Capricorn District Municipality

Risk Profile Report based on the GreenBook

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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
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 (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 draft Climate Risk Profile report, as well as the accompanying draft Climate Change Adaptation Plan, were developed specifically for Capricorn District Municipality (CDM), 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 fulfillment of steps four and five, each target DM is provided with a draft GreenBook Climate Risk Profile report, as well as a draft Climate Change Adaptation Plan.

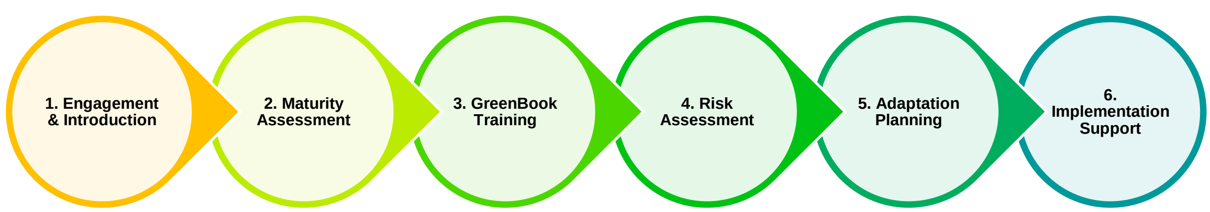

Figure 1: The Value-chain towards the implementation of climate change response and adaptation in municipalities

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

- Build and further the climate change response agenda,

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

1.1. Approach followed

The approach used in the GreenBook, and the Climate Risk Profile is centred around understanding climate-related risk. Climate-related risk implies the potential for adverse consequences resulting from the interaction of vulnerability, exposure, and the occurrence of a climate hazard (see Figure 2). "Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, 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 District, the exposure of settlements to certain climate hazards and their vulnerability are unpacked. In this Climate Risk Profile report, multiple vulnerability indices are provided on the municipal and settlement level, as well as variables for the current and future projected climate. Climate-related hazards such as drought, heat extremes, wildfire, and flooding, as well as and the impact of climate change on key resources, are also set out for the District and its Local municipalities.

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

1.2. Policy framework

There are various regulatory and legislative requirements for climate change response [planning] in South Africa, at local government level. For instance, the Disaster Management Amendment Act of 2015, which aims to provide measures to reduce disaster risks through climate change adaptation and the development of early warning systems, requires each organ of state, provincial government and municipality to identify measures for, as well as indicate plans to invest in, disaster risk reduction (DRR) and climate change adaptation. The Spatial Planning and Land Use Management Act, No. 16 of 2013 (SPLUMA) outlines five principles intended to guide spatial planning, land development and land use management at all levels of planning, including local government level. Amongst them are the principles of (1) spatial resilience, which encourages "flexibility in spatial plans, policies and land use management systems, to ensure sustainable livelihoods in communities most likely to suffer the impacts of economic and environmental shocks" – 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 Capricorn District Municipality (CDM) – named after the Tropic of Capricorn which runs across the District – is one of five Districts in the province of Limpopo. The District covers an area of 16 970 km^2, which represents 12 % of the total surface area of the province, and is situated at the centre of the province, sharing boundaries with Vhembe District to the north, Mopani District to the east, Sekhukhune District to the south and Waterberg District to the west. The District is located at the core of economic development in the Limpopo Province and is home to the capital of the province, i.e., the City of Polokwane, with one national road (i.e., N1) and several regional roads (i.e., R37, R71 and R521) passing through the District's Municipal area (Capricorn District Municipality, 2022; CoGTA, 2020).

The District comprises of four Local Municipalities (LMs), namely Blouberg, Lepelle-Nkumpi, Molemole and Polokwane Local Municipalities. Blouberg LM, which is located at the far northern part of the District, is home to settlements such as Senwabarwana, Helene Franz Hospital, GaMoreise, Ga-Machaba, Avon, Tolwe and Alldays. The settlements of Magatle, Lebowakgomo, Motserereng and Mathibela are located in Lepelle-Nkumpi LM, which is situated in the southern part of the District. Matseke, Morbeng, Nthabiseng, Botlokwa (Mphakane), Ramokgopa, Ga-Phasha, Mogwadi and Mohodi settlements are located in Molemole LM, situated on the north-eastern side of the District; while the City of Polokwane, located south of Molemole LM and north of Lepelle-Nkumpi LM, is home to the settlements of Ga-Chuene, Bergnek, GaMokwane, Ga-Mangou, Mankweng, Polokwane and Sebayeng.

CDM has a total population of 1 372 355, with 1 260 931 people located in settlements. The settlement-based population increased by 6.97 % between 2001 and 2011 and is projected to increase by 14.48 % by 2030. Capricorn's leading economic sectors include Community Services, Trade and Finance – which respectively account for 33 %, 21 % and 19 % of the District's Gross Value Added (GVA). The District's major employing sectors are the Manufacturing sector at 27 %, the Wholesale and Retail Trade, Catering and Accommodation sector, which employs 24 % of the District's working population, as well as the Finance, Insurance, Real Estate and Business Services sector, which employs 10 % of the District's working population. However, Capricorn

District's unemployment rate is high at 37.20 %, mostly as a result of low skills levels, with a majority of the households depending on social grants as a source of income (CoGTA, 2020; Department of Environmental Affairs, 2018). Low levels of education among the rural population thus positions the agricultural sector as a key means to enable food security and job creation for semi- and unskilled job seekers in the District (DEA, 2018).

The Capricorn District is home to several dams, natural water bodies and forests (with some of the most diverse fauna and flora found in South Africa), as well as cultural villages and monuments such as the Greater Mapungubwe Heritage Route, which runs through the District; the Mapungubwe World Heritage Site; Thulamela Archaeological Site; as well as a cluster of heritage sites scattered around Lake Fundudzi (DEA, 2018). The District's biophysical environment is dominated by the Savanna biome, which covers approximately 65 % of the Municipal area, with the remainder being made up of Forest (4 %), Grassland (19 %) and Azonal (11 %) biomes (CDM, 2022). Savanna climates are characterized by high temperatures and relatively low precipitation – thus making such areas susceptible to wildfires during dry seasons.

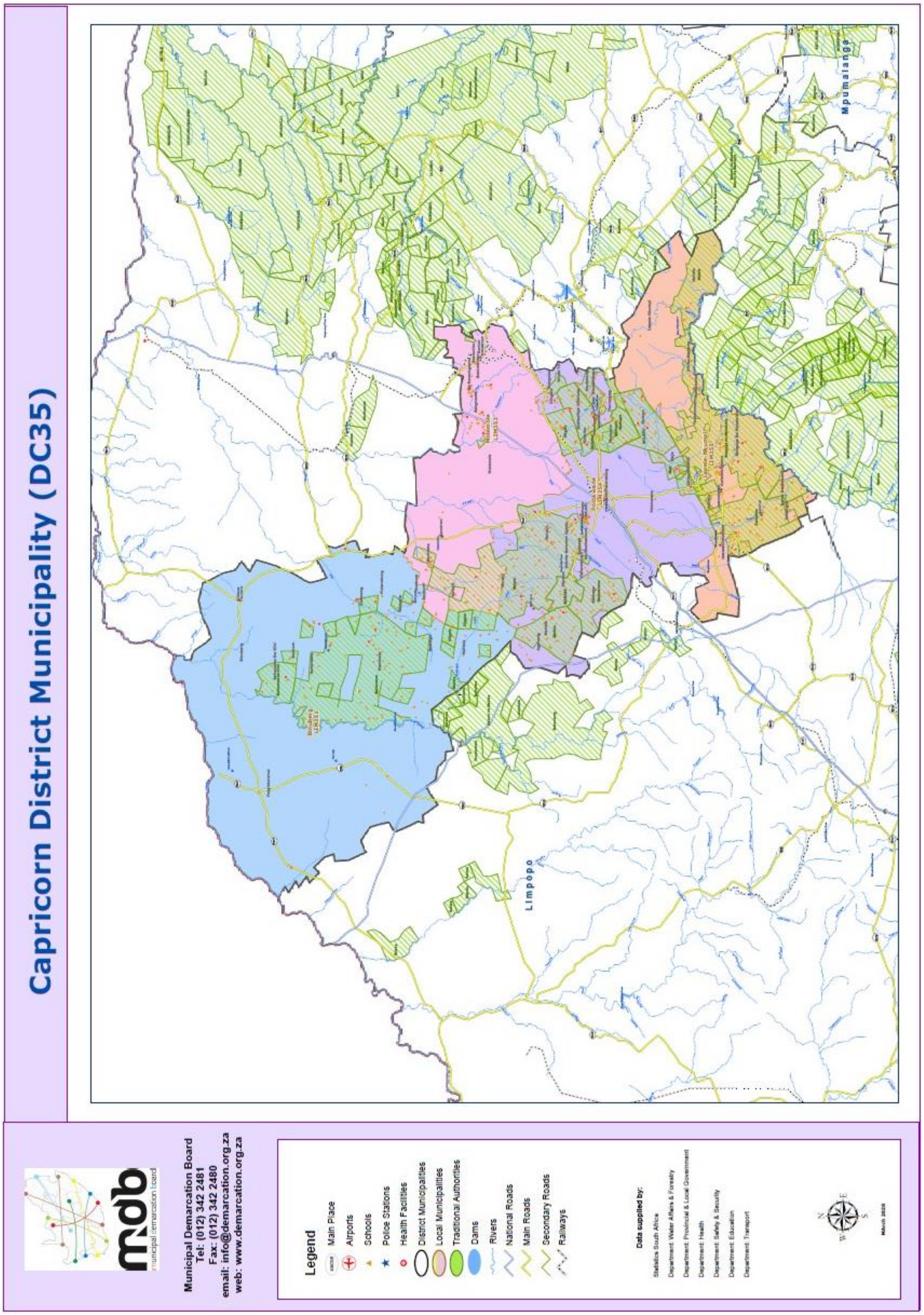

Figure 3: Capricorn District Municipality (Municipal Demarcation Board, 2022), with Local Municipalities shaded in different colours

2. Baseline and future climate risk

This section starts with an overview of vulnerability and population change projections, unpacking the components of vulnerability on both the municipal and settlement level as well future population pressures. Thereafter the current and future climate is discussed in terms of temperature and rainfall across the District. Current as well as future exposure to drought, heat, wildfire, and flooding 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 Capricorn 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 Capricorn 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 Capricorn 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 Local Municipality in the Capricorn 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 are only available for Socio-Economic Vulnerability and Economic Vulnerability

Table 1: Vulnerability indicators across Capricorn District Municipality for 1996 and 2011

LOCAL MUNICIPALITY	SEVI 1996	SEV 2011	Trend	EcVI 1996	EcVI 2011	Trend	PVI	Trend	EnVI	Trend
Blouberg	6.03	5.93	↘	5.91	5.35	↘	6.63	N/A	3.64	N/A
Lepelle-Nkumpi	4.78	5.04	↗	5.99	8.78	↗	5.87	N/A	5.33	N/A
Molemole	5.08	5.01	↘	5.26	7.47	↗	6.67	N/A	3.82	N/A
Polokwane	4.19	3.19	↘	4.74	6.80	↗	7.22	N/A	6.17	N/A

Socio-economic vulnerability (SEVI) within the CDM has decreased (i.e., improved) across all Local Municipalities, except Lepelle-Nkumpi LM, between 1996 and 2011. The latter Municipality also has the highest economic vulnerability (EcVI) in the District, and the fifth highest (out of a total of 22 Local Municipalities) in the province. This Local Municipality (i.e., Lepelle-Nkumpi) has the highest unemployment rate in the District (26.80 %), while the City of Polokwane recorded the District's lowest (16.60 %) rate of unemployment in the same period (CoGTA, 2020). However, most Local Municipalities in Capricorn – with the exception of Blouberg – experienced a downward trend, in terms of economic vulnerability (EcVI), between 1996 and 2011. These significant increases in economic vulnerability (EcVI) thus make the respective Local Municipalities, particularly their economies, more susceptible to the negative impacts of external shocks, including those induced by climate change. The City of Polokwane also had the highest physical (PVI) and environmental (EnVI) vulnerability, i.e., in 2011. Considering that the

Secondary City is well connected, the high physical vulnerability score thus indicates the structural vulnerabilities present in the City. Moreover, the high environmental vulnerability score alludes to the existing pressure on the City's natural environment and resources from increased urbanisation, land-use change, economic development and population growth; thus, making the both the City's environment and urban/settlement fabric vulnerable to climate-related hazards and extreme events.

2.1.2. Settlement vulnerability

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

A brief description of each Local Municipality within the DM follows below.

Blouberg

The major settlements in this Local Municipality are Senwabarwana, Helene Franz Hospital, GaMoreise, Ga-Machaba, Avon, Tolwe and Alldays. The latter settlement (i.e., Alldays) faces the highest growth pressure, while Avon (along with Ga-Machaba) has a socio-economically vulnerable population, as well as a highly vulnerable natural environment. Traditional areas also face high environmental vulnerability. Tolwe is the most remote settlement in the Local Municipality, with very high regional connectivity vulnerability, while GaMoreise has a highly vulnerable economy. Senwabarwana, Tolwe, Ga-Machaba and several traditional areas in Blouberg LM, have high service access vulnerability.

Lepelle-Nkumpi

The major settlements in this Local Municipality are Magatle, Lebowakgomo, Motserereng and Mathibela. Parts of Lebowakgomo face a very high growth pressure and very high economic vulnerability, while the settlements of Magatle and several traditional areas in the Local Municipality have socio-economically vulnerable populations. Both Magatle and Mathibela are remote settlements, with very high regional connectivity vulnerability; the latter settlement (i.e., Mathibela) also has high environmental-, economic and service access vulnerability. Other settlements with high economic vulnerability are Magatle and several traditional areas. Motserereng and several traditional areas constitute additional settlements with high service access vulnerability.

Molemole

The major settlements in this Local Municipality are Matseke, Morbeng, Nthabiseng, Botlokwa (Mphakane), Ramokgopa, Ga-Phasha, Mogwadi and Mohodi. The settlement facing the highest growth pressure in the Local Municipality is Mogwadi. The settlements of Morbeng, Botlokwa, Mohodi and several traditional areas have socio-economically vulnerable populations. Morbeng, Nthabiseng and several traditional areas are remote settlements, with high regional connectivity vulnerability. The settlements of Mohodi and Nthabiseng have high environmental vulnerability, while the latter settlement (i.e., Nthabiseng), and Botlokwa (Mphakane) have highly vulnerable economies. Mohodi also has high service access vulnerability.

Polokwane

The major settlements in this Local Municipality are Ga-Chuene, Bergnek, GaMokwane, Ga-Mangou, Mankweng, Polokwane and Sebayeng. The settlement of Polokwane faces the highest growth pressure in the Local Municipality, while parts of Ga-Chuene and several traditional areas have socio-economically vulnerable populations. The settlements of Ga-Mangou and Sebayeng have high environmental vulnerability; moreover, both of them, as well as Bergnek and several traditional areas, are remote, with very high regional connectivity vulnerability. Parts of Ga-Chuene have high economic vulnerability, while the settlements of Bergnek and GaMokwane have high service access vulnerability.

2.1.3. Population growth pressure

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

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

Table 2: Settlement population growth pressure across Capricorn District Municipality

Population per municipality	2011	Medium Growth Scenario	
		2030	2050
Blouberg	174 804	154 701	114 000
Lepelle-Nkumpi	231 139	222 516	183 425
Molemole	126 552	112 928	86 869
Polokwane	728 436	941 494	1 067 109
Capricorn DM Total	1 260 931	1 431 639	1 451 403

The District's population is projected to increase by 16 % between 2011 and 2050, under a medium growth scenario. Most of this growth will take place in the settlements within the City of Polokwane. Most settlements in Blouberg-, Lepele-Nkumpi- and Molemole Local Municipalities are likely to see a decline in population between 2030 and 2050. Figure 4 depicts the growth pressures that the settlements across the District will likely experience. The settlements that will see high growth pressures up to 2050, include Polokwane, Mankweng, Ga-Mangou and Sebayeng, all of which are situated in the City of Polokwane.

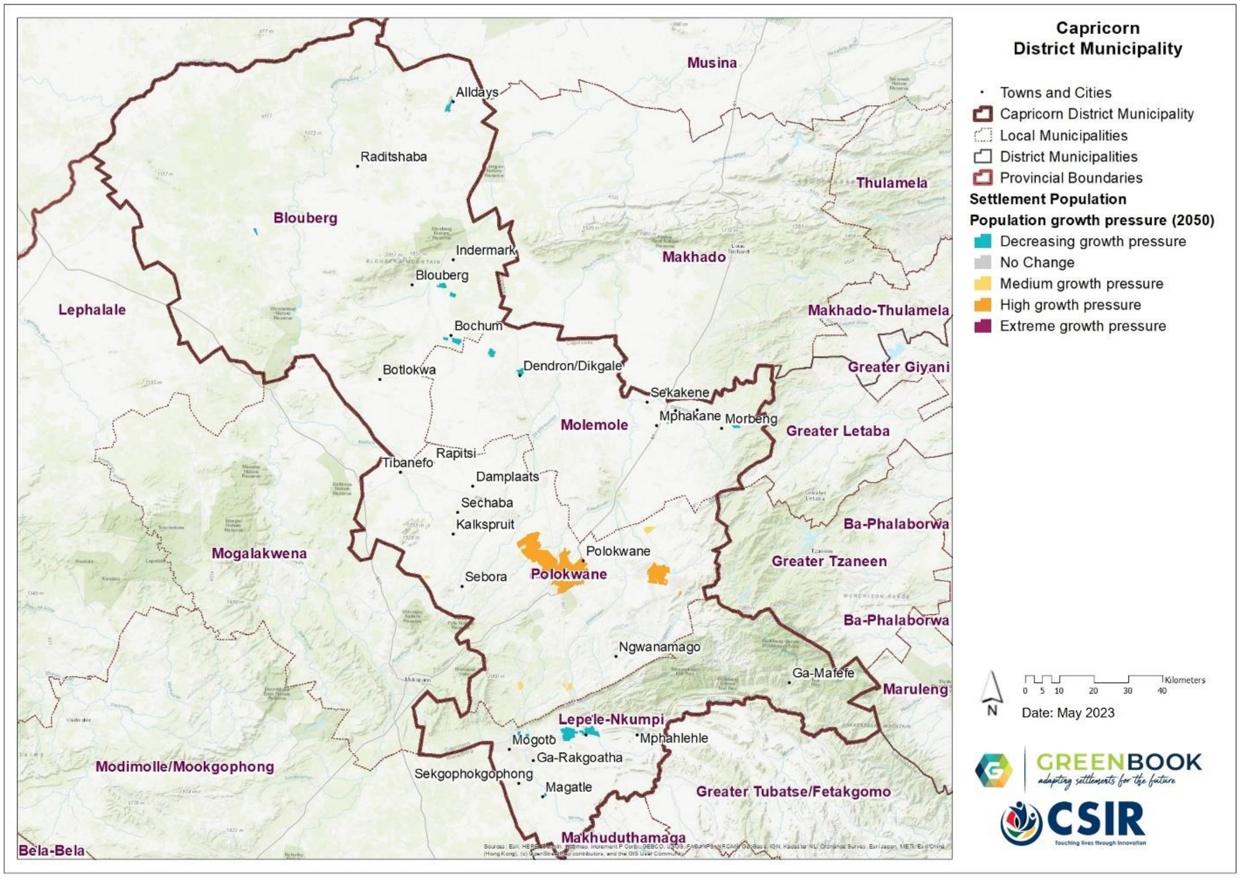

Figure 4: Settlement-level population growth pressure across Capricorn District Municipality

2.2. Climate

An ensemble of very high-resolution climate model simulations of present-day climate and projections of future climate change over South Africa has been performed as part of the GreenBook. The regional climate model used is the Conformal-Cubic Atmospheric Model (CCAM), a variable-resolution Global Climate Models (GCMs) 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 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/low emissions scenario (assuming a reduction in CO_2 emissions into the future), whilst RCP 8.5 is a low mitigation/high emissions scenario (assuming "business as usual" emissions).

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

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

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

For each of the climate variables discussed below:

a) The simulated baseline (also termed “current” climatological) state over South Africa calculated for the period 1961–1990 is shown (note that the median of the 6 downscaled GCMs is shown in this case).
b) The projected changes in the variables are subsequently shown, for the time-period 2021–2050 relative to the baseline period 1961-1990.
c) An RCP 8.5 scenario (low mitigation) is shown.

2.2.1.Temperature

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

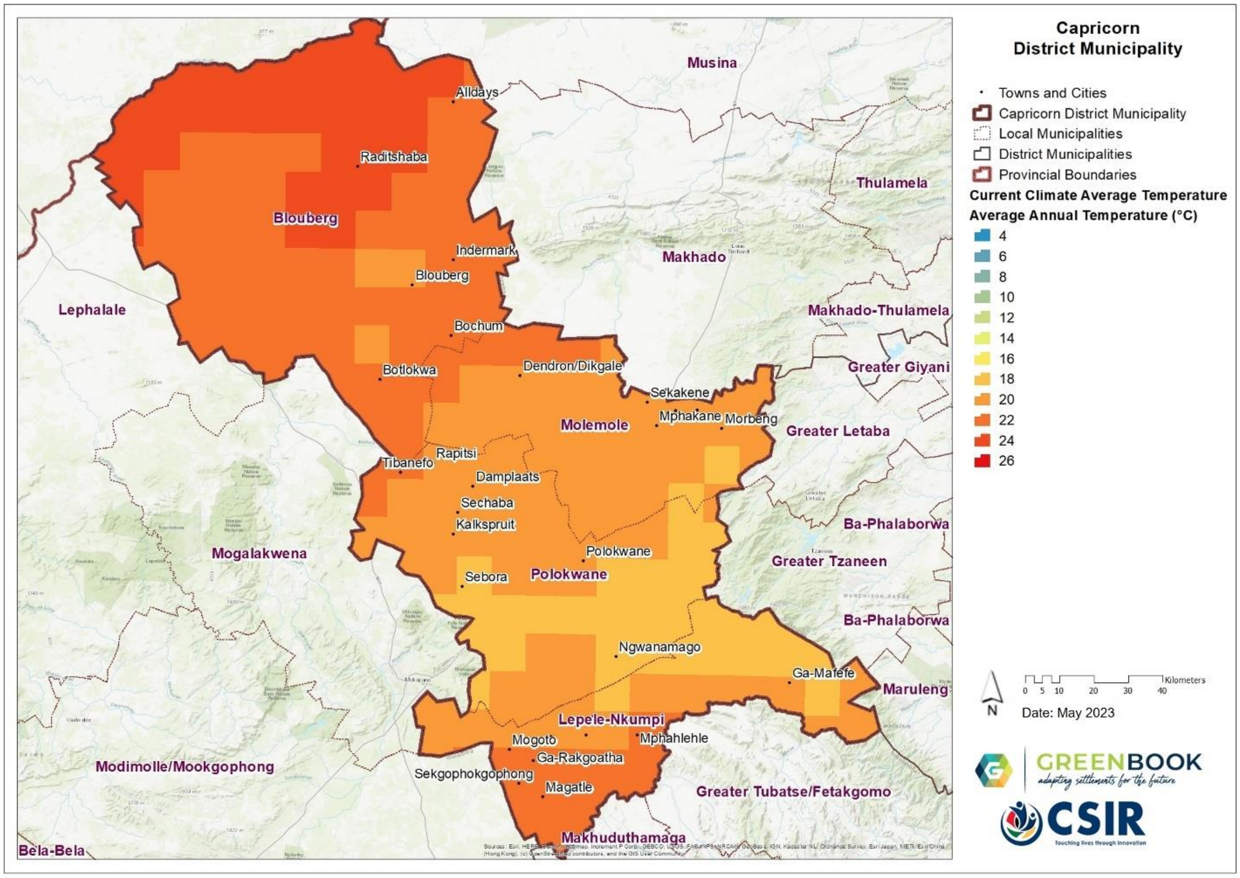

Figure 5: Average annual temperature (°C) for the baseline period 1961-1990 for Capricorn District Municipality

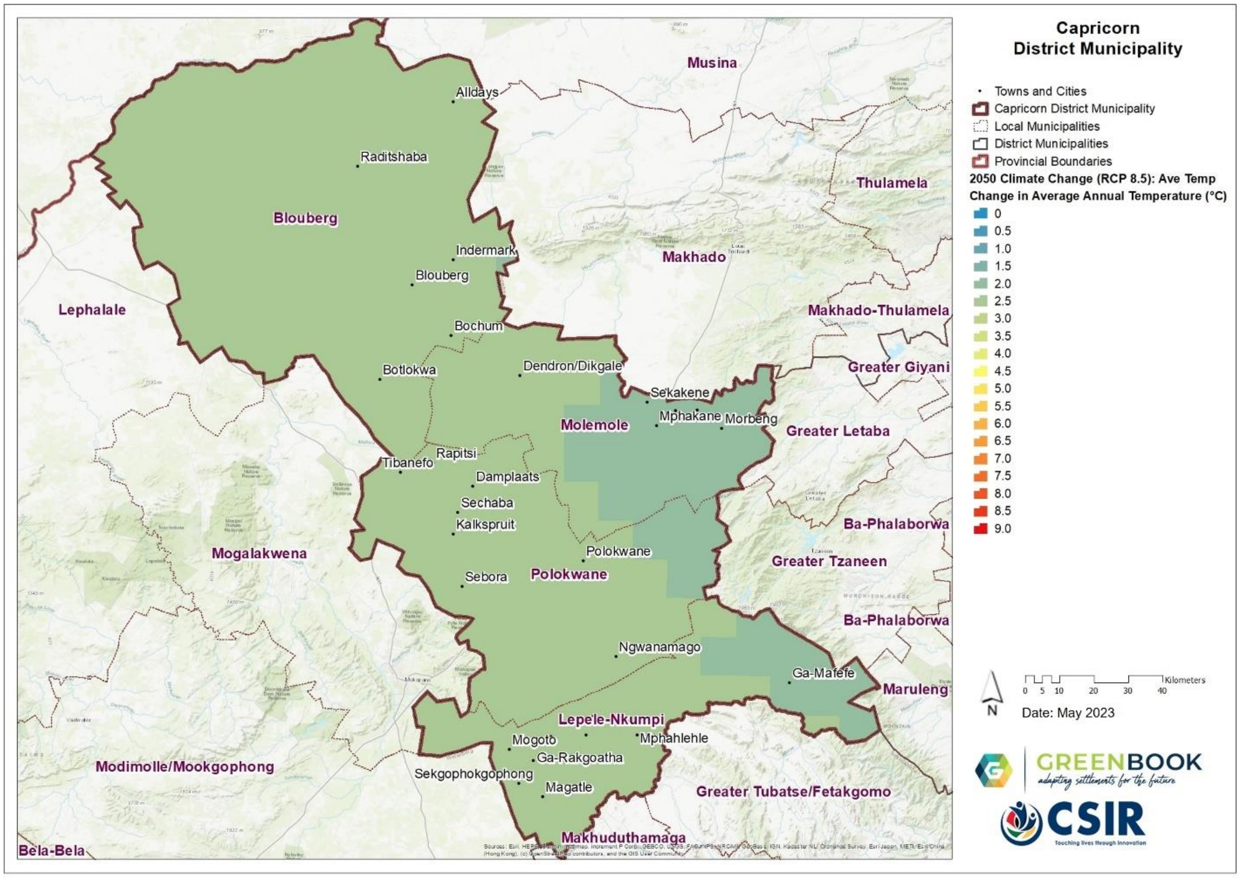

Figure 6: Projected change in average annual temperature (°C) from the baseline period 1961 – 1990 to the future period 2021-2050 for Capricorn District Municipality, assuming an RCP 8.5 emissions pathway

CDM experiences current average annual temperatures of between 16 and 22 °C, with higher averages found near and along the north-western border of the District, and particularly in the Local Municipality of Blouberg. The projections show average annual temperature increases of between 2.5 °C and 3 °C across the District by 2050, under a "business as usual" emissions scenario (RCP 8.5). The greatest increases are expected in most parts of the District, including the western, central, northern and south-western parts of the District (see Figure 6). Capricorn District's relatively lower average annual temperature increases are projected along the south- and central-eastern parts of the District, particularly in the eastern parts of Lepelle-Nkumpi- and Molemole LMs, as well as the east of the City of Polokwane.

2.2.2. Rainfall

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

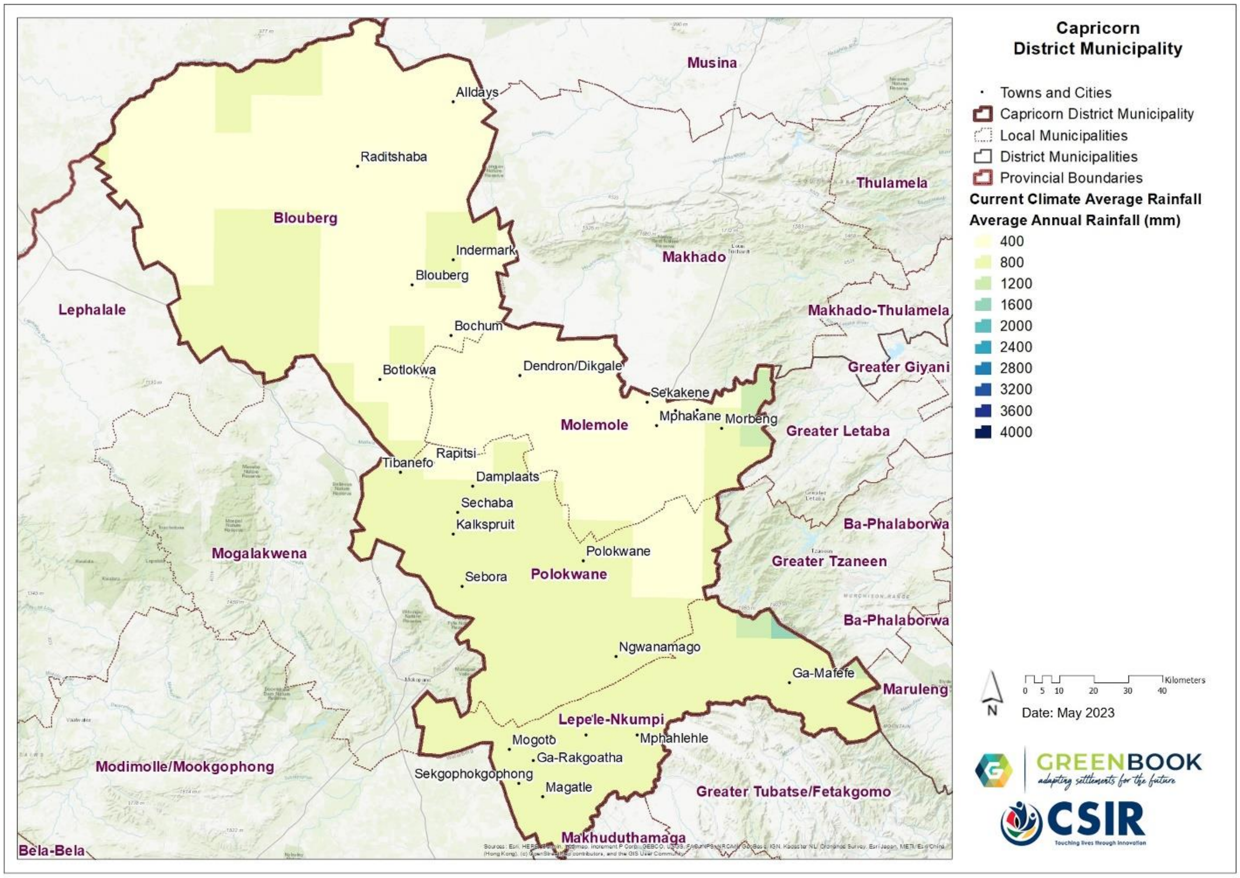

Figure 7: Average annual rainfall (mm) for the baseline period 1961-1990 for Capricorn District Municipality

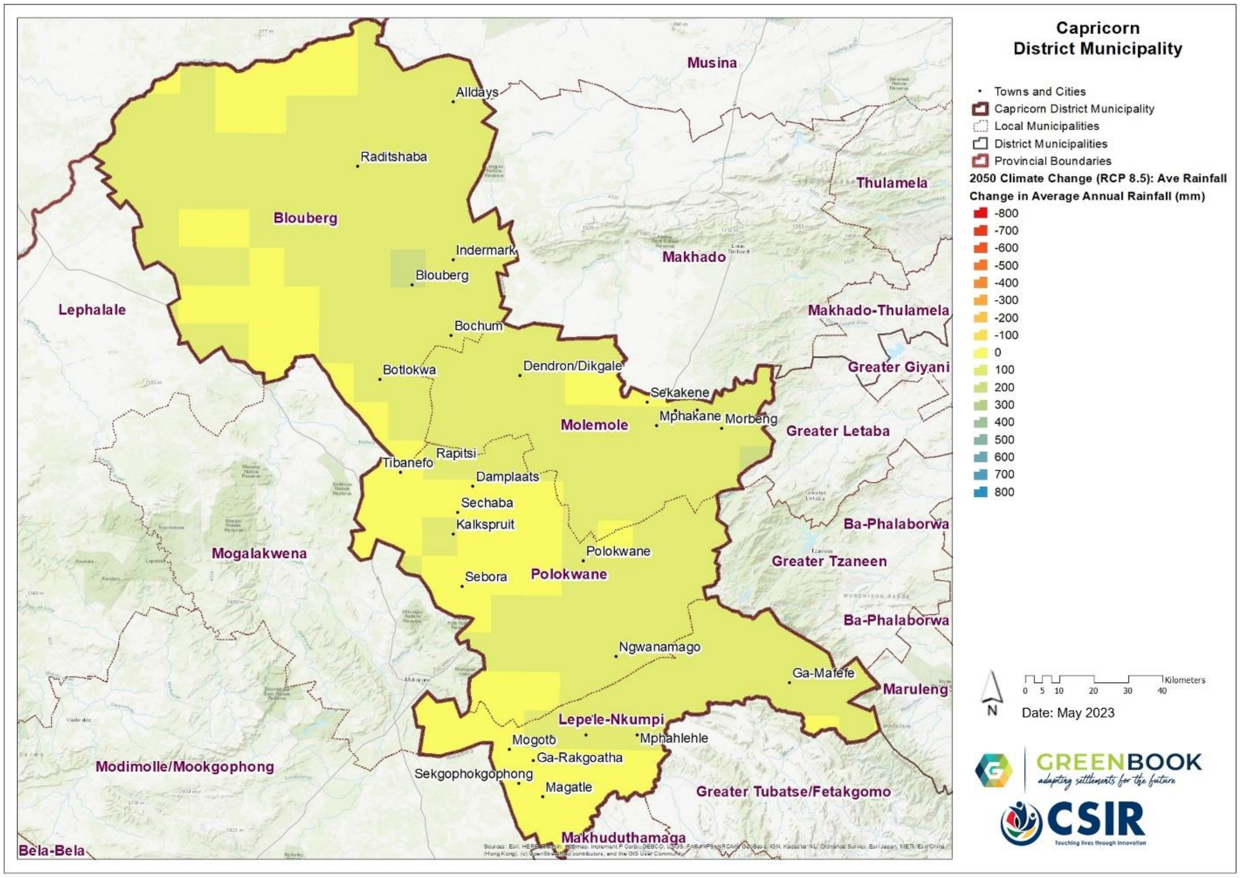

Figure 8: Projected change in average annual rainfall (mm) from the baseline period to the period for the period 2021-2050 for Capricorn District Municipality, using an RCP8.5 emissions pathway

The Capricorn District experiences current GCM derived average annual rainfall of between 248 and 1 273 mm, with significant average rainfall recorded across a few settlements in the south east, including Morbeng in the Local Municipality of Molemole. The projections show changes in average annual rainfall of between 23.5 mm less and 93 mm more rainfall across the District by 2050 under a high, i.e., "business as usual", emissions scenario (RCP 8.5). Considerable decreases (23.5 mm less) to modest increases (56.0 mm more) in average annual rainfall are expected mostly in the Local Municipality of Blouberg, while slight decreases (8.6 mm less) to substantial increases (93.1 mm) are expected across the Local Municipality of Lepelle-Nkumpi. The rest of the DM will generally experience similar to slightly higher average annual rainfall into the future (2050) under a high (RCP 8.5) emissions scenario, thus, indicating the possibility of slightly wetter conditions in the future.

2.3. Climate Hazards

This section showcases information with regards to Capricorn 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).

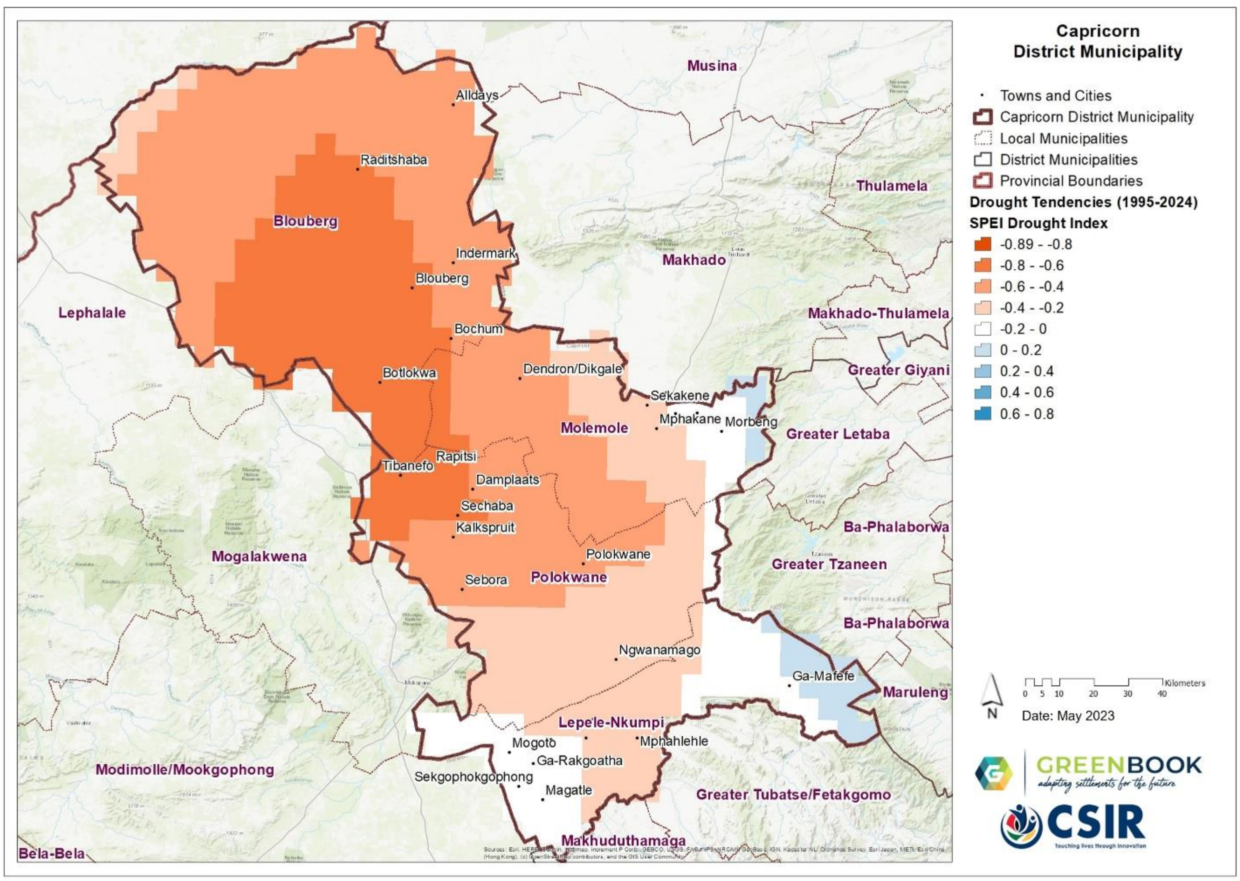

Figure 9: Projected changes in drought tendencies from the baseline period (1986 – 2005) to the current period (1995 - 2024)

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 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.

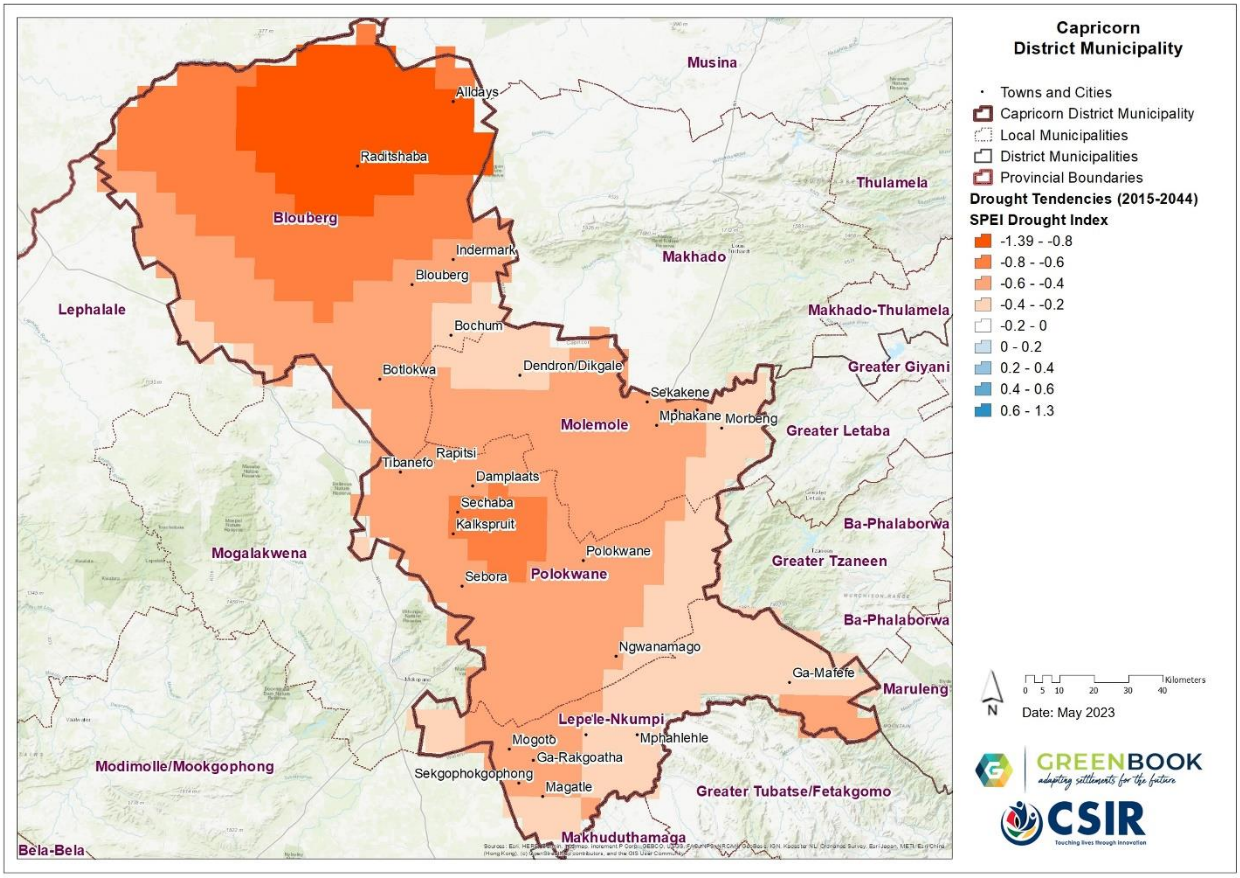

Figure 10: Projected changes in drought tendencies from the baseline period (1986–2005) to the future period (2015-2044)

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.

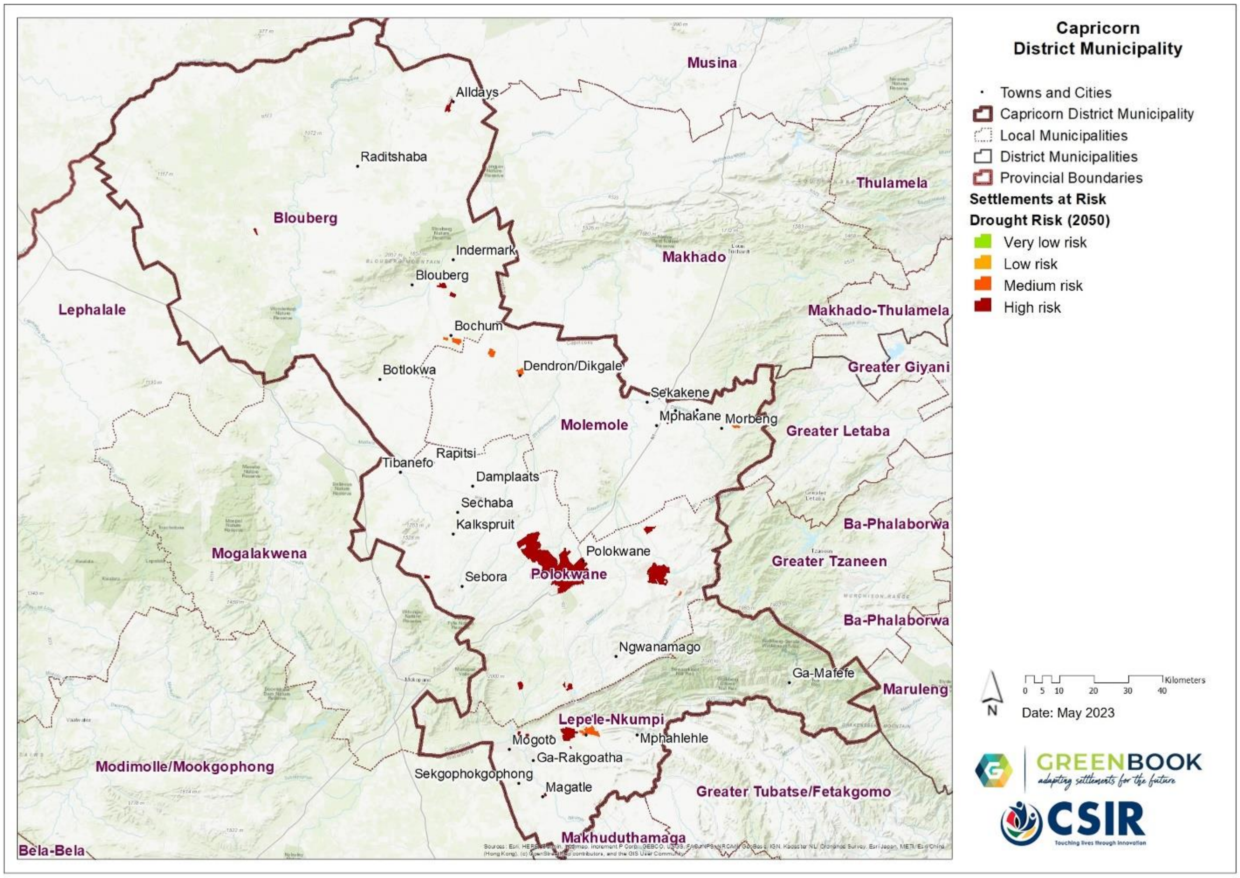

Figure 11: Settlement-level drought risk for Capricorn District Municipality

As outlined in Figure 9, at the baseline, Blouberg LM and large parts of Molemole- and Polokwane LMs, are exposed to high drought tendencies, with a few settlements, including the eastern parts of Morbeng and Ga-Mafefe, exposed to periods of excessive rainfall. Drought tendencies are projected to become more frequent and intense further into the future, particularly in the northern and central parts of the DM (Figure 10). All settlements across the District, face a medium to high drought risk into the future (See Figure 11).

2.3.2. Heat

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

The annual heatwave days map (Figure 13) under baseline climatic conditions depicts the number of days (per 8x8 km grid point) where the maximum temperature exceeds the average maximum temperature of the warmest month of the year at that location by at least 5 °C, and that for a period of at least three consecutive days.

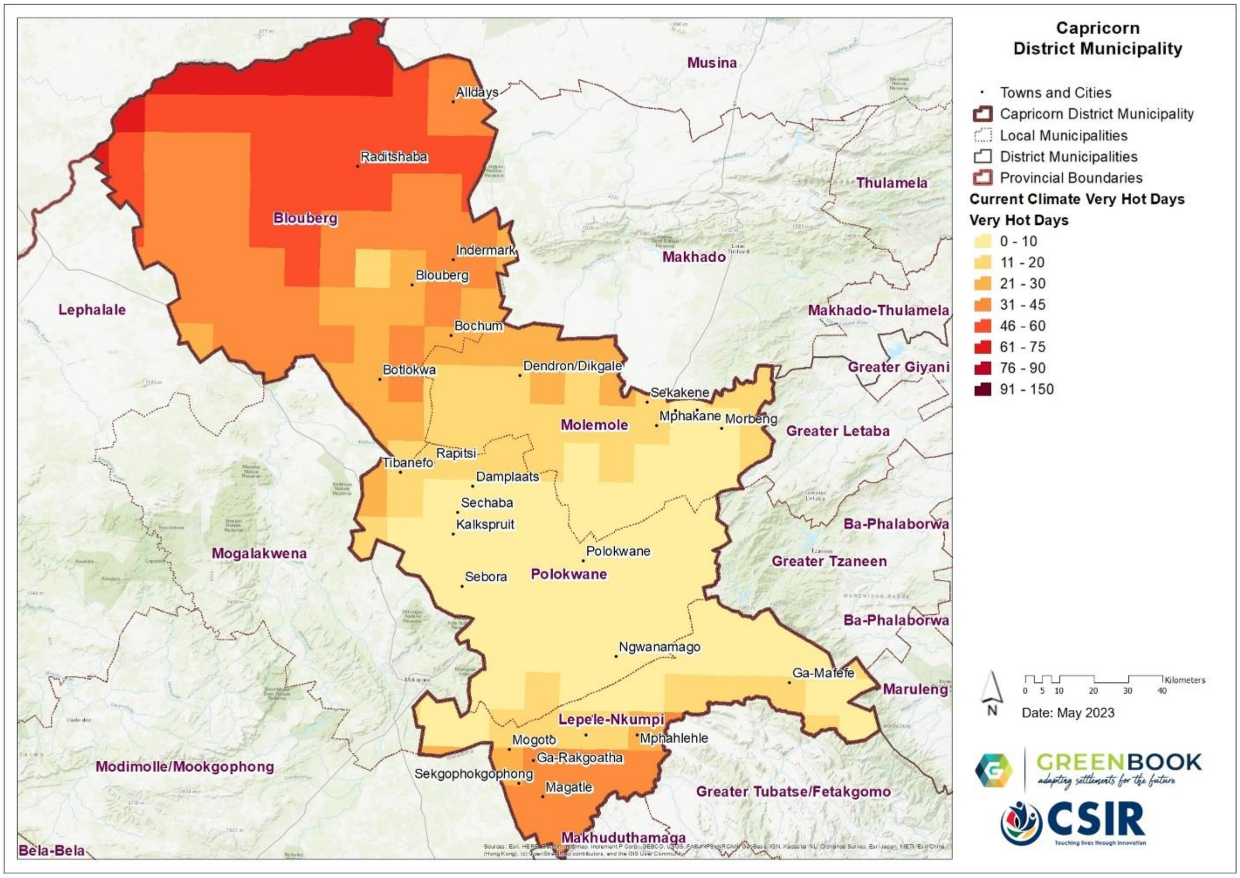

Figure 12: Annual number of baseline very hot days across Capricorn District Municipality under current climatic conditions when daily temperature maxima exceed 35°C

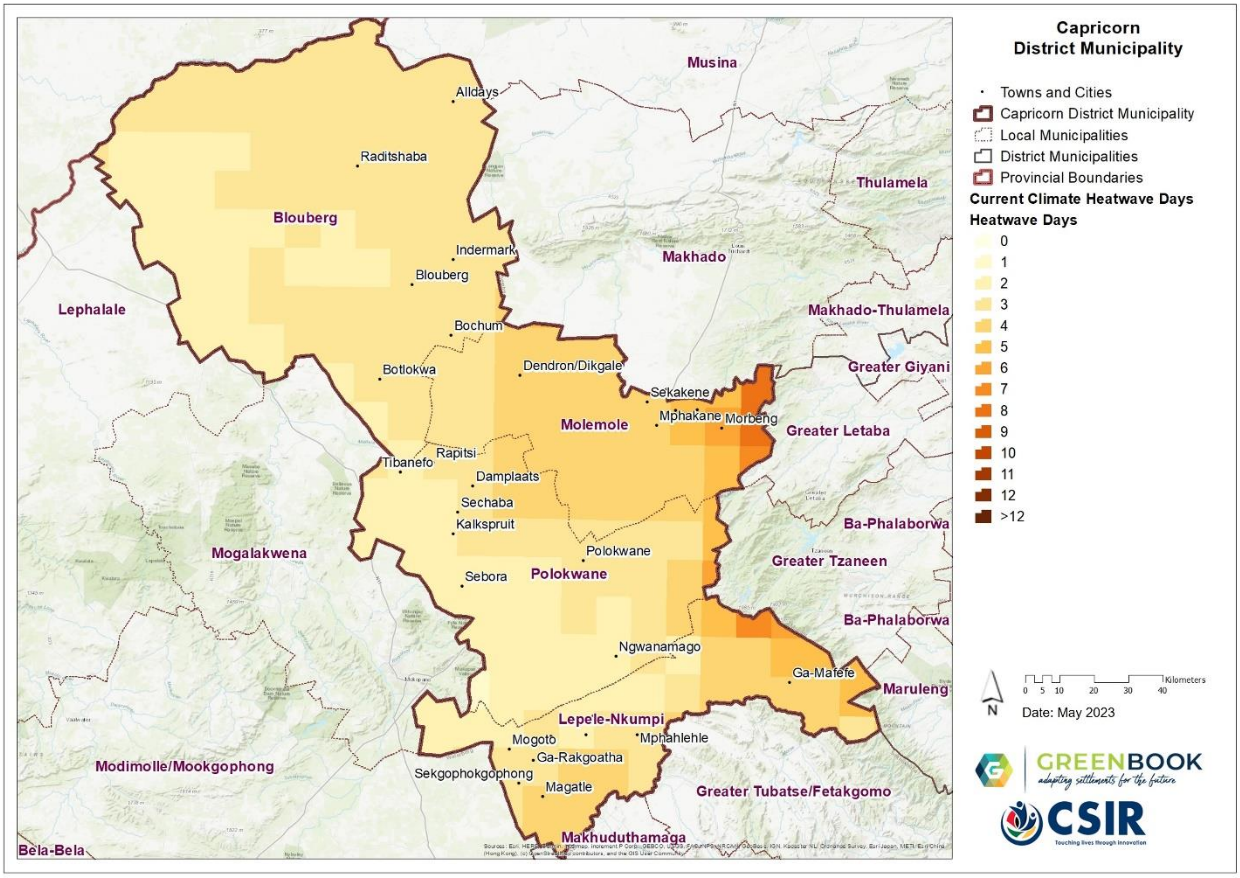

Figure 13: Annual number of heatwave days under GCM derived baseline climatic conditions across Capricorn District Municipality

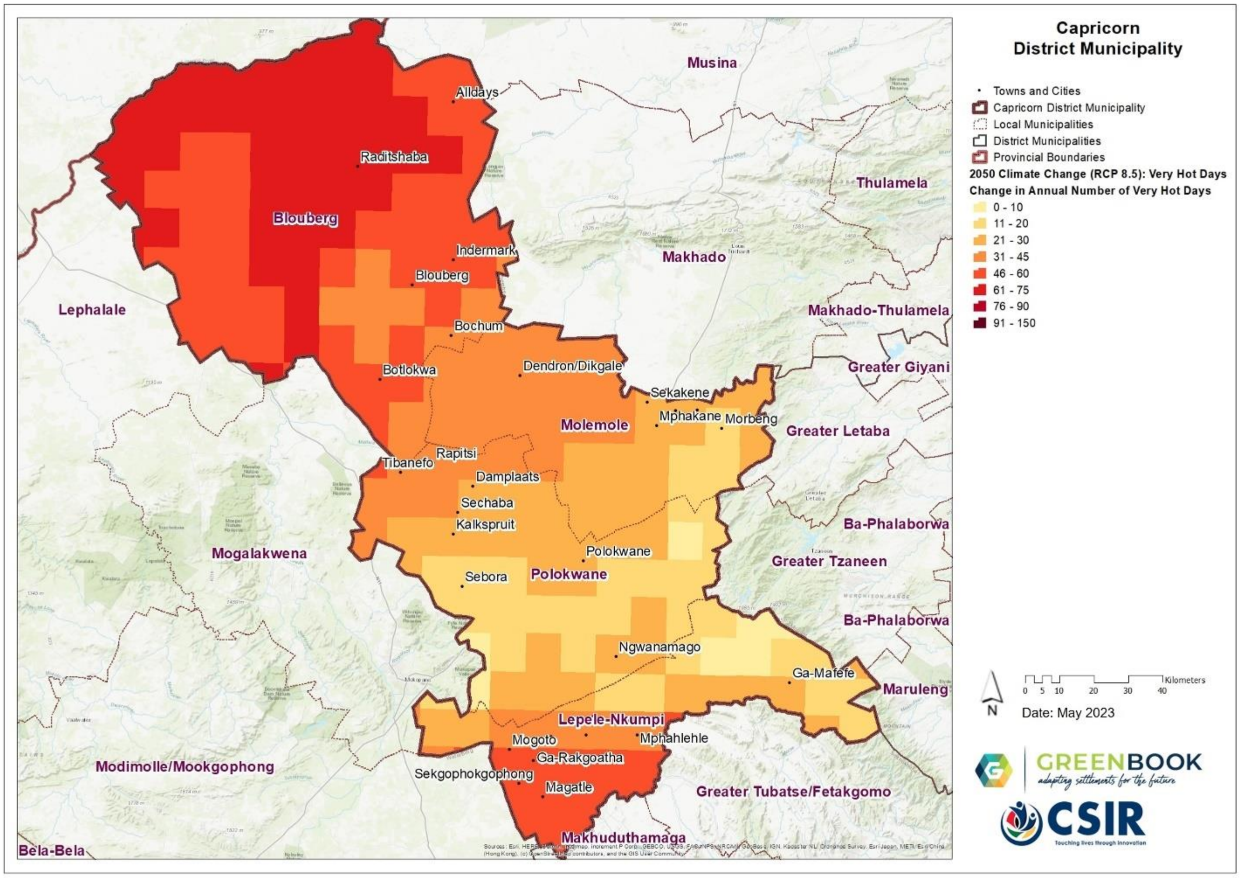

Figure 14: Projected change in average annual average number of very hot days with daily temperature maxima exceeding 35°C from 1961-1990 to 2021-2050 for Capricorn District Municipality (RCP8.5)

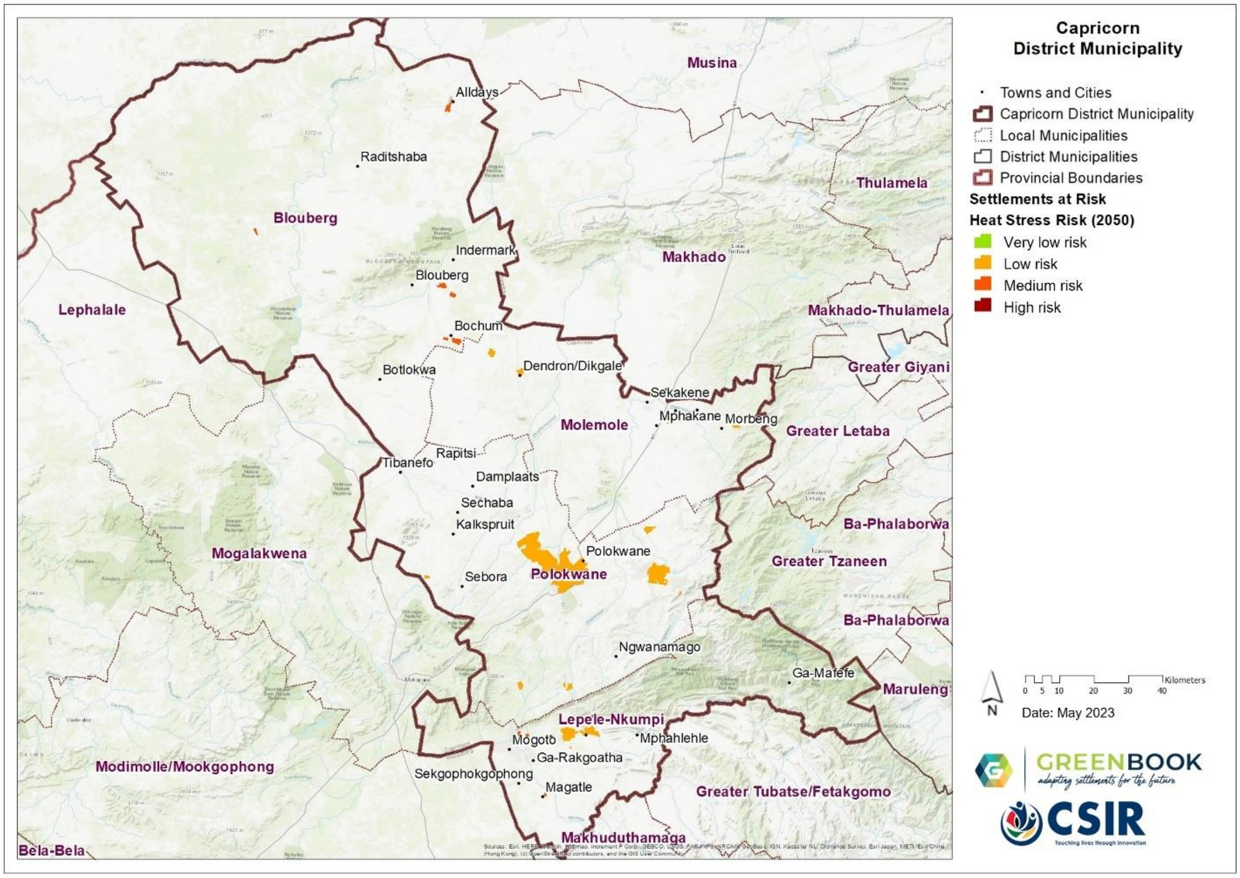

Figure 15: Heat risk across Capricorn District Municipality at settlement level

Under baseline conditions, a significant number of hot days (45 days and more) are experienced in the north-western parts of the District, especially along the north of Blouberg LM. This northern Local Municipality currently experiences between 61 and 75 very hot days per year. Very hot days are also more likely to be experienced in the southern parts of the District, particularly across the southwest parts of the District, in the Municipality of Lepelle-Nkumpi (See Figure 12). The number of very hot days are projected to increase in the areas that are already more likely to experience extreme heat (See Figure 14). Heatwave events are more likely to take place along the south-eastern border of the District, especially in Molemole LM, as well as north-eastern parts of Lepelle-Nkumpi LM (See Figure 13).

Figure 15 depicts the levels of heat risk of settlements under projected future climates. 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. Settlements in CDM face a low to medium risk of heat stress into the future (2050); the settlements that face the greatest risk to heat stress, i.e., in relation to other settlements in the District, are located in Local Municipality of Blouberg.

2.3.3. Wildfire

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

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

The projected number of fire danger days for an 8 x 8 km grid-point under an RCP 8.5 "business as usual" emissions low mitigation (worst case) scenario was calculated. A fire danger day is described as a day when the McArthur fire-danger index (McArthur 1967) exceeds a value of 24. The index relates to the chances of a fire starting, its rate of spread, its intensity, and its difficulty of suppression, according to various combinations of air temperature, relative humidity, wind speed and both the long and short-term drought effects. Future settlement risk is informed by the projected change in the number of fire danger days.

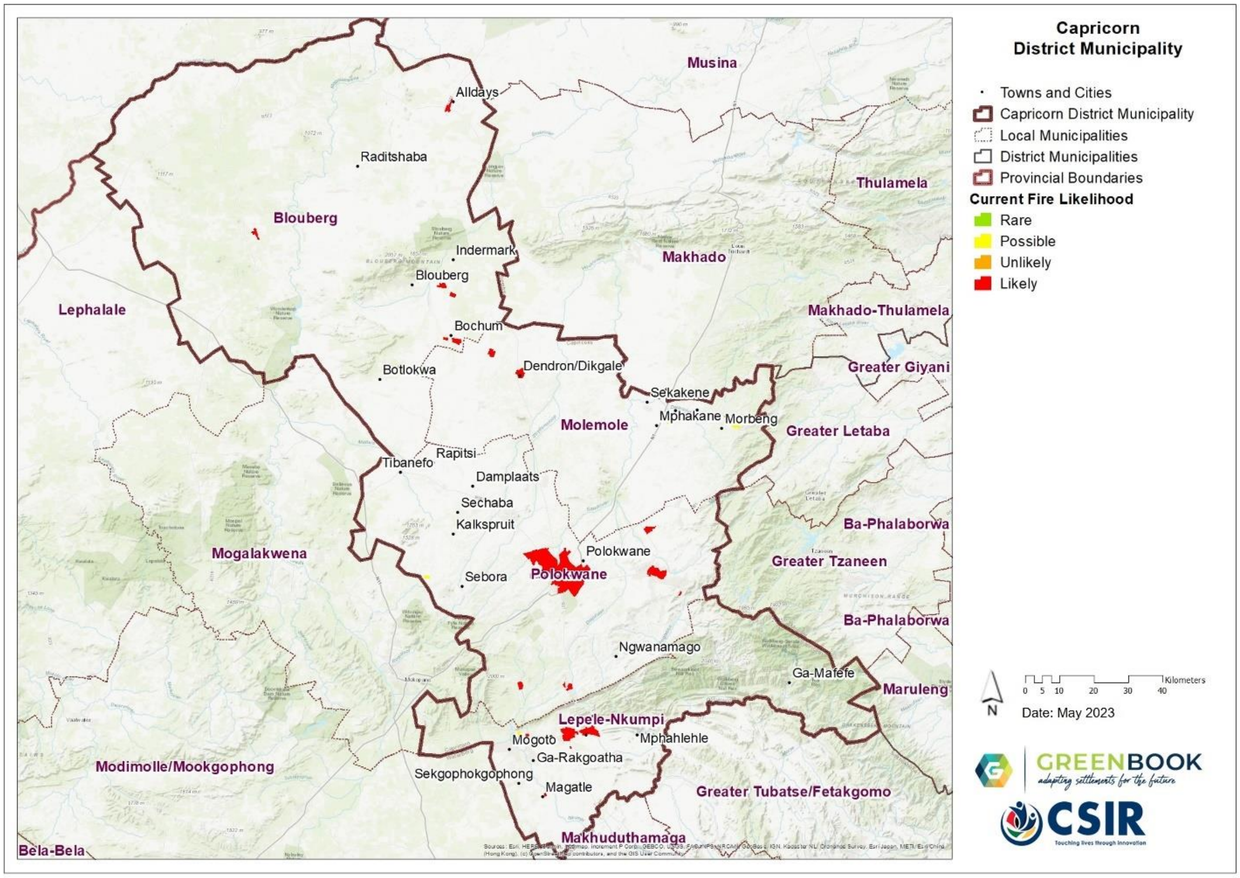

Figure 16: The likelihood of wildfire under current climatic conditions across settlements in Capricorn District Municipality

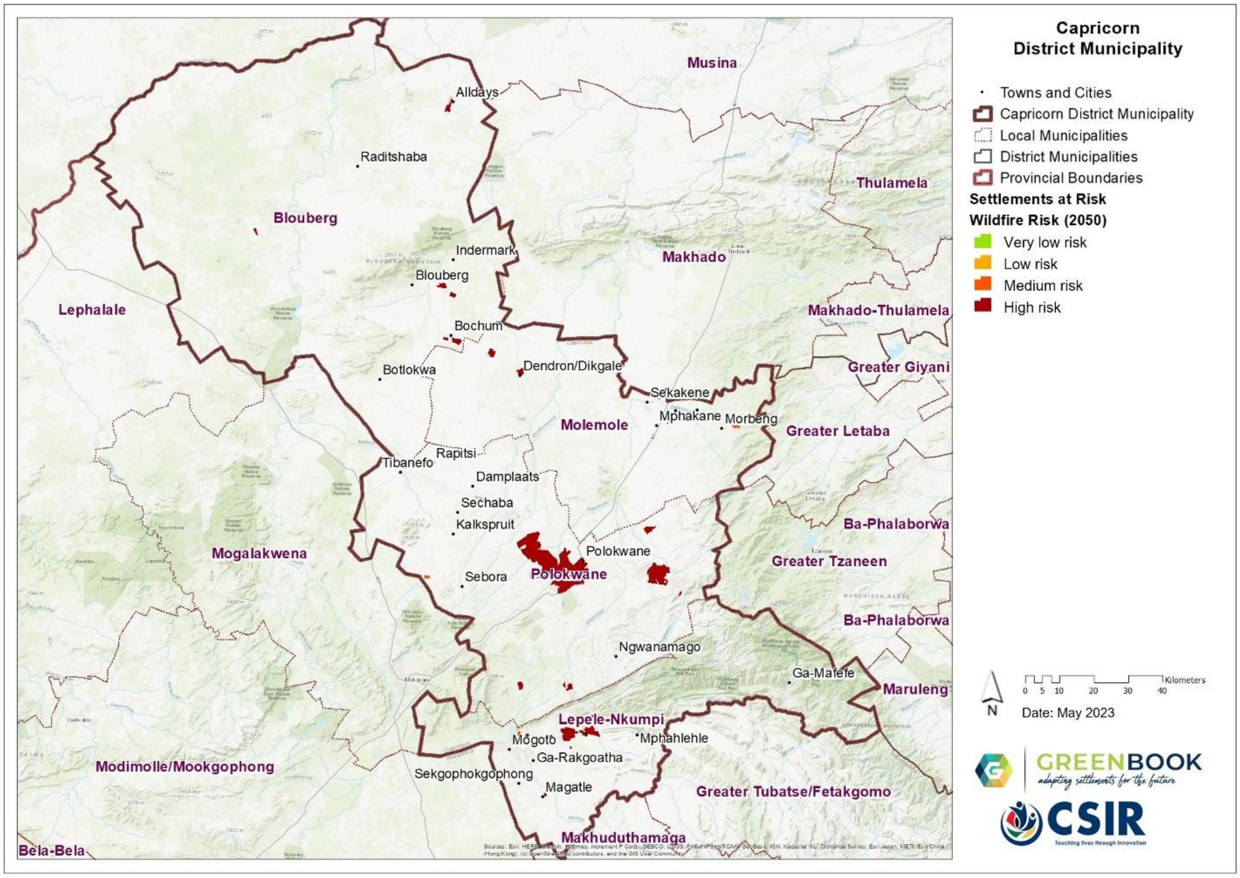

Figure 17: The likelihood of wildfire under projected future climatic conditions across settlements in Capricorn District Municipality

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 under current climatic conditions, while Figure 17 depicts the settlements that could be at risk of increases in wildfires by the year 2050. Settlements which are likely to experience wildfires on their wildland-urban interface include Polokwane, as well as several other settlements scattered across east and southern parts of the City of Polokwane, the western parts of Lepelle-Nkumpi LM, as well as along or near the border of Molemole and Blouberg LMs, with an additional two settlements (including Alldays) located further north, in the Municipality of Blouberg (Figure 16). It is projected that the same settlements face an increased risk of wildfires into a climate-changed future, at least up to 2050 (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.

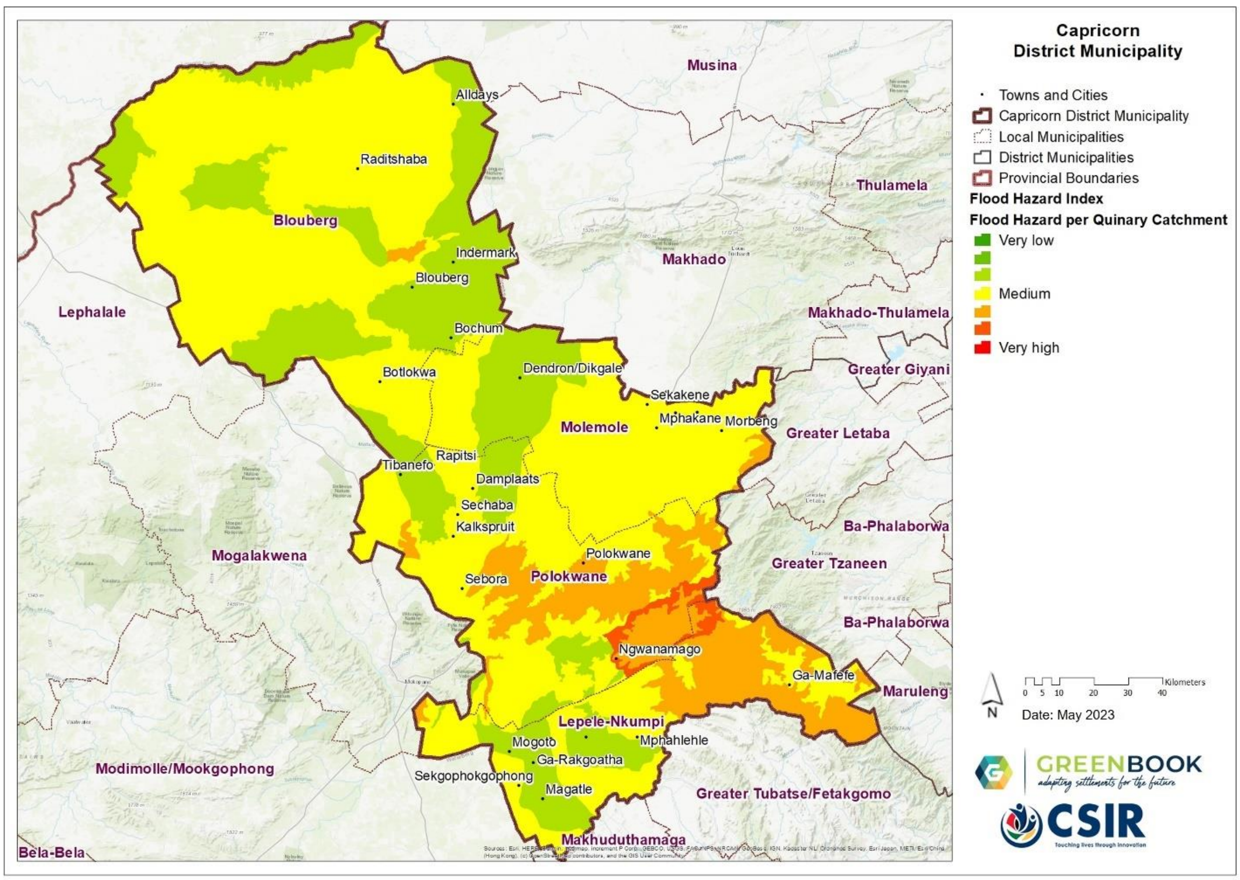

Figure 18: The flood hazard index across Capricorn District Municipality under current (baseline) climatic conditions

Figure 18 depicts the flood hazard index of the different individual 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, with parts of Polokwane and Lepelle-Nkumpi LMs recording a medium to high flooding hazard. Most parts of the District have a low to medium flooding hazard.

Figure 19 depicts the projected change into the future for extreme rainfall days for an 8 x 8 km grid. This was calculated by assessing the degree of change when projected future rainfall extremes (e.g., 95th percentile of daily rainfall) are compared with current rainfall extremes. A value of more than 1 indicates an increase in extreme daily rainfalls. Slight to significant decreases in the number of extreme rainfall days are expected around the northern parts of Capricorn, particularly across the Local Municipalities of Blouberg and Molemole, while slight to significant increases in the number of extreme rainfall days are expected in the southern parts of the DM, particularly across the Local Municipalities of Polokwane and Lepelle-Nkumpi.

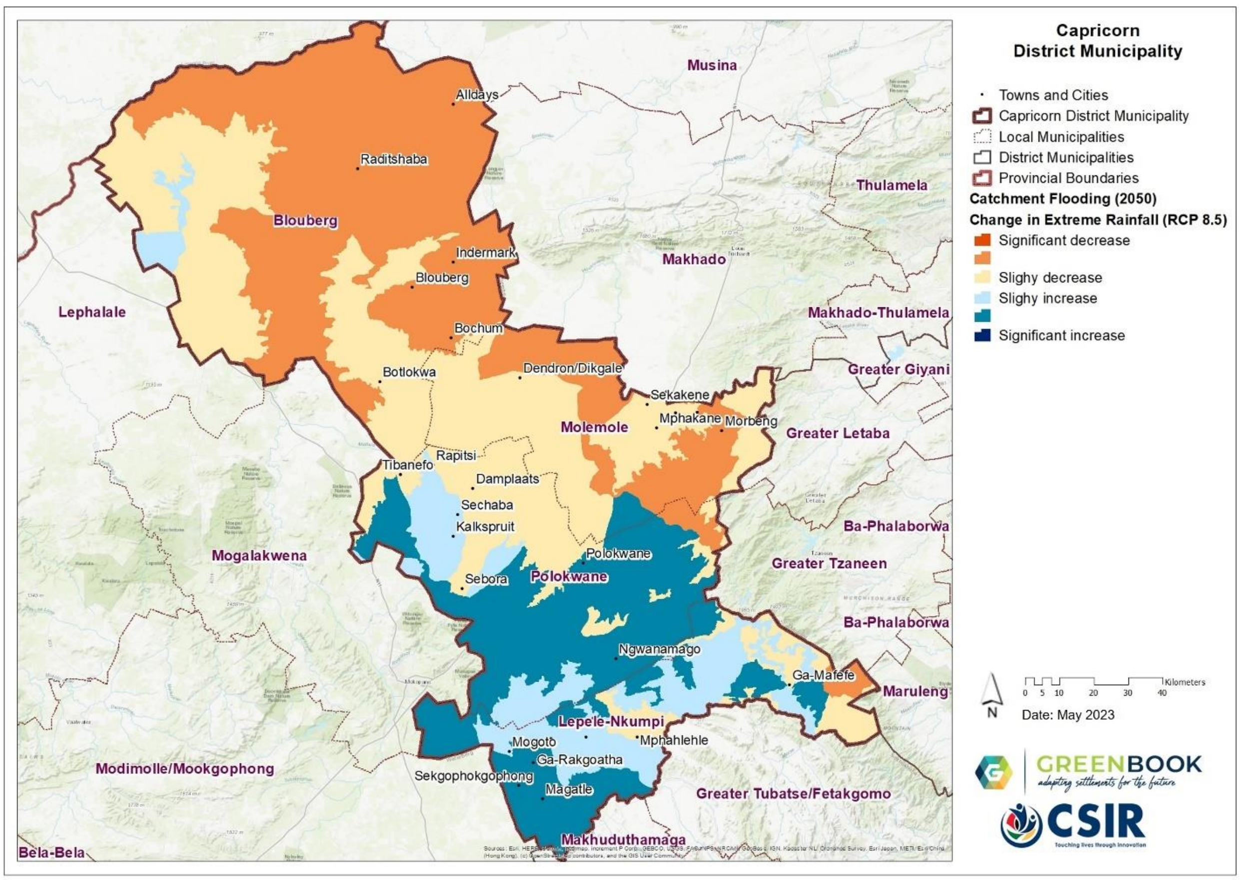

Figure 19: Projected Change into the future in extreme rainfall days across Capricorn District Municipality

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. Two settlements on the east of Polokwane, including Sebayeng and Mankweng, face a high risk of flooding in the future (2050), while a medium risk of flooding is projected for the settlement of Polokwane. The rest of the settlements in the District face very low to low flood risk into a climate-changed future, at least up to 2050.

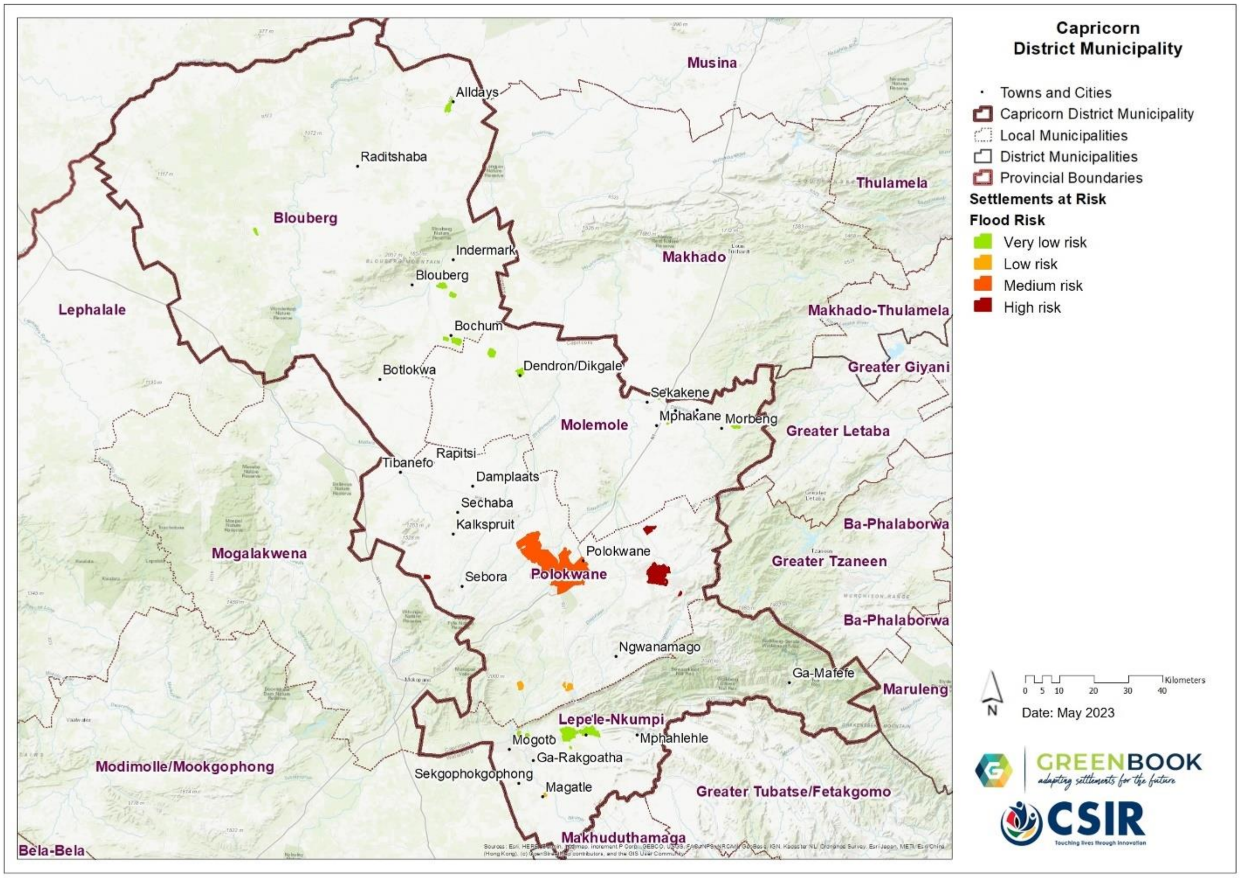

Figure 20: Flood risk into a climate change future at settlement-level across Capricorn District Municipality.

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 Capricorn 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. In the Capricorn District, there is a mix of surface water and groundwater dependent towns. Most settlements in Polokwane LM rely on a combination of the two, while most settlements across Lepelle-Nkumpi, Molemole and Blouberg LMs rely entirely on groundwater.

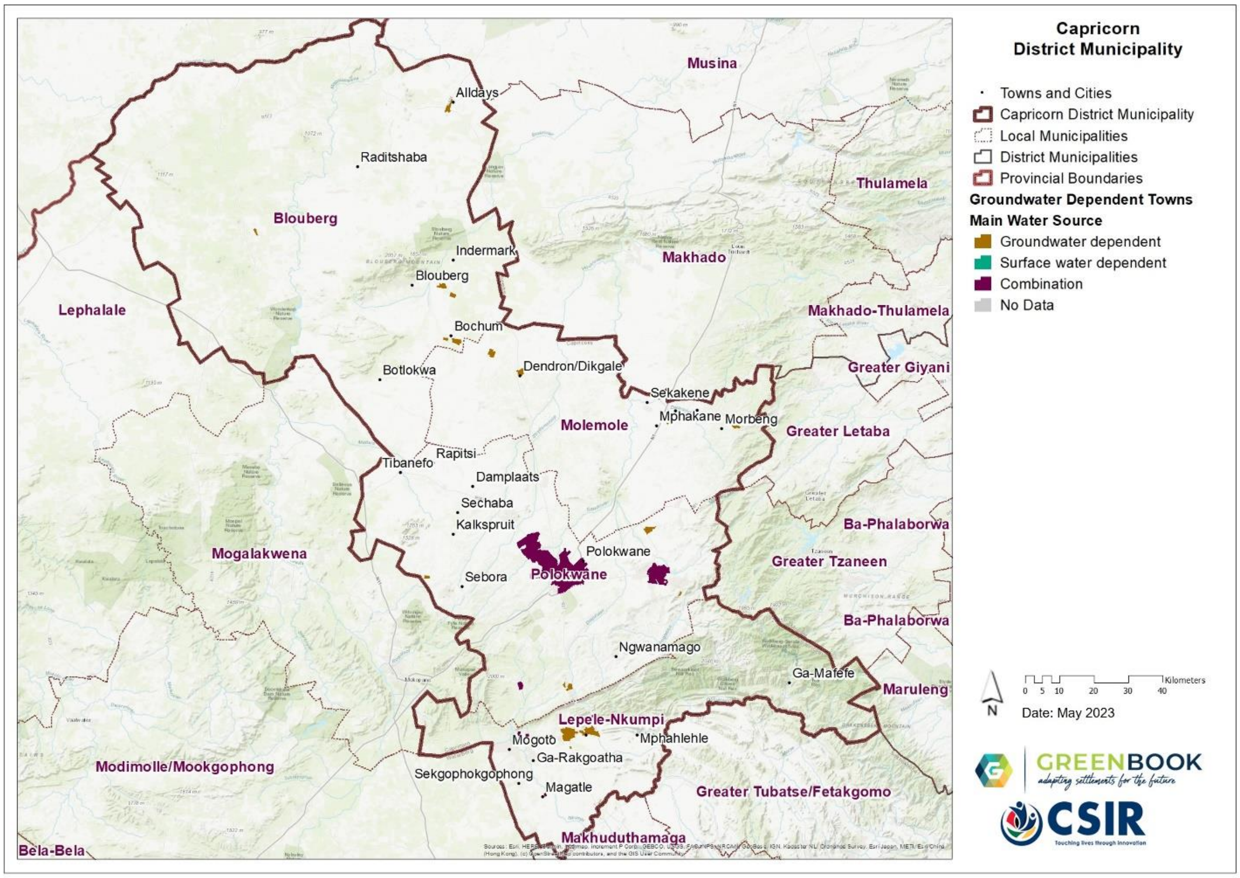

Figure 21: Main water source for settlements in the Capricorn District Municipality

Figure 22 indicates the occurrence and distribution of groundwater resources across the District Municipality, showing distinctive recharge potential zones, while Figure 23 indicates the projected change in groundwater recharge potential. Figure 24 indicates the groundwater dependent settlements that may be most at risk of groundwater depletion based on decreasing groundwater aquifer recharge potential and significant increases in population growth pressure by 2050. Current groundwater recharge potential is high across the south-west and south-eastern parts of the District, with central and northern parts of the District experiencing a moderate recharge potential (Figure 22). Most parts of the District are expected to experience a decrease in groundwater recharge potential by 2050, with the exception of a few pockets scattered across the north, as well as along the south west and south-eastern parts of the District (Figure 23).

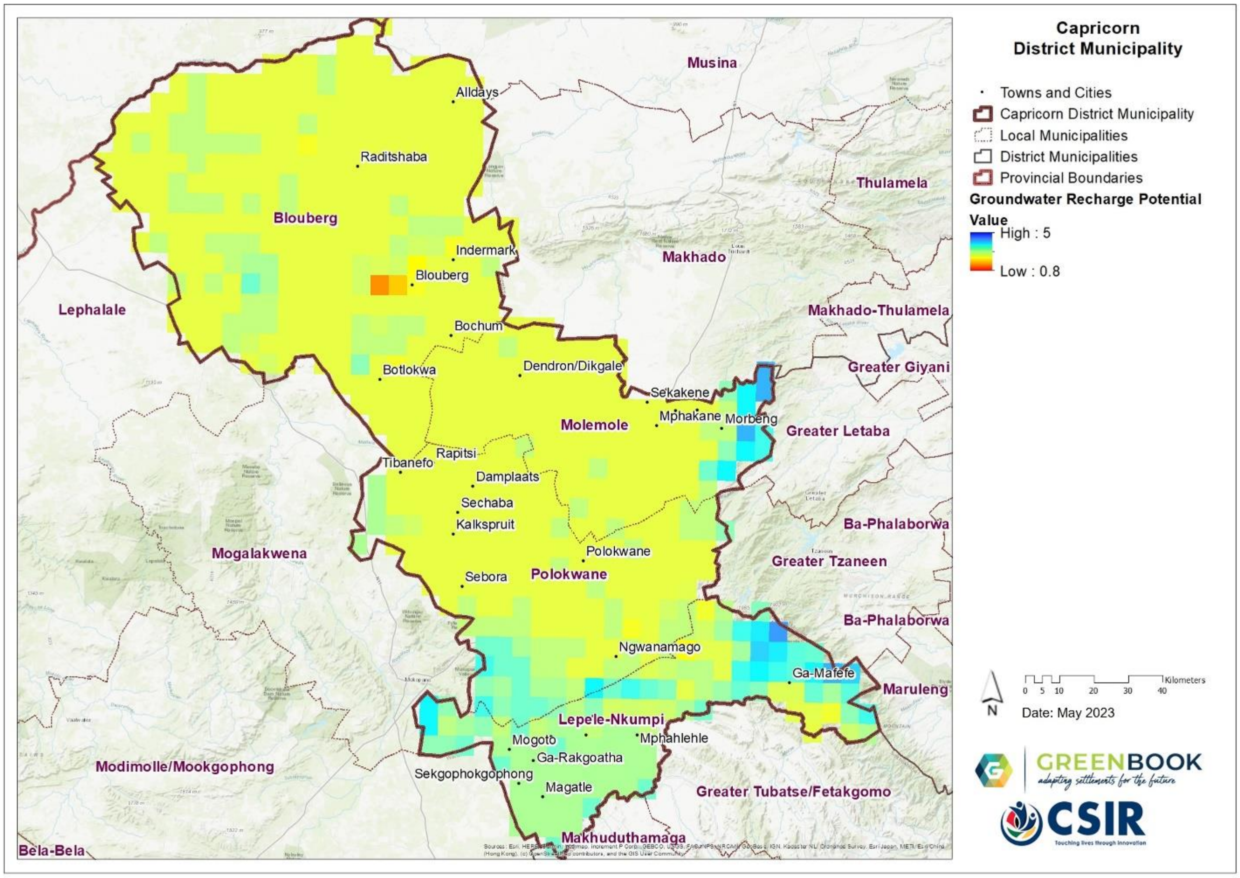

Figure 22: Groundwater recharge potential across Capricorn District Municipality under current (baseline) climatic conditions

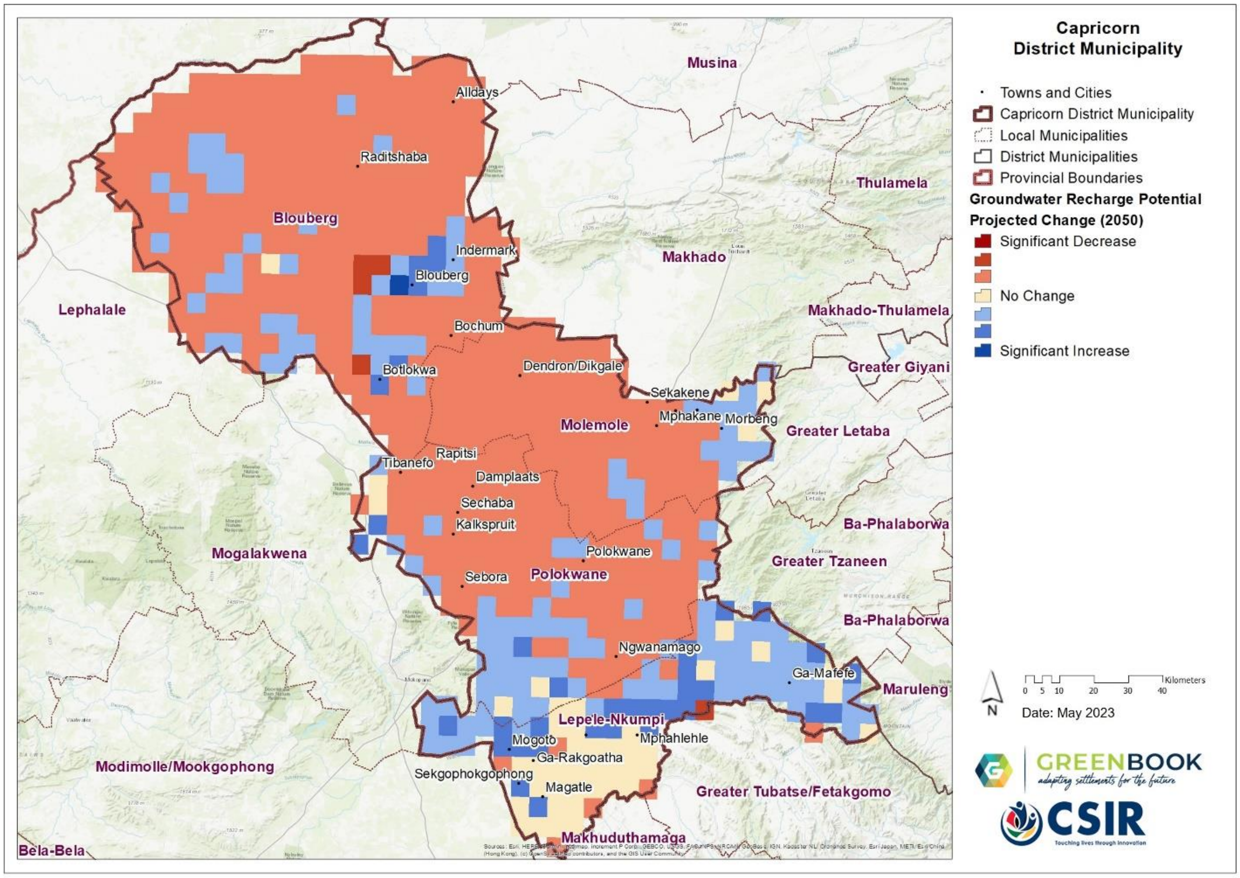

Figure 23: Projected changes in groundwater recharge potential from baseline climatic conditions to the future across Capricorn District Municipality

Considering projected future groundwater recharge potential combined with population growth, it is likely that the settlement of Polokwane and surrounding areas, as well as parts of Mankweng, will face a high risk of groundwater depletion towards 2050 (See Figure 24).

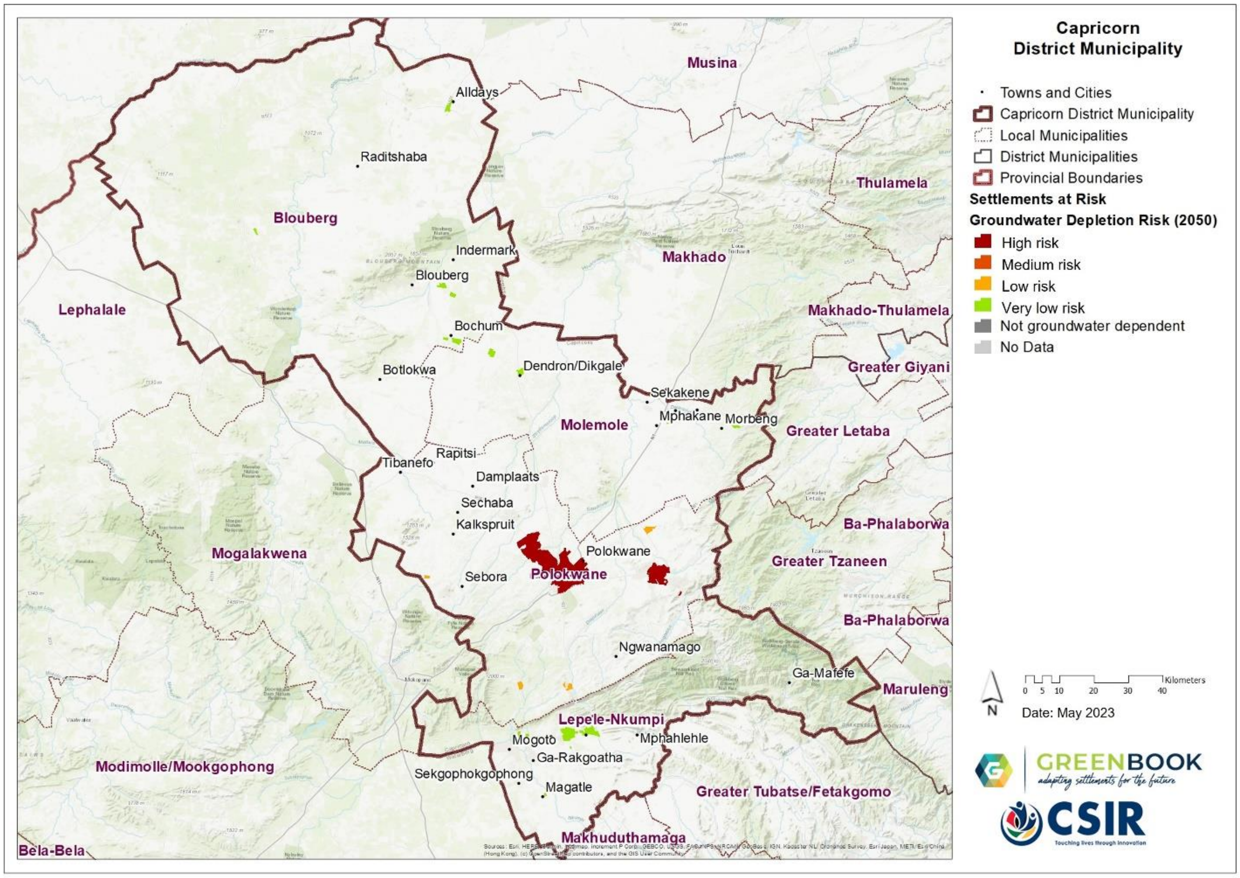

Figure 24: Groundwater depletion risk at settlement level across Capricorn District Municipality

Table 3 provides an overview of current water supply vulnerability (i.e., demand versus supply) for the Local Municipalities in the Capricorn District Municipality based on the data compiled for the Department of Water and Sanitation's (DWS) All Town's Study (Cole, 2017). A water supply vulnerability score above 1 indicates that demand is more than supply, while a score below 1 indicates that supply is meeting demand.

Table 3: Current water supply and vulnerability across Capricorn District Municipality

Local Municipality	Water Demand per Capita (l/p/d)	Water Supply per Capita (l/p/d)	Current Water Supply Vulnerability
Blouberg	114.1	107.83	1.06
Lepelle-Nkumpi	98.94	105.22	0.94
Molemole	97.62	96.23	1.01
Polokwane	111.43	140.01	0.8

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

Blouberg

Blouberg LM's water demand is currently higher than supply, but because of the projected decline in the population in Blouberg, water supply vulnerability is projected to improve into the future.

Lepelle-Nkumpi

Water supply vulnerability is currently relatively low in the Local Municipality and because of the projected population decline, combined with increased mean annual runoff, water supply vulnerability is not expected to increase into the future (at least up to 2050).

Molemole

Water supply is already vulnerable in Molemole LM, as demand is currently higher than supply; but because of the projected population decline and increase in regional water supply, water supply vulnerability is projected to decrease to between 0.94 and 0.74 by 2050.

Polokwane

Water supply vulnerability in Polokwane LM is relatively low, but is expected to significantly increase to between 1.05 and 1.55 by 2050. Water supply vulnerability is driven by the projected high population growth pressure, a decrease in average annual rainfall and increased evaporation.

2.4.2. Agriculture, forestry, and fisheries

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

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

The methodological approach to understanding the impact of climate and climate change on agriculture, forestry, and fisheries, consisted of four components. Firstly, the most important areas in terms of Gross Value Added (GVA) and employment for the agriculture, forestry and fisheries sector relative to the other sectors of the South African economy were determined. Secondly, an analysis of climate change scenarios was done using historical climate variables, as well as multi-model projections of future climates to help identify specific climate-related risk factors for agriculture within specific regions. Thirdly, crop suitability modelling was done to indicate how the area suitable for crop production under the present climate conditions might shift or expand under the scenarios of future climate change, in addition to using the Temperature Humidity Index (THI) to assess heat stress in livestock. Finally, the climate change analysis was used in conjunction with the crop modelling outputs to assess the potential impacts of climate change over a specific area, or for a specific crop, to give more detail on how predicted climate changes translate into location/crop specific impacts. This was developed at a local municipal level and guided by the outcome of the agricultural industry sector screening and climate scenario analysis.

The agricultural sector contributes 6.60 % to the total employment in the District (Capricorn District Municipality, 2022). The potential impact of climate change and climate hazards on agriculture is notable considering that over 23 000 individuals (in 2016) were dependent on the sector for employment. Furthermore, while the agricultural sector constitutes one of the three major sectors in Blouberg Local Municipality, Molemole Local Municipality mainly comprises of both commercial and subsistence agricultural activities. In fact, a large part of Molemole's economy depends on agricultural development, as the municipality is known for its production of potatoes and tomatoes for the export markets. However, crop production in Molemole has contracted significantly, with many crop farmers shifting to game farming (Capricorn District Municipality, 2022).

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

Blouberg

In Blouberg LM, the AFF sector contributes 9.20 % to the local GVA, which is a contribution of 0.32 % to the national GVA for the AFF sector. Of the total employment in the Local Municipality, 27.69 % is within the AFF sector. The main agricultural commodities are maize, beef cattle and chickens. Climate projections show a generally hotter and (potentially) wetter climate, which could result in an increase in maize yield for the near future. However, towards 2050, heat stress can negatively impact production. The projected climate could also lead to increased water availability. However, hot and moist conditions in rangelands could lead to an increase in the spread of disease and parasites. The projected increase in heat stress may also result in reduced cattle growth and reproduction performance, as well as require increased investment in ventilation and cooling, to maintain optimal seasonal temperatures and reduce the risk of heat stress for chickens (Heat stress on birds reduces body weight gain, reproduction efficiency and egg quality).

Lepelle-Nkumpi

In Lepelle-Nkumpi LM, the AFF sector contributes 1.58 % to the local GVA, which is a contribution of 0.14 % to the national GVA for the AFF sector. Of the total employment, 6.06 % is within the AFF sector. The main agricultural commodities are beef cattle, maize and potatoes. Climate projections show a generally hotter and (possibly) wetter climate. Increased heat stress can lead to reduced growth and reproductive efficiency for livestock, as well as reduced production for maize crops, while increase in rainfall could result in increased maize yields into the near future. Hotter and wetter conditions could increase the yield of potatoes (due to increased concentration of CO_2), as root crop plants benefit from elevated carbon dioxide levels owing to higher rates of photosynthesis.

Molemole

In Molemole LM, the AFF sector contributes 12.26 % to the local GVA, which is a contribution of 0.41 % to the national GVA for the AFF sector. Of the total employment, 32.35 % is within the AFF sector. The main agricultural commodities are beef cattle, potatoes and subtropical fruit. Climate projections show a generally hotter and wetter climate. While the impact of hot and moist conditions on cattle and potatoes remains the same (See sections on Blouberg and Lepelle-Nkumpi Local Municipalities), the same conditions affect the production of subtropical fruit differently. For instance, hot and moist conditions increase the exposure of such fruit to pests and diseases. Moreover, extreme temperatures can contribute to poor tree flowering, fruit setting and decreases in production.

Polokwane

In Polokwane LM, the AFF sector contributes 0.93 % to the local GVA, which is a contribution of 0.49 % to the national GVA for the AFF sector. Of the total employment, 3.48 % is within the AFF sector. The main agricultural commodities are maize, potatoes and chickens. Similar to the rest of the Local Municipalities in the District, climate projections show a generally hotter and (possibly) wetter climate, becoming drier towards the end of 2050.

3. Recommendations

The greatest risks faced across the Capricorn District are increased temperatures, heat extremes and drought. However, the projected potential for slight increases in average annual rainfall may offset some of the negative impacts associated with these risks. Several settlements in the City of Polokwane, including Polokwane, Sebayeng, and parts of Mankweng also face a high risk of wildfires and flooding, while most of the settlements in Blouberg LM are projected to face a high risk of heat stress into the future. The same areas, with the exception of the settlements in the Blouberg LM, are expected to experience very high population growth pressure, thus indicating the increased exposure of people to those climate hazards. The areas that are seeing significant population growth are also expected to experience an increase in water supply vulnerability, where demand will outstrip supply. Moreover, the same populous areas, which rely on a combination of groundwater and surface water, face a high risk of groundwater depletion into the future (2050). This therefore indicates the need to diversify water supply (or water sources), improve groundwater recharge and conserve available potable water in those areas.

Most of the Local Municipalities in Capricorn experienced a downward trend in economic vulnerability, particularly between 1996 and 2011, thus alluding to the need to create more resilient and diverse local economies. Furthermore, with the exception of the City of Polokwane, all of the Local Municipalities in the District are expected to experience significant population decline – therefore indicating the possible migration of these populations to the province's capital. This projected trend may put strain on the City's resources (which is already facing extreme growth pressure) and expose more people to major climate hazards such as flooding and wildfire – which, as highlighted earlier, are more likely to occur in and around the Secondary City, compared to other areas in the District. Moreover, the cascading effects of these hazards pose severe health risks to people and animals, (for instance) through smoke pollution from wildfires, as well as the spread of water- and vector borne diseases from flooding and high temperatures. It is therefore necessary to ensure that systems are in place to maintain and ensure the public's health, should the need arise.

The Local Municipalities projected to experience population decline currently have large numbers of socio-economically vulnerable populations - this may be indicative of some of the factors driving out-migration in those areas. Factors such as the lack of jobs, declining local services, and inadequate housing options may push people to move away to find better opportunities and a better quality of life elsewhere. It is therefore necessary to manage out-migration in these areas by addressing the underlying causes such as unemployment; and as noted earlier, the low levels of education among rural populations makes the agricultural sector a key avenue for the creation of jobs for those populations, i.e., semi- and unskilled workers. The District therefore stands to benefit from adapting the sector to future climate conditions and their impacts. Moreover, in so doing, Capricorn will also be contributing towards ensuring its food security into the future.

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

1. To ensure water security in the face of climate change: Given the water scarcity challenges in the country, as well as the effects that the projected increase in population growth and drought tendencies will have on the District's future water supply – developing comprehensive strategies for water resource management is crucial. As part of these strategies, CDM could therefore prioritize water infrastructure maintenance; invest in efficient water supply infrastructure to meet future demand; promote water conservation practices by implementing strategies such as public awareness campaigns, leak detection and repairs, water metering and billing; as well as explore measures to secure alternative water sources such as rainwater (harvesting), groundwater (recharge and extraction) and wastewater (reuse).

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

3. To prioritise the health and safety of communities in the face of a changing climate: Climate change hazards such as heat extremes, wildfires and flooding pose serious risks to public health and safety. Heat-related illnesses such as heatstroke, as well as health challenges associated with smoke pollution, which is a cascading effect of wildfires, are some of the health risks associated with these hazards. Moreover, hot and wet conditions, which are expected to be more prevalent in CDM, often lead to the increased spread of water- and vector-borne diseases, while extreme weather events may cause people physical harm. It is therefore necessary to ensure that adequate systems are in place to mitigate (or respond to) the adverse consequences of such impacts. Implementing early warning systems for extreme weather events, ensuring access to climate-sensitive health services (such as heat illness prevention or disease surveillance), and improving emergency response capacity, are some of the measures that the District could look into. Furthermore, public education about the risks of climate change to health and safety is also crucial.

4. To develop climate-resilient, low-carbon, diverse and inclusive rural economies that are socially responsible, environmentally sustainable and that provide job opportunities for unskilled, semi-skilled and skilled local residences: A climate-resilient rural economy would be one that can absorb and recover from climate shocks; that also contributes minimally to climate change. This might involve promoting sustainable agricultural practices that are adaptive to changing climate conditions, investing in renewable energy sources, and encouraging diversification of the rural economy into sectors that are less climate-sensitive. Furthermore, efforts to create more inclusive economies, that also provide job opportunities at all skill levels, may involve training programs for local residents, policies to support small and medium enterprises, as well as the implementation of measures designed to ensure that the benefits of economic activities are equitably distributed.

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

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