components of risk are dynamic. Climate hazards are driven by natural climate variability and anthropogenic climate change. Human activity contributes to Greenhouse Gas emissions that increase temperatures 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.

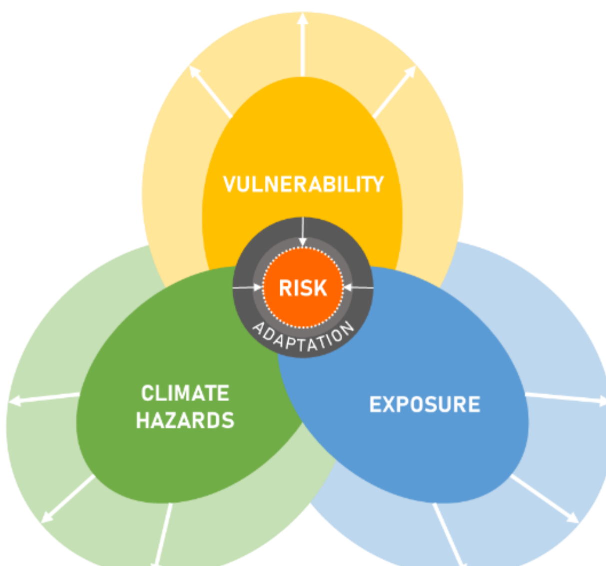

Figure 2: The interaction between the various components of risk, indicating the opportunity to reduce risk through adaptation (based on IPCC, 2014 and IPCC, 2021)

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 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, flooding, and coastal flooding and 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 all levels of planning, including 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 in support of climate change adaptation, 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 Sedibeng District Municipality (SDM) covers 4 173 km^2 of the Gauteng Province. The District is situated in the southern portion of Gauteng, bordering the Free State, North West and Mpumalanga provinces, thus bordering on the Districts of Gert Sibande (Mpumalanga), Fezile Dabi (Free State) and Dr Kenneth Kaunda (Northwest). The District is home to three Local Municipalities (LM), namely the Emfuleni, Lesedi and Midvaal Local Municipalities. Towns within these Municipalities include Vereeniging, Vanderbijlpark, Meyerton and Heidelberg. Townships include Evaton, Sebokeng, Boipatong, Bophelong, Sharpeville, Nigel and Devon. The District has a total population of 1 039 908 people (1.80 % of South Africa's total population). The population grew by 1.40 % between 2021-2016, and 1.60 % between 2016-2019 (CoGTA, 2020.).

The District's major contributor to the regional economy is the Manufacturing Sector, accounting for 23.80 % of the total Gross Value Added (GVA) (i.e., R17.4 billion). The second largest sector is the Community Services Sector (23.70 %), followed by the Finance Sector (20.50 %). The Agriculture Sector contributes least to the regional economy (CoGTA, 2020).

The biophysical environment of the District is dominated by grassland, with scattered areas of savanna. The Vaal River and Vaal Dam are key water sources within the District and the Province. It is considered to be the most important water source in the country. The high concentration of people and industrial development lead to several environmental challenges within the District, such as loss of biodiversity, water- and air-quality, and encroachment on sensitive habitats (DEA, 2018).

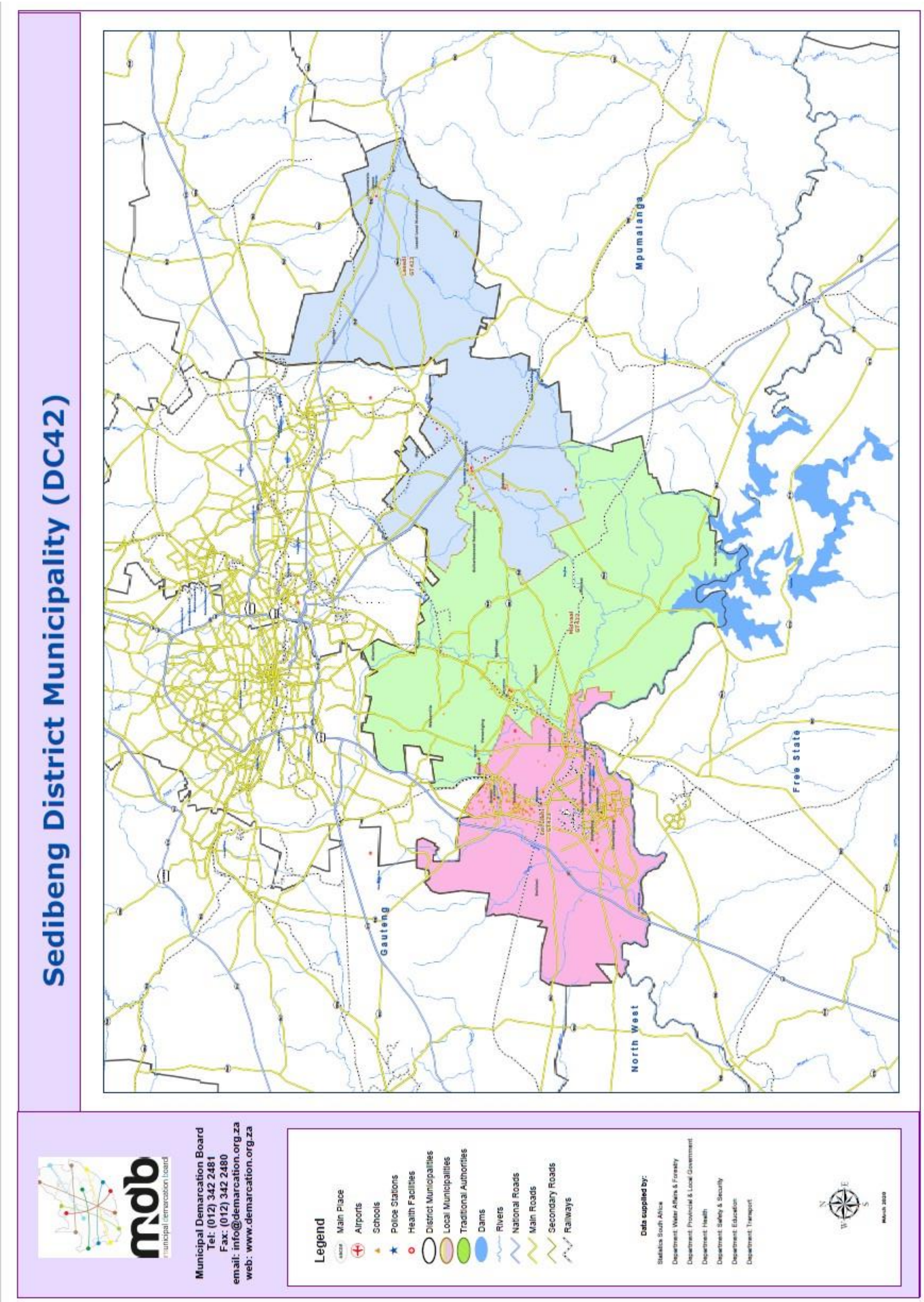

Figure 3: Sedibeng District Municipality (Municipal Demarcation Board, 2022), with Local Municipalities shaded in different colours

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 as 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 are 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 Sedibeng 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 Sedibeng 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 municipalities in Sedibeng 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 Sedibeng District is given 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 Sedibeng District Municipality

LOCAL MUNICIPALITY	SEVI 1996	SEV 2011	Trend	EcVI 1996	EcVI 2011	Trend	PVI	Trend	EnVI	Trend
Emfuleni	2.77	2.82	↗	5.80	7.96	↗	4.20	n/a	5.95	n/a
Lesedi	4.46	3.13	↘	4.85	6.72	↗	4.41	n/a	4.30	n/a
Midvaal	2.95	2.21	↘	2.91	5.06	↗	5.11	n/a	3.86	n/a

Socio-economic vulnerability has decreased (improved) for two Local Municipalities between 1996 and 2011, namely Midvaal and Lesedi. Emfuleni LM's socio-economic vulnerability has decreased slightly. In 2011 Midvaal LM had the lowest socio-economic vulnerability, and Lesedi LM had the highest. Emfuleni LM has the highest economic vulnerability in the District and the second highest in the Province. The District experienced significant deindustrialisation because of the decline in the steel industry. The unemployment rate is therefore very high at 50.70 %, with a job shortage of 120 218. The District has therefore the highest poverty levels in the Gauteng Province. Only 42.60 % of the Sedibeng's population is employed (CoGTA, 2020).

2.1.2. Settlement vulnerability

The unique set of indicators outlined below highlight the multi-dimensional vulnerabilities of the settlements within the Sedibeng 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 indictors, that show the level of services offered and rendered within a settlement and it includes the settlement's (1) access to basic services (electricity, water, sanitation, and refuse removal), (2) the 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.

Emfuleni Local Municipality

The major settlements in this Local Municipality are Sebokeng, Vereeniging, Vanderbijlpark, Evaton, and Sharpeville. Settlements are projected to experience no increase, or even a decrease, in population growth, therefore no major population growth pressure is expected on local government in this Municipality.

Lesedi Local Municipality

The major settlements in this Local Municipality are Heidelberg and Ratanda. Heidelberg faces extreme growth pressure between 2011 and 2050, and Ratanda faces high growth pressure. Ratanda has high economic and socio-economic vulnerability and is poorly connected to the region. However, it has good service access.

Midvaal Local Municipality

The major settlements in this Local Municipality are Meyerton and Lakeside. Both settlements are faced with extreme growth pressure, and Lakeside has a very high socio-economic and economic vulnerability. Both settlements have good regional connectivity.

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 assumptions of their in- and out-migration assumptions. The medium growth scenario (Table 2) assumes that the peak of population influx from more distant and African 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 Sedibeng District Municipality

Population per municipality	2011	Medium Growth Scenario	
		2030	2050
Emfuleni	721 583	746 789	688 656
Lesedi	99 505	145 821	197 199
Midvaal	95 286	158 016	243 747
Sedibeng DM Total	916 374	1 050 626	1 129 602

The District's population is projected to increase by 23 % between 2011 and 2050, under a medium growth scenario. Most of this growth will take place in the settlements within Midvaal LM. Emfuleni LM will possibly see a decline in population numbers between 2011 and 2050. 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 Heidelberg and Meyerton.

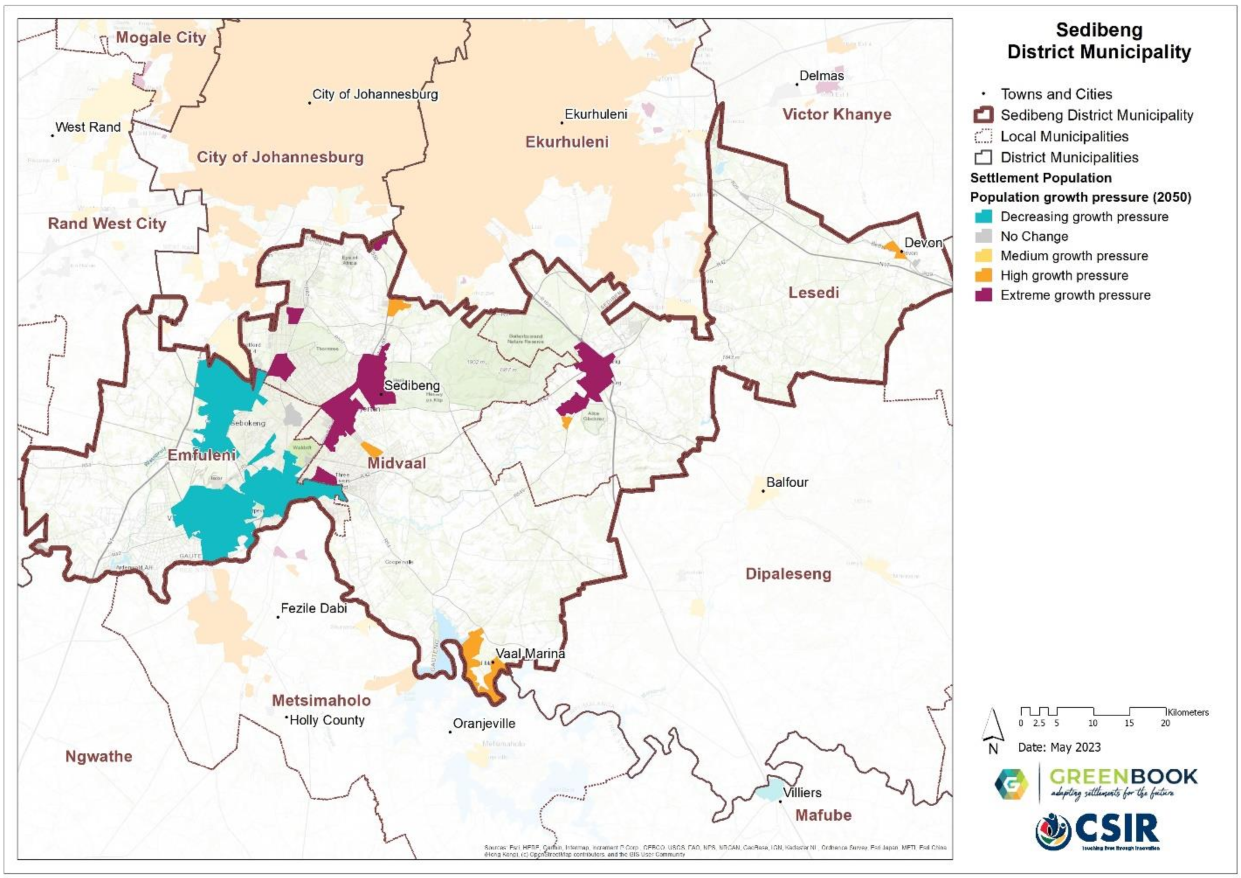

Figure 4: Settlement-level population growth pressure across Sedibeng District Municipality

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 Model (GCM) developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). CCAM runs coupled to a dynamic land-surface model CABLE (CSIRO Atmosphere Biosphere Land Exchange model). GCM simulations of the Coupled Model Inter-Comparison Project 5 (CMIP5) and the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), obtained for the emission scenarios described by Representative Concentration Pathways 4.5 and 8.5 (RCP 4.5 and RCP 8.5) were first downscaled to 50 km resolution globally. The simulations span the period 1960–

2100. RCP 4.5 is a high mitigation scenario (assuming a reduction in CO_2 emissions into the future), whilst RCP 8.5 is a low mitigation scenario (assuming "business as usual" emissions).

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

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

For more information on the climate simulations, see the GreenBook Climate Change Story Map and the full technical report.

For each of the climate variables discussed below:

a) The simulated baseline (also termed "current" climatological) state over South Africa calculated for the period 1961–1990 is shown (note that the median of the 6 downscaled GCMs 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 1961-1990.
c) An RCP 8.5 scenario (low mitigation) is assumed.

2.2.1.Temperature

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

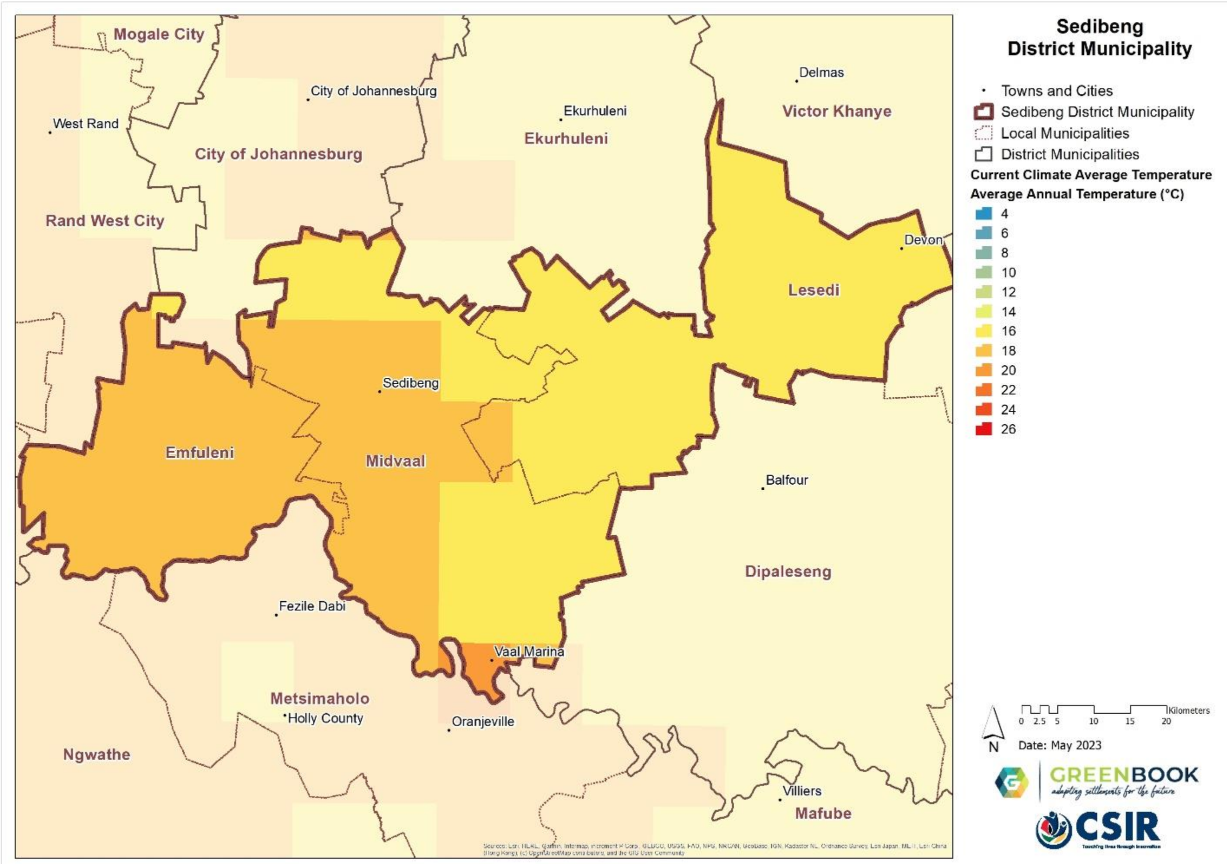

Figure 5: Average annual temperature (°C) for the baseline period 1961-1990 for Sedibeng District Municipality

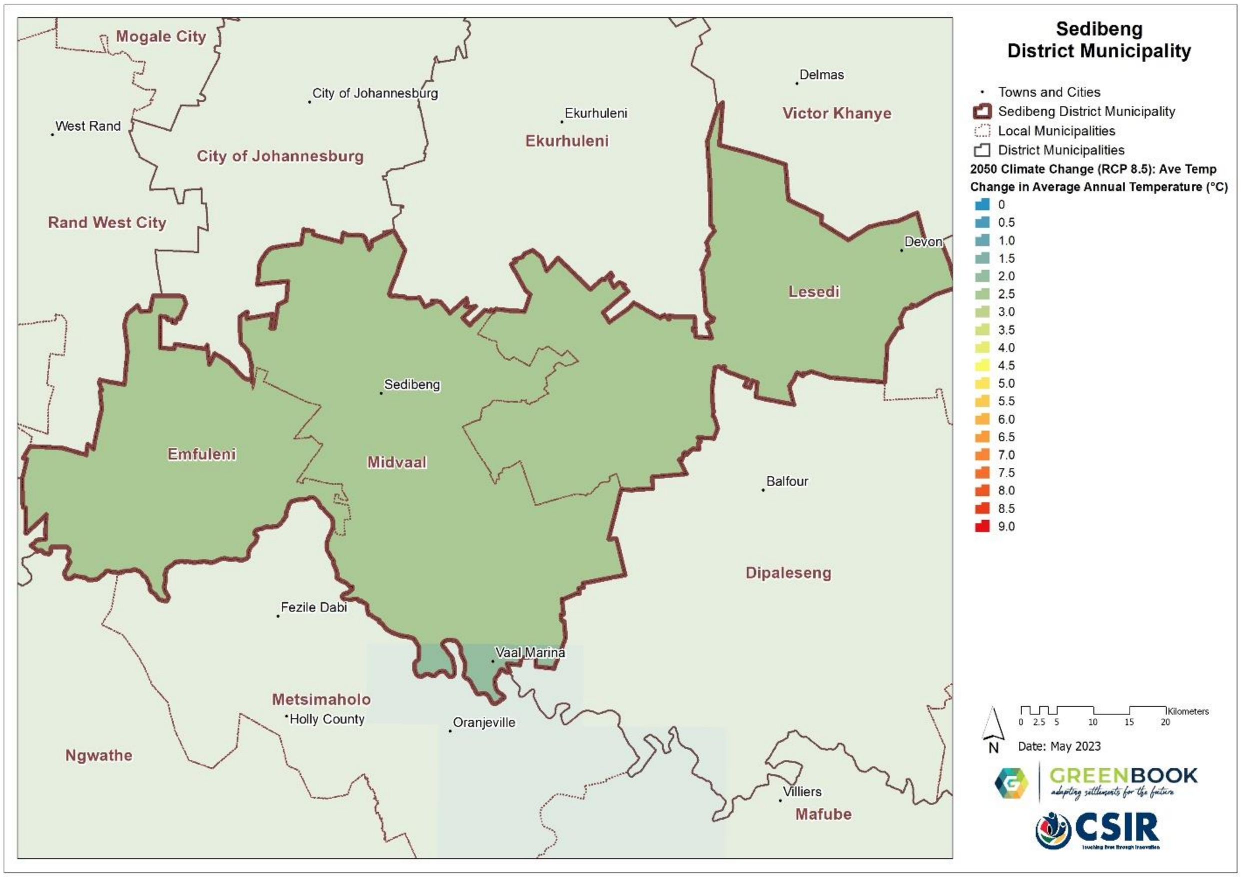

Figure 6: Projected change in average annual temperature (°C) from the baseline period to the period 2021-2050 for Sedibeng District Municipality, assuming an RCP 8.5 emissions pathway

The District experiences current average annual temperatures of between 16 °C and 20 °C, with higher averages found in Emfuleni LM, and parts of Midvaal LM in the west. The projections show average annual temperature increases of between 2 °C and 3 °C across the District by 2050, under a low mitigation scenario. The projected increase in temperature is very much the same for the three Local Municipalities, with the lowest projected increase for the Vaal Marina in the Local Municipality of Midvaal.

2.2.2. Rainfall

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

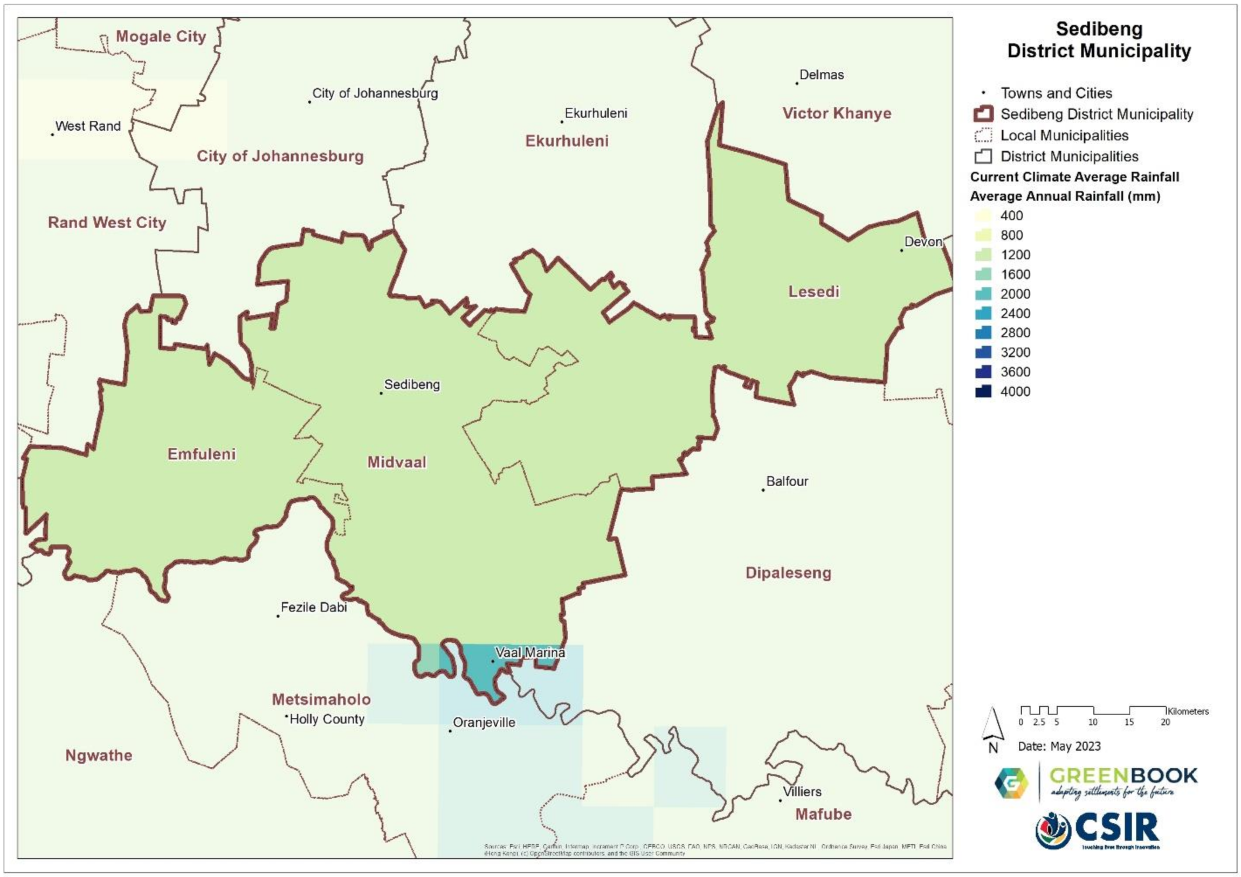

Figure 7: Average annual rainfall (mm) for the baseline period 1961-1990 for Sedibeng District Municipality

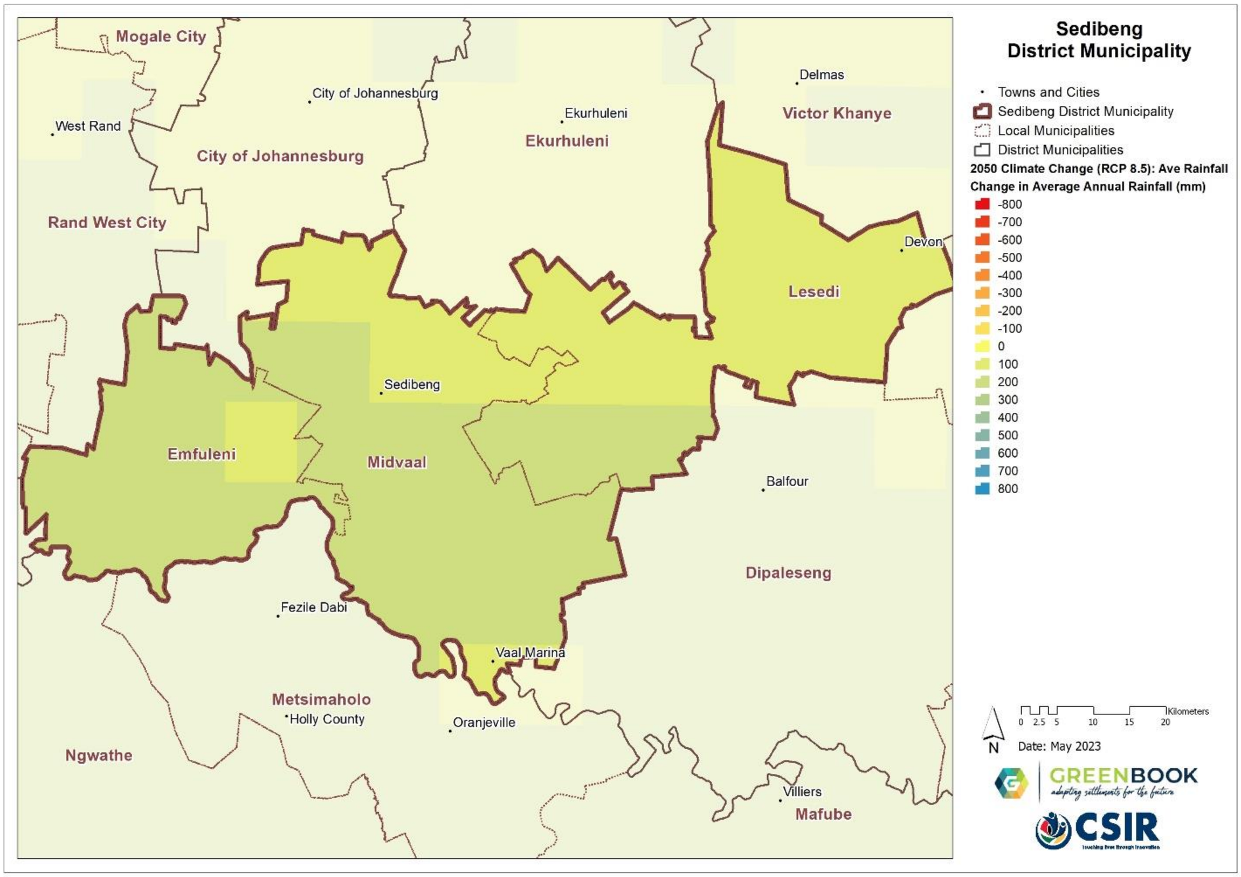

Figure 8: Projected change in average annual rainfall (mm) from the baseline period to the period 2021-2050 for Sedibeng District Municipality, assuming an RCP8.5 emissions pathway

The District experiences current average annual rainfall of 1000 mm, with a higher average of 1600 mm found around Vaal Marina in Midvaal. The projections show average annual rainfall change of between 12 mm less and 188 mm more across the District by 2050, under a low mitigation (i.e., a "business as usual" greenhouse gas emissions) scenario. Increases in rainfall are expected across all three Local Municipalities, while slightly less rainfall is expected in the northern corner of Lesedi.

2.3. Climate Hazards

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

2.3.1. Drought

The southern African region (particularly many parts of South Africa) is projected to become generally drier under enhanced anthropogenic forcing, with an associated increase in dry spells and droughts. To characterise the extent, severity, duration, and time evolution of drought over South Africa, the GreenBook uses primarily the Standardised Precipitation Index (SPI), which is recommended by the World Meteorological Organisation (WMO) and is also acknowledged as a universal meteorological drought index by the Lincoln Declaration on Drought. The SPI, with a two-parameter gamma distribution fit with maximum likelihood estimates of the shape and scale parameters, was applied on monthly rainfall accumulations for a 3-, 6-, 12-, 24- and 36-months base period. The SPI severity index is interpreted in the context of negative values indicating droughts and positive values indicating floods. These values range from exceptionally drier (<-2.0) or wetter (>2.0) to near-normal (region bounded within -0.5 and 0.5).

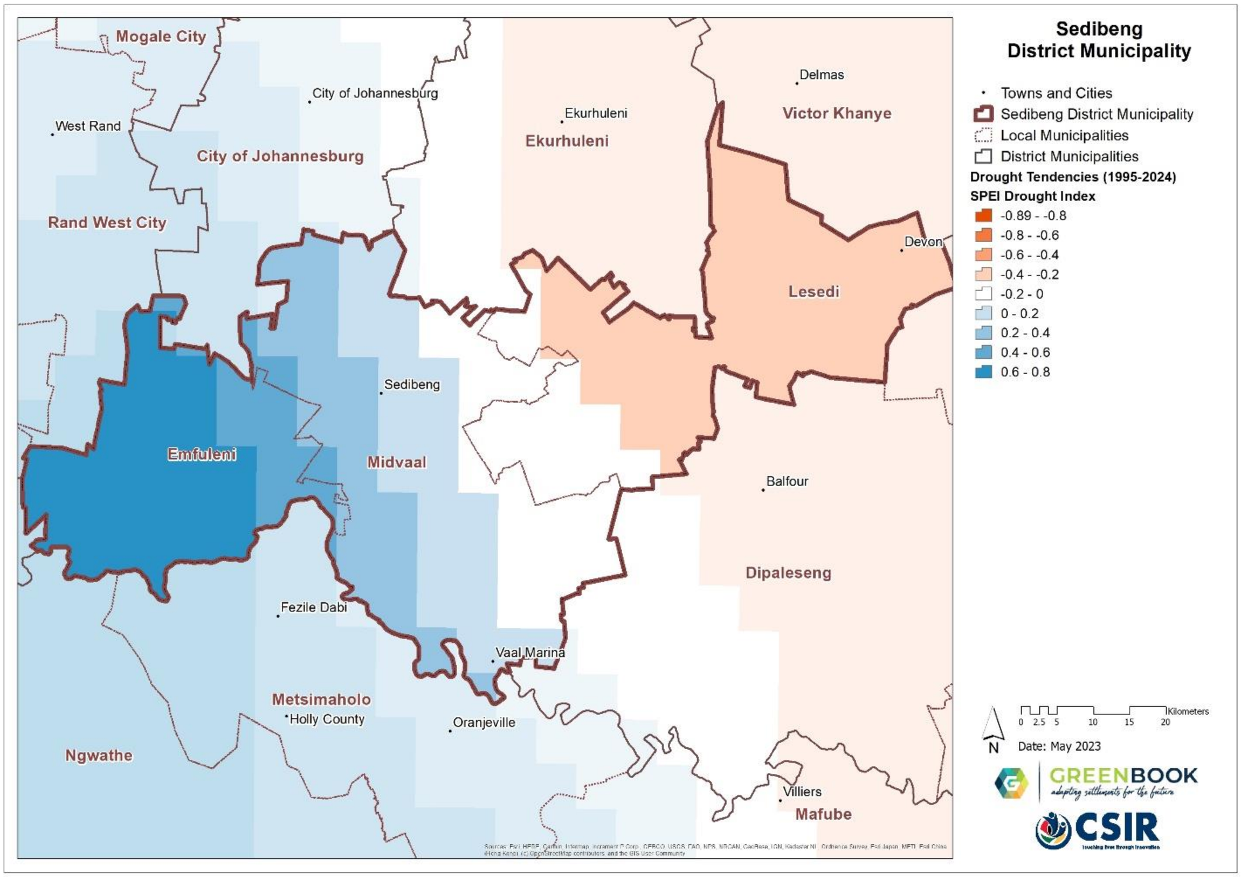

Figure 9: Projected changes in drought tendencies from the baseline period (1986 – 2005) to the current period (1995 - 2024)

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

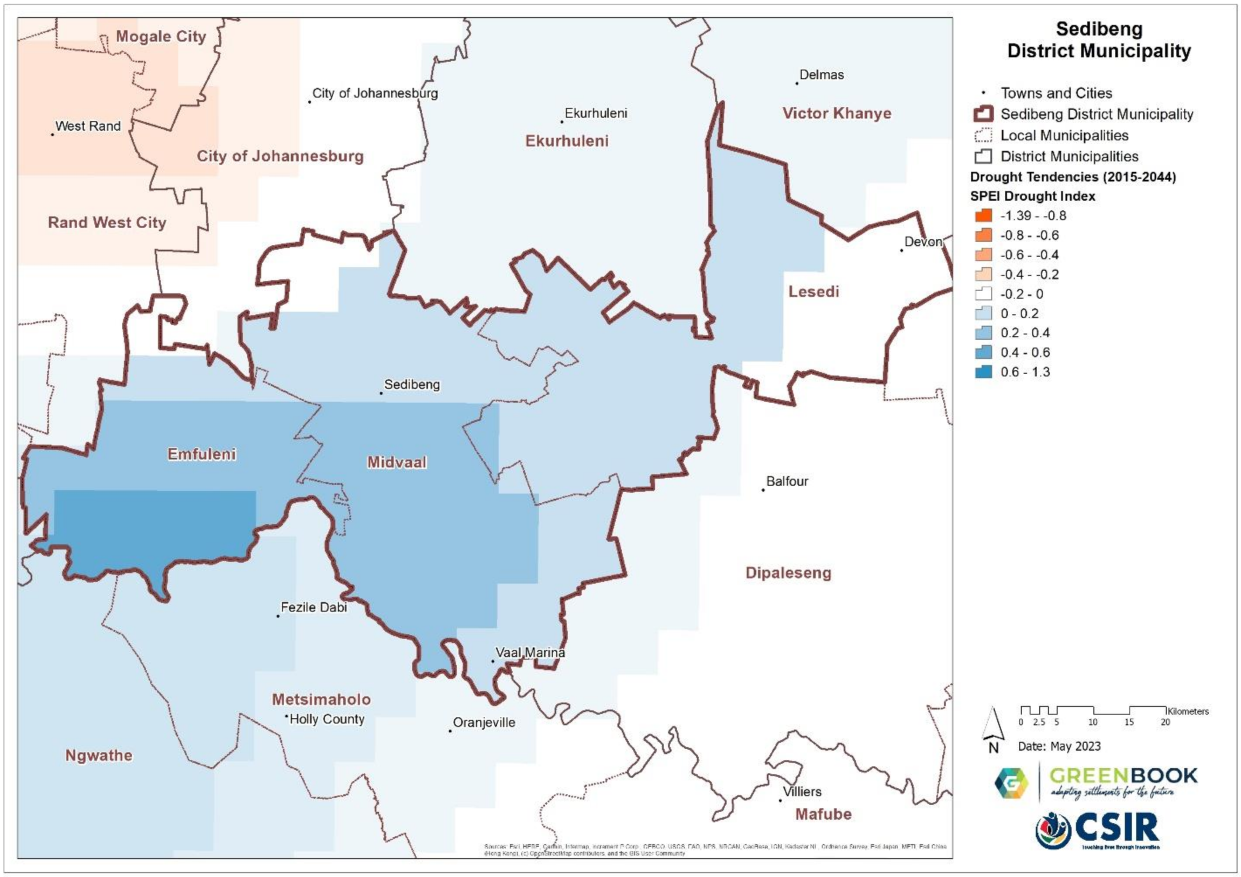

Figure 10: Projected changes in drought tendencies from the baseline period (1986–2005) to the future period (2015-2044)

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.

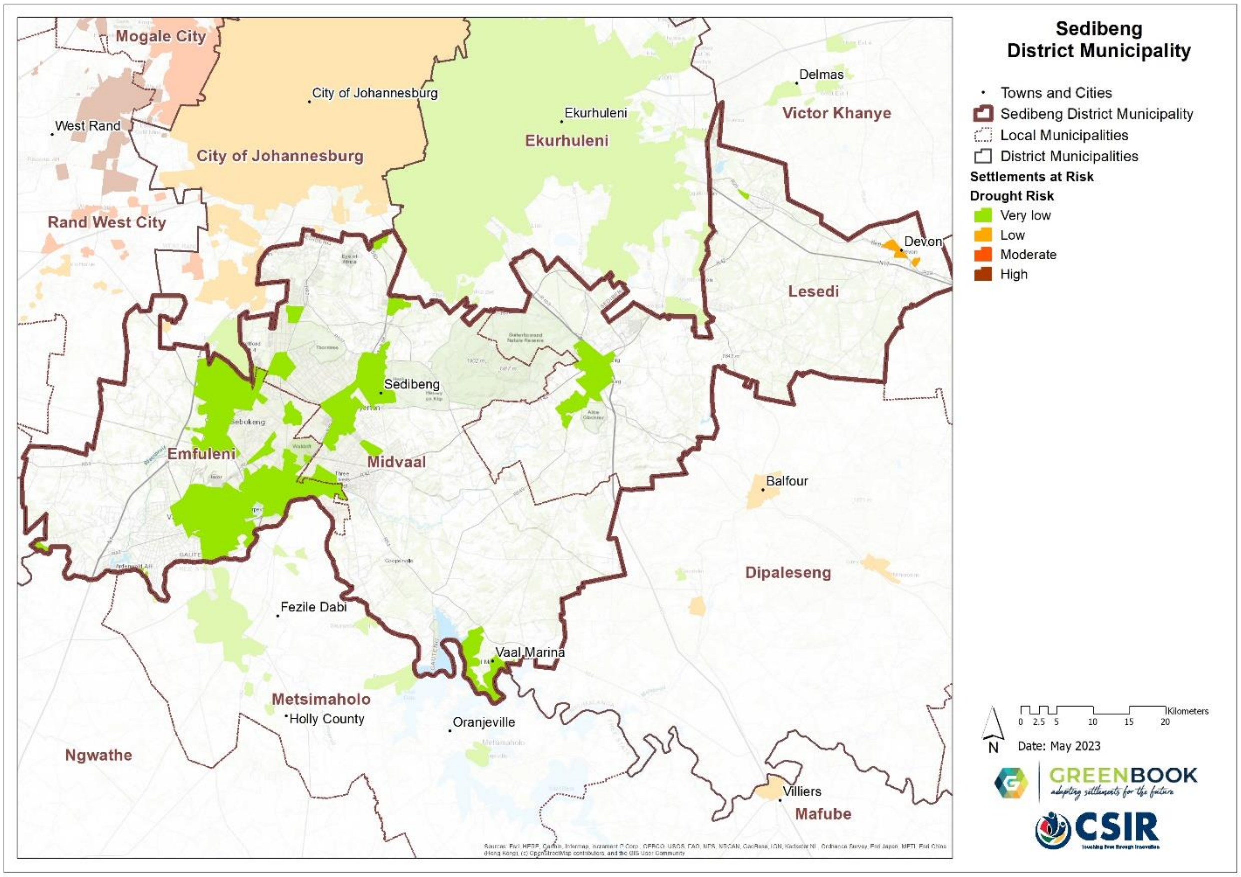

Figure 11: Settlement-level drought risk for Sedibeng District Municipality

None of the settlements across this District are at a high risk of drought. At the baseline, the eastern part of the District has some low exposure to drought tendencies, which are projected to decrease towards 2050. Drought does not seem to be a major climate risk during the baseline period or in the future.

2.3.2. Heat

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

The annual heatwave days map under baseline climatic conditions (Figure 14) depicts the number of days (per 8x8 km grid point) where the maximum temperature exceeds the average maximum temperature of the warmest month of the year at that location by at least 5°C, and that for a period of at least three consecutive days.

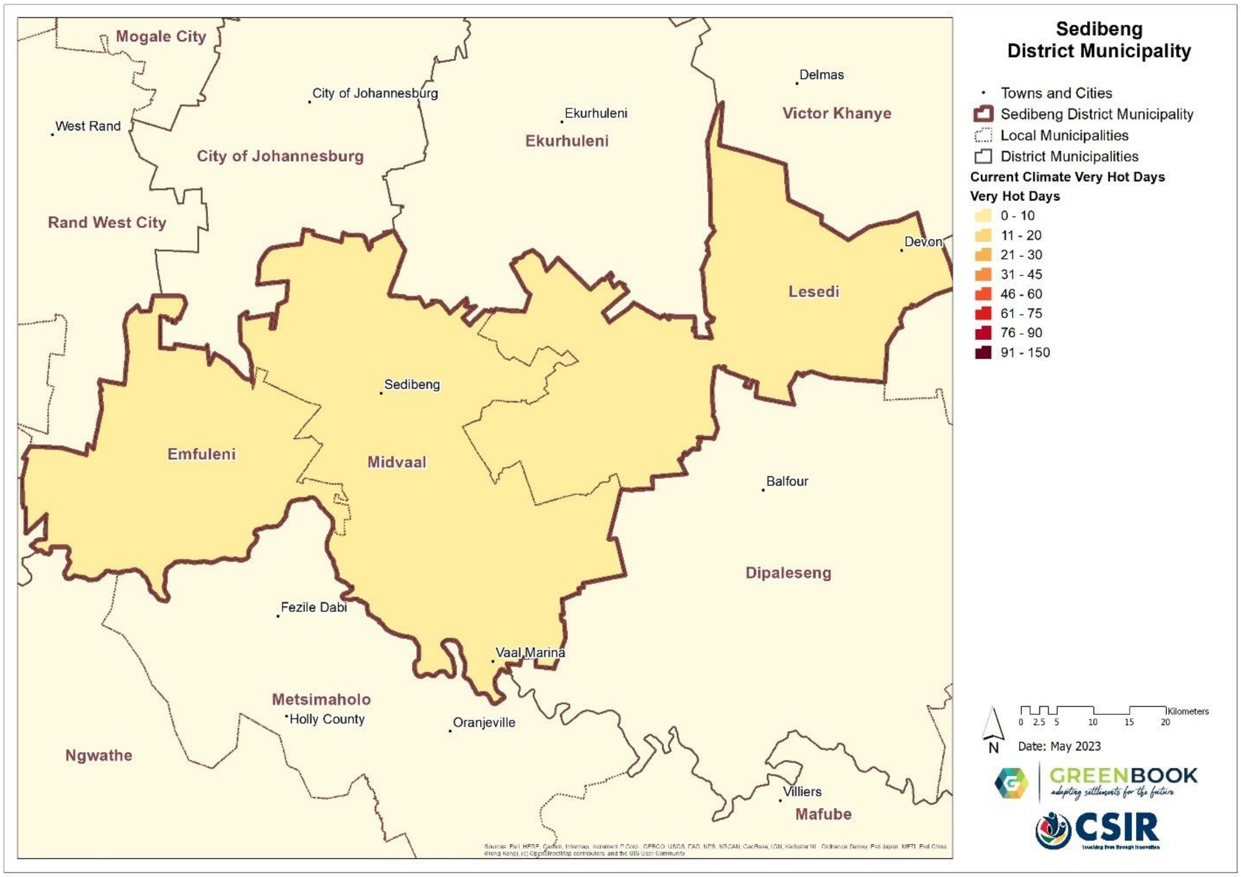

Figure 12: Annual number of very hot days across Sedibeng District Municipality under current climatic conditions when daily temperature maxima exceeding 35°C

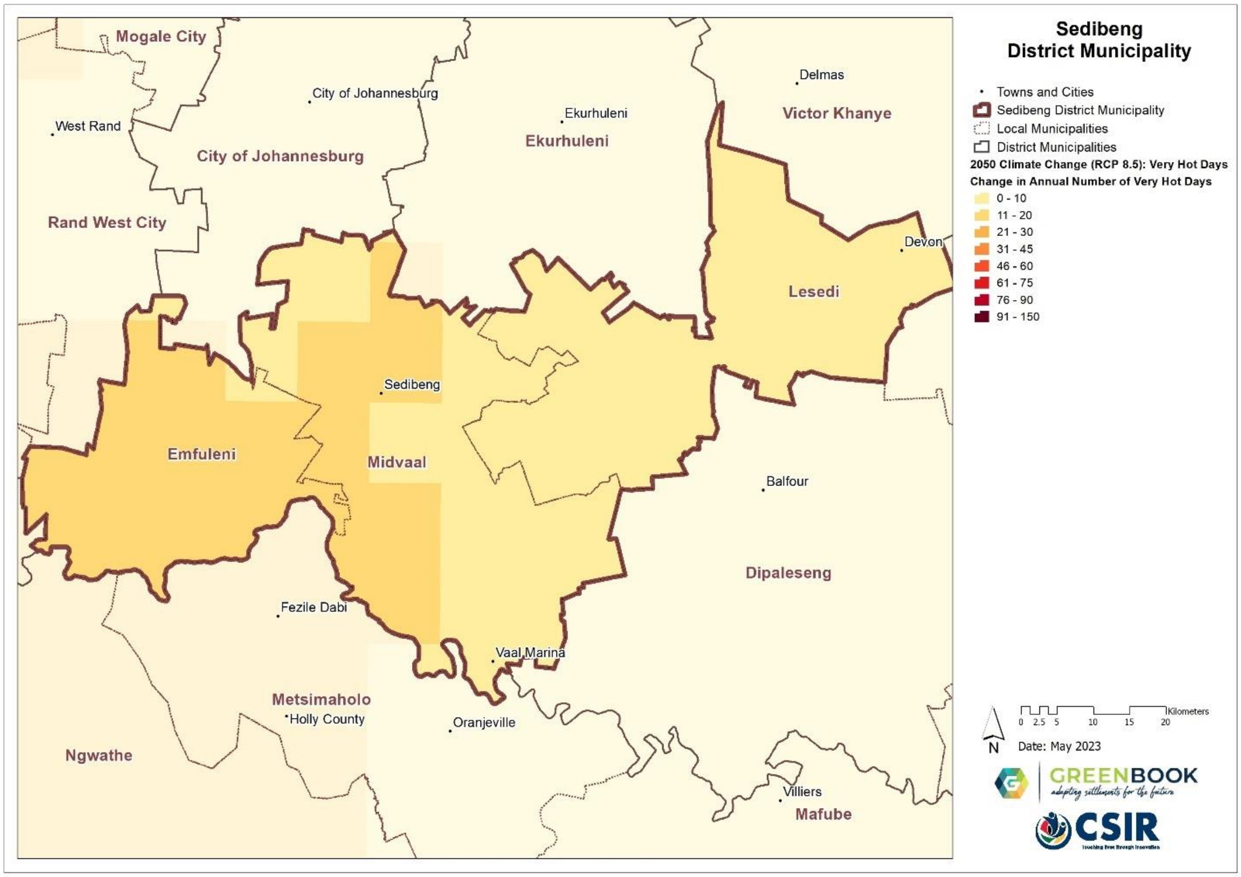

Figure 13 Projected change in average annual average number of very hot days with daily temperature maxima exceeding 35°C from 1961-1990 to 2021-2050 for Capricorn District Municipality (RCP8.5)

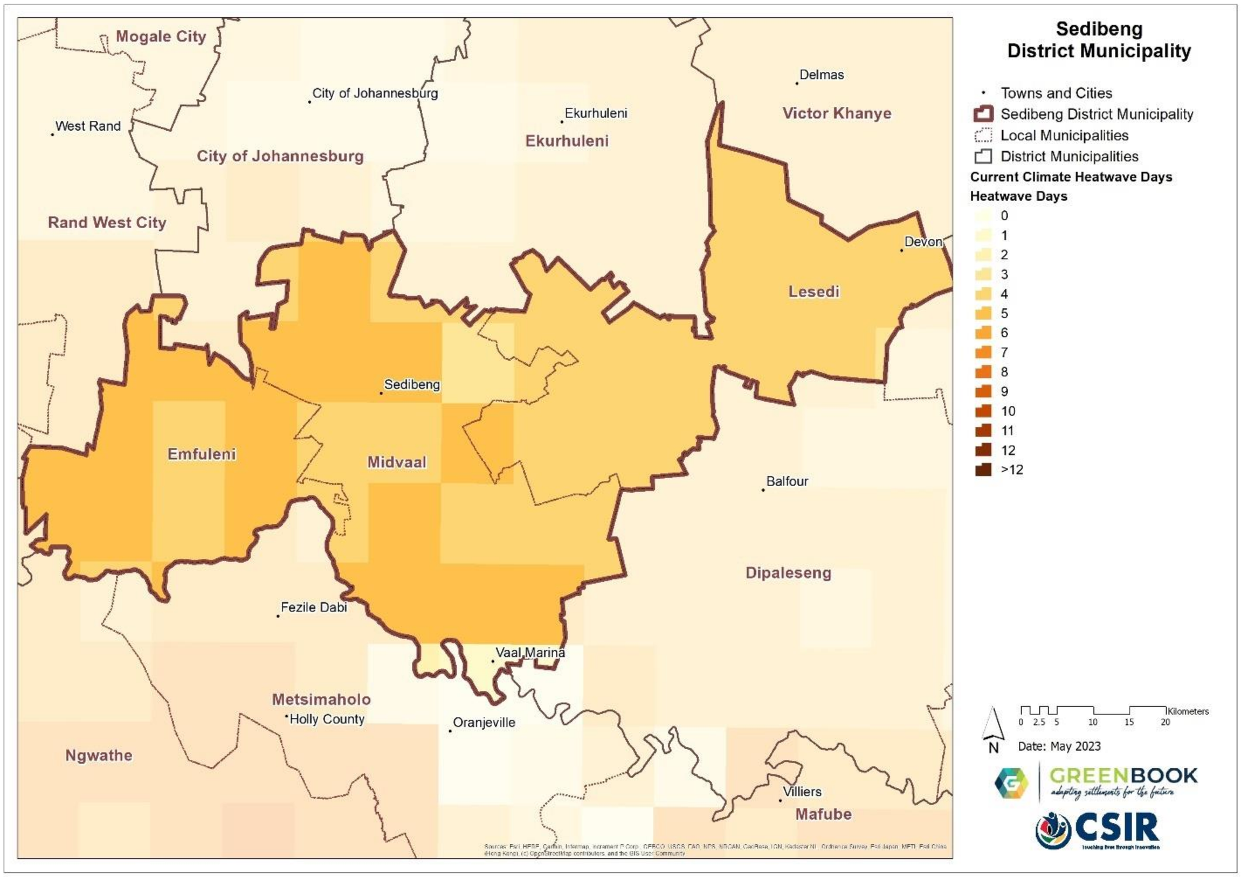

Figure 14 Annual number of heatwave days under GCM derived baseline climatic conditions across Sedibeng District Municipality

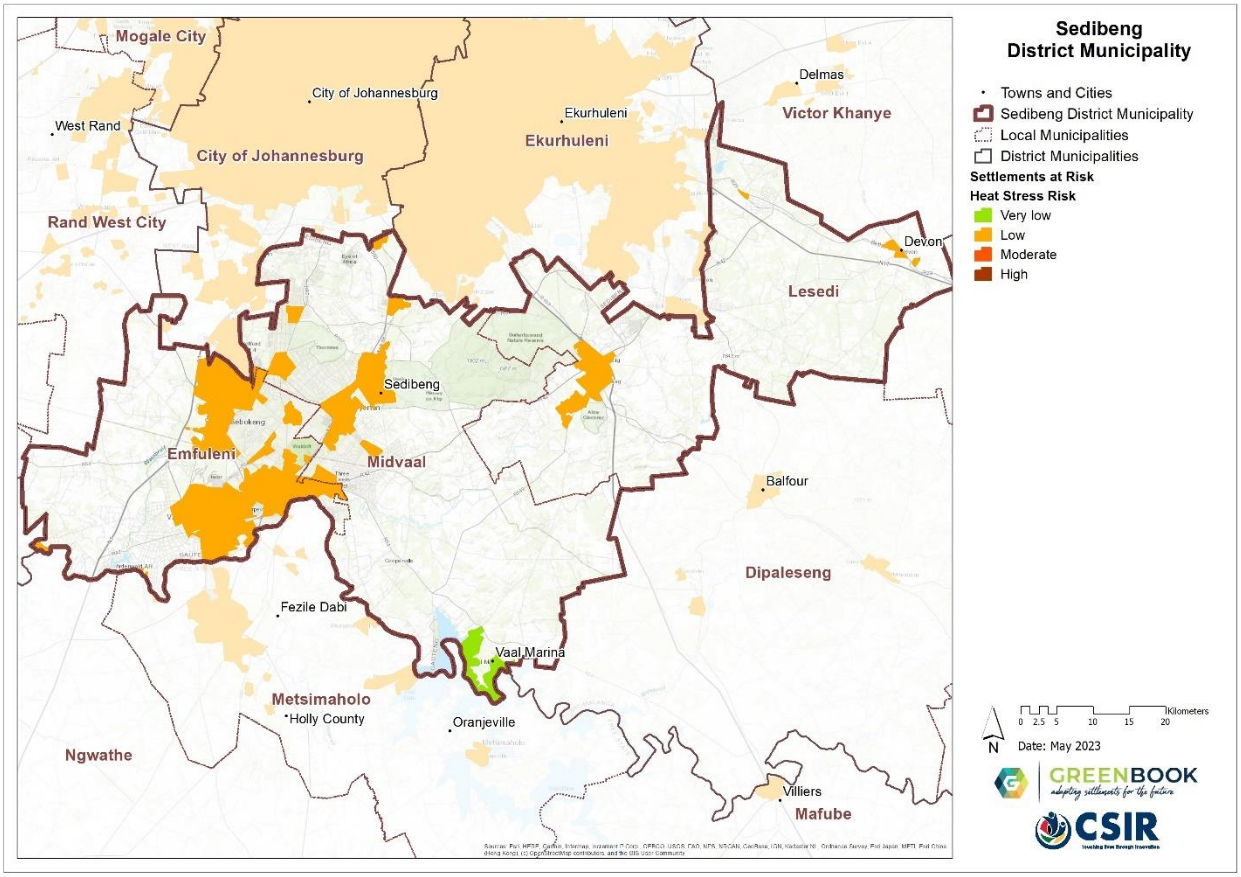

Figure 15: Heat risk across Sedibeng District Municipality at settlement level in the 2050s

During the baseline period, the number of very hot days experienced by the District is between 0 and 2 per annum across the District. The number of heatwave days experienced by the District during the baseline period ranges from 0.2 to 5 per annum and are more likely to occur in the western part of the District. The change in the number of very hot days is projected at between 0 and 10 more days in the eastern half of the District, and between 11 and 20 more days in the western half of the District.

Figure 15 depicts levels of heat risk of settlements under projected future climates. The risk is mostly low for all settlements, and very low in the Vaal Marina. 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 (though unlikely in Sedibeng).

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 'low' to 'extreme'. 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" emissions 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.

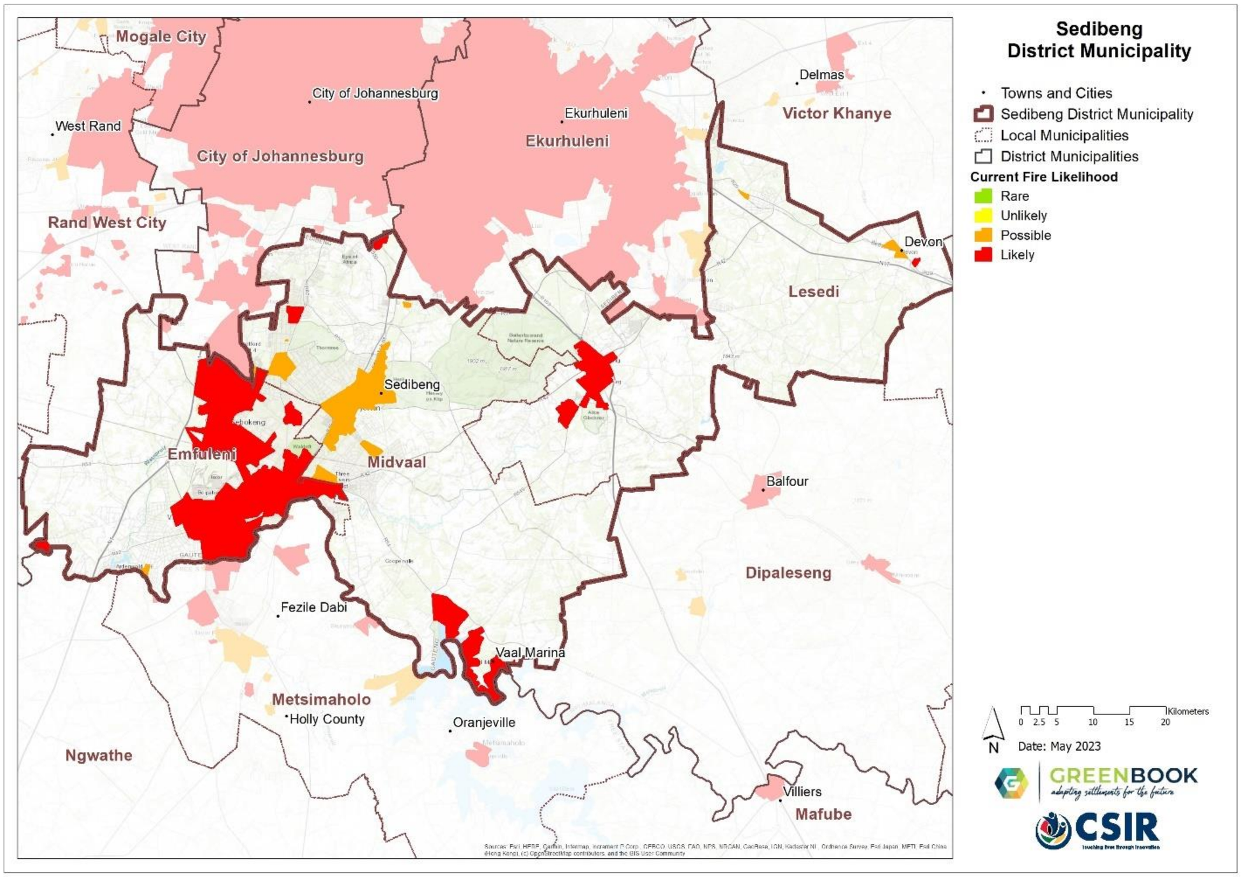

Figure 16: The likelihood of wildfires under current climatic conditions across settlements in Sedibeng District Municipality

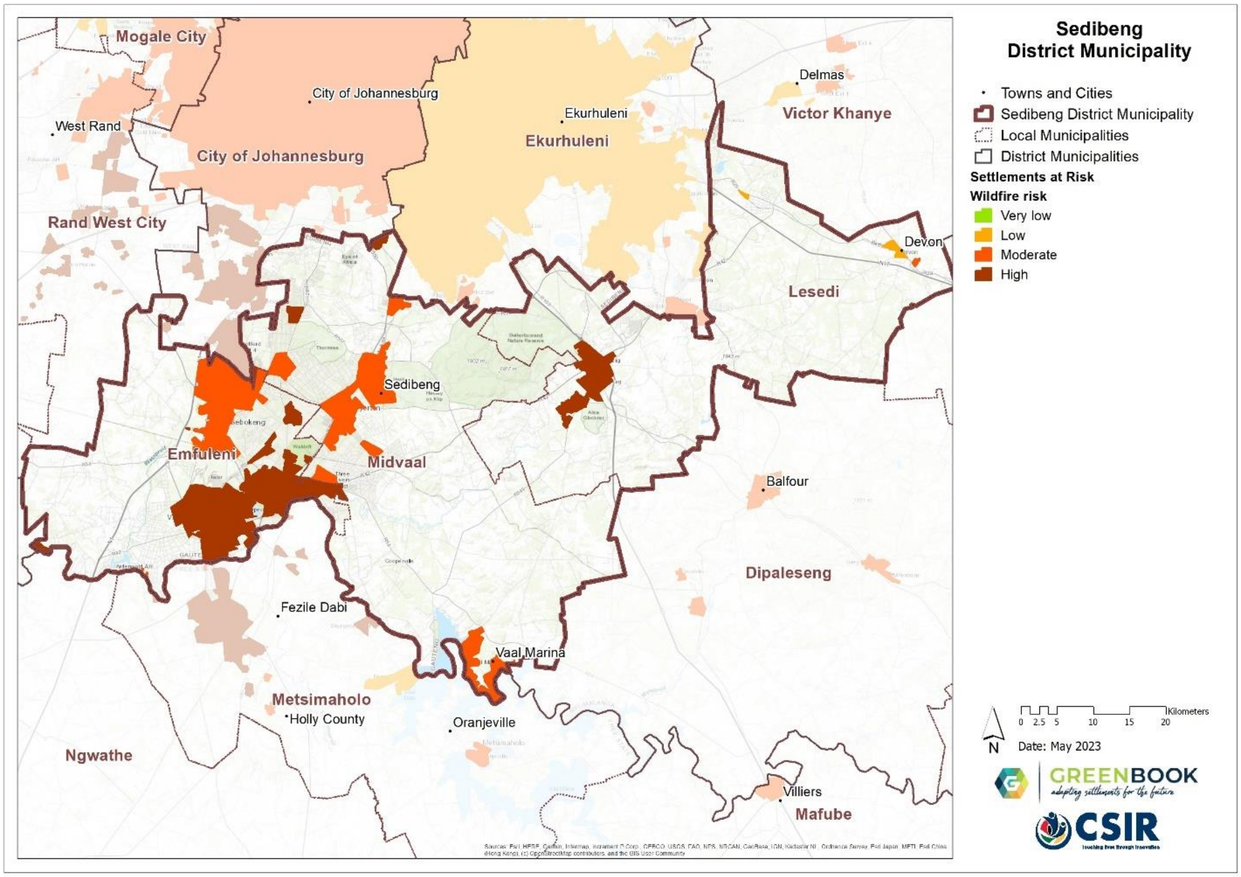

Figure 17: The likelihood of wildfires under projected future climatic conditions Sedibeng District Municipality

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 settlements in the District, under current climatic conditions, while Figure 17 depicts the settlements that could be at risk of increases in exposure to wildfires by the year 2050. Settlements which are likely to experience wildfires on their wildland-urban interface include Heidelberg, Vaal Marina, Sebokeng, Sharpeville, Boipatong, Vanderbijlpark, Vereeniging and Evaton, with a possibility of wildfires in Meyerton. It is projected that of these settlements, Vanderbijlpark, Sharpeville, Boipatong, Vereeniging and Heidelberg could see a high risk of wildfire in the future, while the risk for future wildfires in Sebokeng, Evaton, Meyerton and Vaal Marina is moderate (Figure 17).

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, 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 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 days from 1961-1990 to the 2050s.

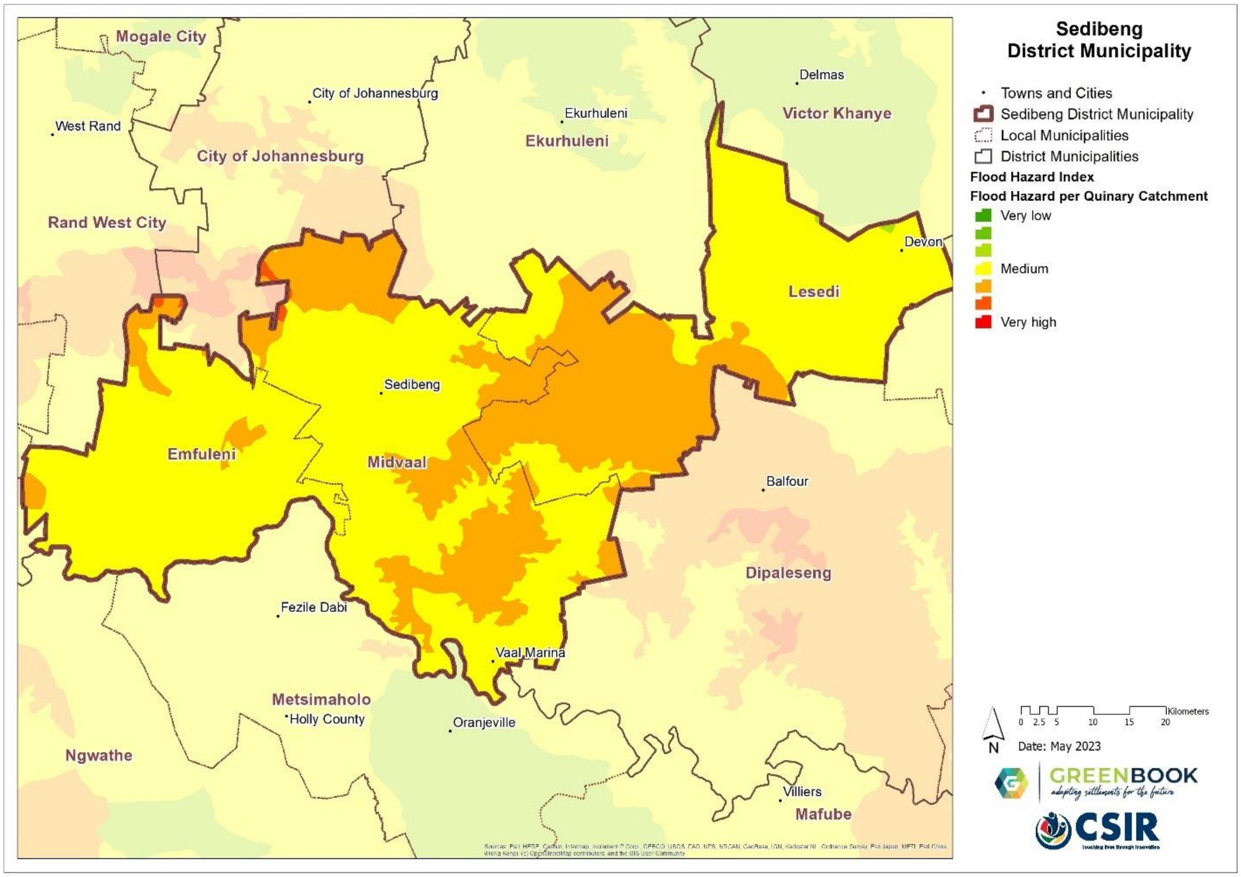

Figure 18: The current flood hazard index across Sedibeng District Municipality under current (baseline) climatic conditions

Figure 18 depicts the flood hazard index of the different individual Quinary catchments (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 very low flooding hazard, while red indicates a very high flood hazard. There is some variation in the flood hazard index across the District. Most parts of the District have a medium and higher flooding hazard risk, with pockets of very high flooding hazard risk.

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. A slight decrease in the number of extreme rainfall days is expected in the western parts of the District, while slight to significant increases in the number of extreme rainfall days are expected in the eastern parts, especially in Lesedi LM.

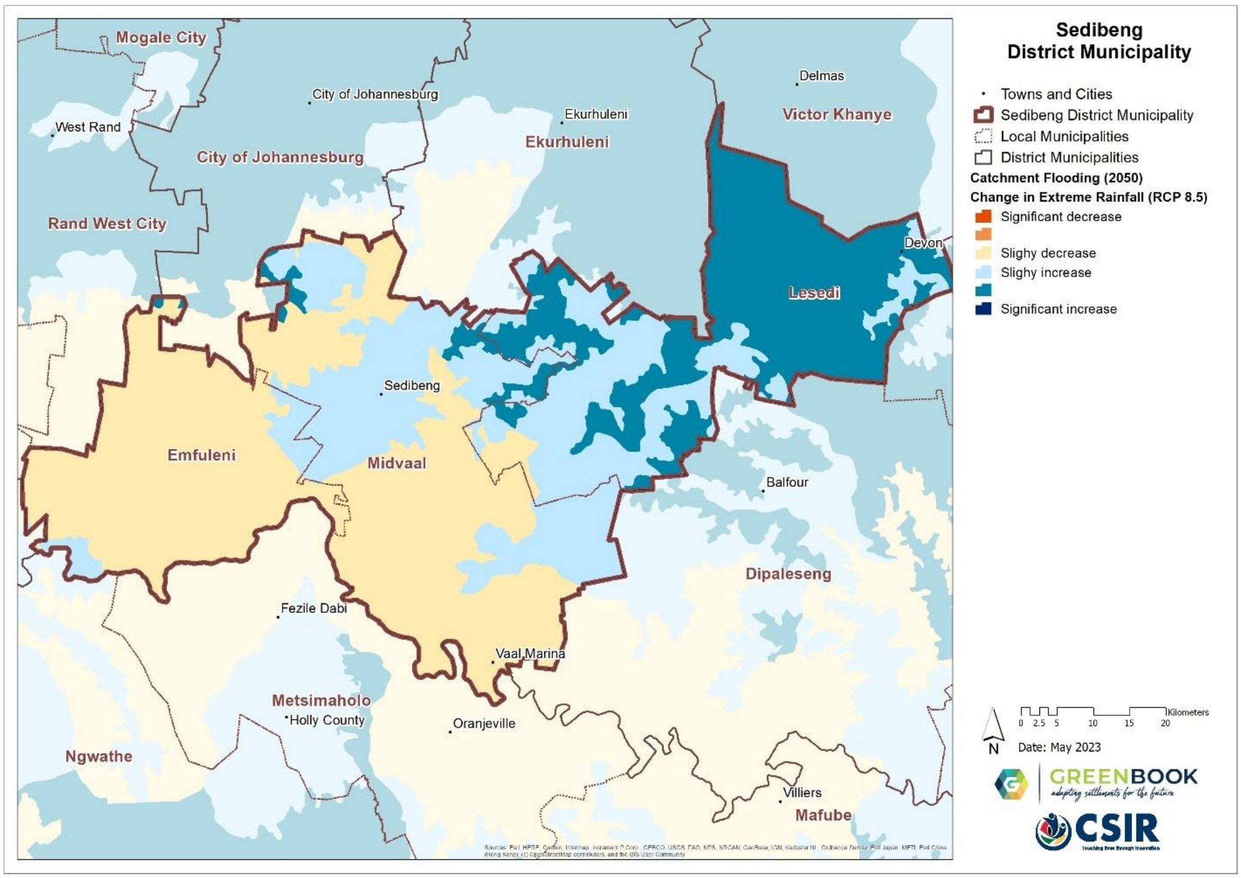

Figure 19: Projected change into future in extreme rainfall days across Sedibeng District Municipality

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 Heidelberg and Walkerville.

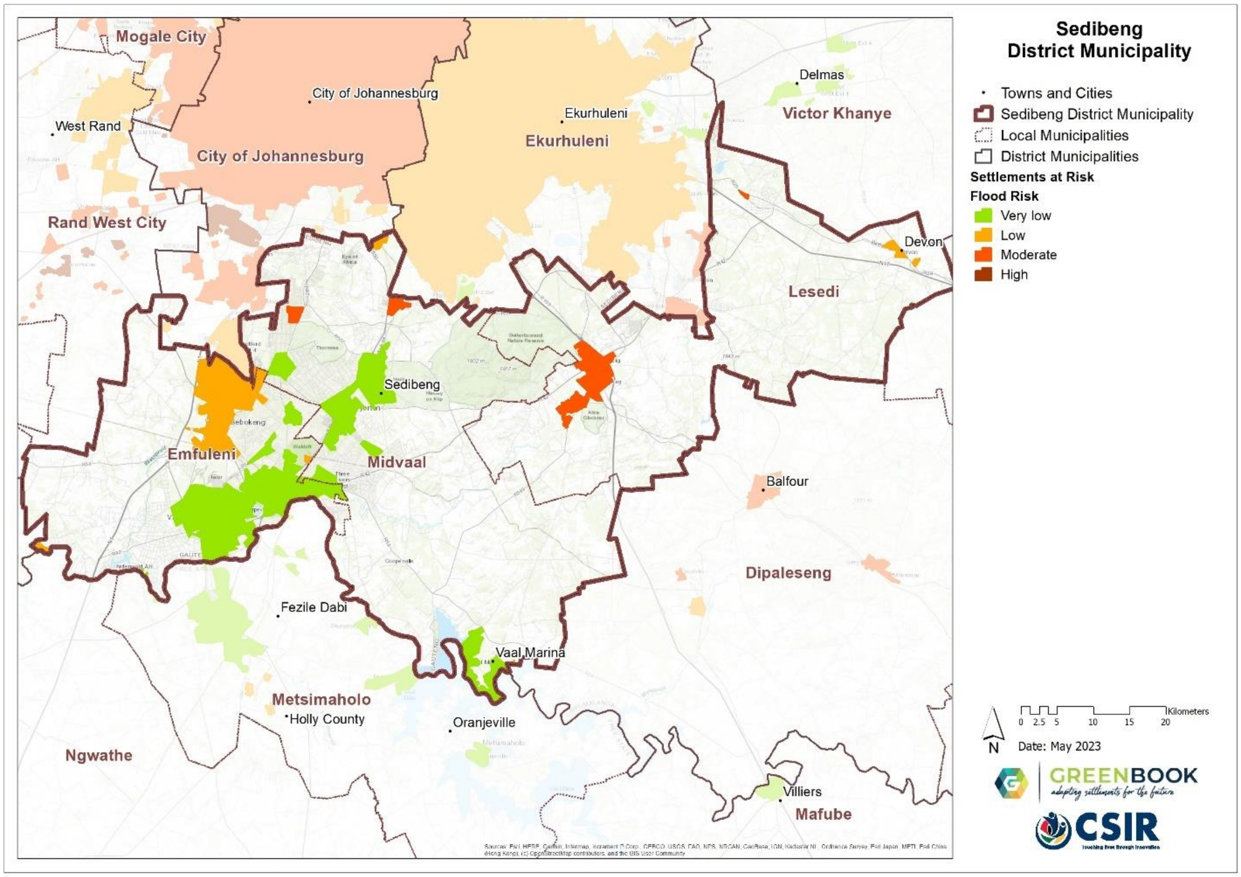

Figure 20: Flood risk across into a climate change future at settlement level Sedibeng District Municipality.

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 Sedibeng District Municipality.

2.4.1. Water resources and supply vulnerability

South Africa is a water-scarce country with an average rainfall of approximately about 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, the availability and distribution of which are highly influenced by climate variability and change. An analysis of the impact of climate change on potential groundwater recharge was conducted for the period 2031 to 2050. The Villholth GRiMMS (Groundwater Drought Risk Mapping and Management System) formulation (Vilholth et al., 2013), which implemented a composite mapping analysis technique to produce an explicit groundwater recharge drought risk map, was adapted to formulate a series of potential groundwater recharge maps for the far-future across South Africa. Finally, the future period 2031 to 2050 was compared with the historical period 1961 to 1990.

Figure 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 to be groundwater dependent. None of the three Local Municipalities in Sedibeng are groundwater dependent.

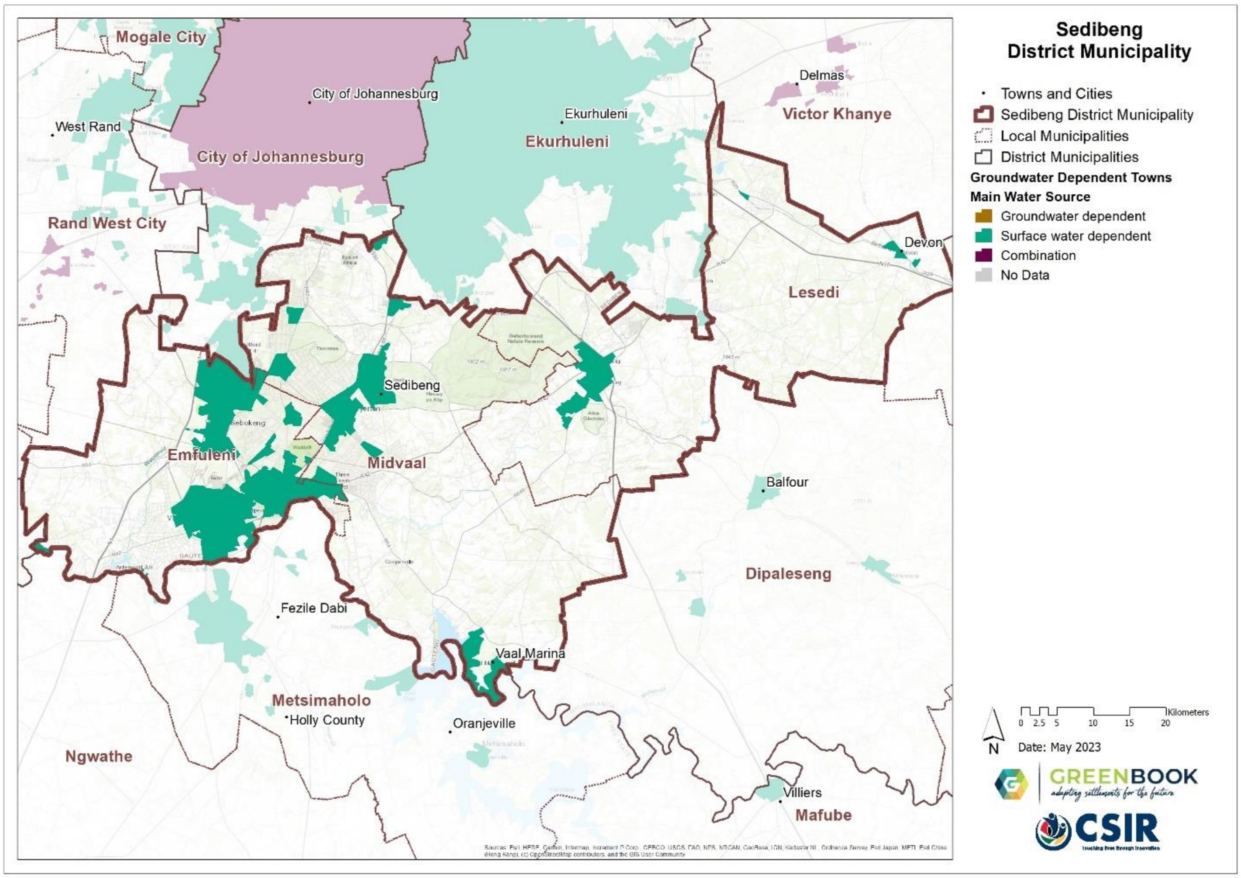

Figure 21: Main water source for settlements in the Sedibeng District Municipality

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

Local Municipality	Water Demand per Capita (l/p/d)	Water Supply per Capita (l/p/d)	Current Water Supply Vulnerability
Emfuleni	311.34	311.34	1.0
Lesedi	488.64	663.28	0.74
Midvaal	537.10	671.37	0.8

Current and future water supply vulnerability estimations are based on: 1) a local water supply perspective incorporating changes to population growth coupled with exposure to climate risk and 2) a regional water supply perspective, based on impacts of regional water supply assuming supply is part of the integrated regional and national bulk water supply network. The water supply vulnerability estimations do not consider 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.

Emfuleni Local Municipality

Emfuleni LM's water demand is equal to its supply, but with the projected decrease in the population growth rate in Emfuleni, the future water supply does not seem to be vulnerable.

Lesedi Local Municipality

Water supply vulnerability is currently relatively low in the Municipality, but because of the projected population increase, water supply vulnerability could increase in the future.

Midvaal Local Municipality

Water supply vulnerability is currently relatively low in the municipality but because of the projected population increase, water supply vulnerability could increase in the future.

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 regarding 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 practised 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 the least of all the sectors to the local GVA of the District Municipality, at only 1.08 % (CoGTA, 2020). Below, the main agricultural commodities for each Municipality within the Sedibeng District are discussed below in terms of what the impact of climate change might be on those commodities under an RCP 8.5 “business as usual” emissions scenario.

Emfuleni

In Emfuleni LM, the AFF sector contributes 0.61 % to the local GVA, which is a contribution of 0.32 % to the national GVA for the AFF sector. Of the total employment, 1.94 % is within the AFF sector. The main agricultural commodities are maize for grain, beef cattle and chicken eggs. Climate projections show a generally hotter and wetter climate with more extreme rainfall events. These conditions could potentially increase the maize yield in the near future, but heat stress in the long-term can negatively impact production. Hot and moist conditions cause increased spread of disease and parasites, affecting growth and reproduction performance of beef cattle. Heat stress will have a negative effect on birds and increase the production costs to maintain temperatures.

Lesedi

In Lesedi LM, the AFF sector contributes 1.70 % to the local GVA, which is a contribution of 0.15 % to the national GVA for the AFF sector. Of the total employment, 6.85 % is within the AFF sector. The main agricultural commodities are beef cattle, chickens, and maize for grain. Climate projections show a generally hotter and wetter climate with more extreme rainfall events. Hot and moist conditions are likely to cause increased spread of disease and parasites, affecting growth and reproduction performance of beef cattle. Heat stress will have a negative effect on birds and increase the production costs to maintain temperatures. However, the same conditions could potentially increase the maize yield in the near future, but heat stress in the long-term can negatively impact production.

Midvaal

In Midvaal LM, the AFF sector contributes 11.17 % to the local GVA, which is a contribution of 0.12 % to the national GVA for the AFF sector. Of the total employment, 5.03 % is within the AFF sector. The main agricultural commodities are maize for grain and beef cattle. Climate projections show a generally hotter and wetter climate with more extreme rainfall events. These conditions could potentially increase the maize yield in the near future, but heat stress in the long-term can negatively impact production. Hot and moist conditions cause increased spread of diseases and parasites, affecting growth and reproduction performance of beef cattle.

3. Recommendations

Sedibeng District has many positive characteristics that make it less vulnerable to the impacts of climate related hazards. The District generally has relatively low socio-economic and physical vulnerabilities. Access to services and regional connectivity are generally good in the major towns of the District. Climate change is also not projected to have a severe impact on the settlements in the District. Current and future drought conditions and heat extremes are not projected to have a major impact on the District.

The hazards with the greatest likelihood of occurring in the Sedibeng District are wildfires on the wildland-urban interface as well as surface water flooding. This likelihood combined with high and extreme population growth pressure in Midvaal and Lesedi Local Municipalities, and economic vulnerability in Emfuleni and Lesedi Local Municipalities, make the District at risk for adverse consequences resulting from climate change. The environment in the District, especially in Lesedi and Emfuleni Local Municipalities, is quite vulnerable to the impacts of climate change. The towns that are seeing significant population growth will become more vulnerable and exposed to climate-related hazards.

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

1. To ensure water security under a changing climate: Given the water scarcity challenges in the country, developing comprehensive strategies for water resource management is crucial. SDM could contribute towards the country's water security by prioritizing water 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 by exploring measures to secure alternative water sources such as rainwater (harvesting), groundwater (recharge and extraction) and wastewater (reuse).

2. To protect natural resources and ecosystems: Protecting and restoring natural ecosystems such as wetlands and riparian areas, will enhance the District's biodiversity, support water resource management, and provide natural buffers against climate-related hazards such as wildfires and surface water flooding. 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 develop effective flood management strategies to mitigate the risks associated with heavy rainfall events: It will become increasingly necessary to develop effective flood management strategies to mitigate the risks associated with heavy rainfall events that are projected for the District. This can involve improving stormwater drainage systems,

creating floodplains and retention basins, and implementing flood early warning systems to protect vulnerable communities and infrastructure.

4. To reduce the vulnerability and exposure of human and natural systems to climate change and extreme events: To minimise the damage and loss stemming from the unavoidable impacts of climate change, it is essential to reduce the exposure and vulnerability of elements found in both human and natural systems present in the District, to climate-related hazards and extreme events. Reducing exposure and vulnerability will involve a combination of infrastructural, behavioural, and institutional changes. For human systems, this might involve building climate-resilient infrastructure, developing or improving existing disaster risk reduction strategies, and enhancing social safety nets for the most vulnerable. For natural systems, this can involve protecting and restoring ecosystems that provide natural buffers against climate impacts, such as wetlands that absorb flood waters.

These goals are not exhaustive and could be complemented by other strategies tailored to the specific context and needs of the SDM. The key to success lies in integrating the programmes and actions that will be identified under each goal, into all aspects of municipal decision-making and operations, as well as engaging communities in these efforts.

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