West Rand District Municipality

Climate Risk Profile Report based on the GreenBook

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Acronyms

°C	Degree Celsius
AFF	Agriculture, Forestry, and Fisheries
AR5	Fifth Assessment Report
CABLE	CSIRO Atmosphere Biosphere Land Exchange model
CBA	Critical Biodiversity Area
CCAM	Conformal-cubic atmospheric model
CDRF	Climate and Disaster Resilience Fund
CMIP5	Coupled Model Intercomparison Project 5
CoGTA	Department of Cooperative Governance and Traditional Affairs
CRVA	Climate Risk and Vulnerability Assessment
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEA	Department of Environmental Affairs
DDM	District Development Model
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
IDP	Integrated Development Plan
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
l/p/d	Litres Per Person Per Day
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
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

WRDM	West Rand District Municipality
WRYM	Water Resources Yield Model
WUI	Wildland-Urban Interface

Glossary of Terms

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

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

Resilience	"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 Climate Change Adaptation Plan, were developed specifically for West Rand District Municipality (WRDM), 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 purpose and strategic objectives of the Climate Risk Profile and the Adaptation Plan are to:

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

The Climate Risk Profile report provides an overview of the unique climate change needs and risks of the district based on the science, evidence, and information from the GreenBook. Climate change trends, hazards, and vulnerabilities are spatially mapped for the district, its local municipalities, and settlements. Finally, the report identifies the major risks that need to be prioritised and sets out adaptation goals to further inform the Adaptation Plan and its implementation framework.

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 1). "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, which in turn affects changes in the occurrence of climate hazards such as drought, flooding, coastal flooding, and heat extremes. Planned as well as unplanned development and growth of our settlements drive the exposure of people, as well as the built- and natural environment to climate hazards. Vulnerability includes the inherent characteristics that make systems sensitive to the effects and impacts of climate hazards. Municipal risk is driven by vulnerability and exposure to certain climate-related hazards.

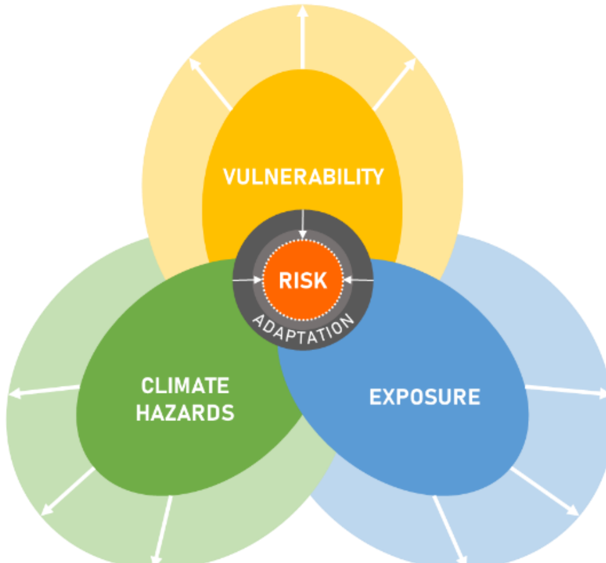

Figure 1: The interaction between the various components of risk, indicating the opportunity to reduce risk through adaptation (based on IPCC, 2014 and IPCC, 2021)

To understand climate risk across a municipal area, the exposure of settlements to certain climate hazards and their vulnerability are unpacked. In this Climate Risk Profile report, multiple vulnerability indices are provided on the municipal and settlement level, as well as variables for the current and future projected climate. Climate-related hazards such as drought, heat extremes, wildfire and flooding, and the impact of climate 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 data were derived using GIS analysis and modelling techniques using secondary data and is not based on local surveys. Additional information to this report is available for local municipalities through the GreenBook Municipal Risk Profile Tool. Municipalities are encouraged to consider both the information available in this report and on the Municipal Risk Profile tool to understand their risk profile. Access the GreenBook and its various resources and tools here: https://greenbook.co.za/

1.2. Policy framework

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

Furthermore, the National Climate Change Response White Paper – which outlines the country's comprehensive plan to transition to a climate resilient, globally competitive, equitable and low-carbon economy and society through climate change adaptation- and mitigation, while simultaneously addressing the country's key priorities, including job creation, poverty reduction, social equality and sustainable development, amongst others – identifies local governments as critical role players that can contribute towards effective climate change adaptation through their various functions, including "[the] planning [of] human settlements and urban development; the provision of municipal infrastructure and services; water and energy demand management; and local disaster response, amongst others." (Republic of South Africa, 2011, p. 38). The Climate Change Bill (B9-2022) takes it further by setting out institutional arrangements for climate change response. Section 7. (1) of the Bill requires that all organs of state affected by climate and climate change align their policies, programmes, and decisions to ensure that the risks of climate change impacts and associated vulnerabilities are considered. Local government is a key player in climate change response as a facilitator and implementer to achieve effective climate response. The Bill requires existing District Intergovernmental Forums to serve as Municipal Forums on climate change, that coordinate climate response actions and activities in their respective Municipalities. The Bill also sets out requirements for each district Municipality to undertake a climate change needs assessment and a climate change response implementation plan. The Climate Risk Report and related Adaptation Plan, provided here, meet most of these requirements and provide the essential information needed by the district Municipality to fulfil its obligations in terms of the Bill.

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 West Rand District Municipality (WRDM) is one of two districts within the Gauteng province. Together with three metropolitan municipalities – namely, the City of Tshwane, City of Johannesburg, and City of Ekurhuleni – West Rand and Sedibeng districts make up the entire Gauteng province. The WRDM is located along the southwestern edge of the Gauteng province and is bordered by the City of Tshwane in the north east, the City of Johannesburg in the east, Sedibeng district in the south east, North West province's Bojanala Platinum district in the north west, and Dr Kenneth Kaunda district in the south west. West Rand encloses a land area of approximately 16 331,7 km^2, and comprises of three local municipalities (LMs), namely Mogale City in the north, Rand West City across the central and south eastern parts of the district, as well as Merafong City, located across the south western parts of the West Rand district – with two major national roads, namely the N12 and N14, traversing the district (CoGTA, 2020).

The West Rand District Municipality recorded a total population of 889 731 in 2019 (about 6.1 % of the total population in Gauteng). This was a result of the 1.2 % annual population growth rate that the district experienced between 2017 and 2019 (CoGTA, 2020). The district's population is projected to increase by an additional 237 392 people between 2011 and 2050, under a high population growth scenario. According to the 2022 Census results, the West Rand District Municipality currently has a total population of 998 466. Of this total population, young children (0-14 years) make up 23,7 %, and the working-age population (15-64 years) accounts for 71,0 %, with the elderly (65+ years) making up the remaining 5,3 %. Also, according to the 2022 national census results, the district's dependency ratio is currently reported at 40,8, with a sex ratio of 102,4. Education indicators reveal that 4,1 % of individuals aged 20 and above have no formal schooling, while 11,1 % have attained higher education qualifications. With regards to housing, the district is home to 356 530 households, with an average household size of 2,8. Moreover, formal dwellings dominate the housing landscape, representing 88,1 % of the housing stock. Sanitation and waste management services are accessible, with 90,7 % of formal dwellings equipped with flushing toilets connected to sewerage, and 84,3 % receiving weekly refuse disposal services. Furthermore, 76,7 % of households enjoy access to piped water within their dwellings, while 95,1 % have electricity for lighting (Stats SA, 2024).

Two primary sectors, namely agriculture and mining, are the biggest drivers of economic activity in the West Rand district. With the agriculture, forestry and fisheries (AFF) sector, as well as the mining sector, jointly making up 28.6 % of the district's economy in 2016, and mining output accounting for 29.2 % of the district's economic output in 2018. Manufacturing, construction, and electricity form the bulk of the district's secondary sectors. Two of the district's tertiary sectors, namely government services and finance, constitute the district's second and third largest contributors to economic activity in the West Rand, with the sectors respectively contributing 19.8 % and 14. 4 % to the district's economic output in 2018 (CoGTA, 2020). However, the West Rand's economy went through a recession in 2018, with growth contracting further by 1.4 % from -1 % in 2017. The decline in economic growth was primarily a result of a decline in mining output. Considering that mining is the largest contributor to the district's economy, a decline in mining output was always going to have serious implications for growth in the region. Unfortunately, in 2018, the sector's economic output contracted by another 7.2 %; while output in other critical sectors such as manufacturing and construction also contracted. Continuously rising input costs and a stagnant gold price are some of the factors that have contributed to this negative outcome. Moreover, West Rand district's unemployment rate (based on the official definition of unemployment) stood at 46.58 % in 2018, which was about 9.75 % of the total number of unemployed people in Gauteng at the time (CoGTA, 2020; WRDM, 2023). The largest employing sectors in the district are mining (22.9%), followed by wholesale and trade (18.7%), business services (14.5%), and community services (12.9%) (DEA, 2018).

The West Rand district falls within three biomes, namely Grassland, which covers a large portion of the district (72%), as well as Savanna (27%), with small pockets of Forests and Azonal Vegetation (both of which cover less than 1 % of the district's total surface area). The fire ecotypes found in the district are moist-, sweet- and sour grasslands. These carry sufficient fuel loads for fires, and as a result, fire hazards in such regions can be extreme. Furthermore, according to the Gauteng Conservation Plan, approximately 27.5 % of the West Rand district is designated as a Critical Biodiversity Area (CBA). CBAs are regions required to meet biodiversity targets for ecosystems, species, and ecological processes, as identified in a systematic biodiversity plan, while ecosystems refer to all living things in an area, and the way they affect each other and their environment. CBAs include wetlands and grasslands, which provide habitat for rare and often endangered plant species listed as threatened ecosystems. The purpose of listing and prioritising the management of these ecosystems is to reduce the rate of species extinction and degradation of ecosystem function (DEA, 2018).

According to the 2011 Gauteng Conservation Plan, the district has approximately 39.6 km^2 of important wetlands, and of these wetlands, only 2.7% is currently under formal conservation. There are also several main river systems that intersect the West Rand, including the Skeerpoort River, Blaauwbankspruit, Magalies River, Rietspruit, Crocodile River, Wonderfonteinspruit, Loopspruit and Leeuspruit. External pressures arising from mining, agricultural and industrial activities in the district are major contributing factors to surface and ground water degradation. Furthermore, Acid Mine Drainage (AMD), resulting from uncontrolled discharge of contaminated water from abandoned mines, is a major environmental problem in the district, as it promotes surface and groundwater pollution, thus threatening aquatic biodiversity. AMD is also responsible for the degradation of soil quality (DEA, 2018).

The West Rand District Municipality's 2023/2024 Integrated Development Plan's (IDP) *Development Priorities* are as follows:

- Priority 1 - End / Reduce poverty and ensure zero hunger
- Priority 2- Good health and wellbeing / Healthy communities
- Priority 3 - Quality education
- Priority 4 - Gender equality
- Priority 5 - Clean water and sanitation
- Priority 6- Affordable clean energy
- Priority 7 - Decent work and economic growth
- Priority 8 - Industry, innovation, and Infrastructure
- Priority 9 - Reduced Inequalities
- Priority 10 - Sustainable communities
- Priority 11 - Peace justice and strong institutions
- Priority 12 - Partnership for goals
- Priority 13 - Be tough on crime
- Priority 14 - Safe working environment
- Priority 15 - Accountable municipal administration
- Priority 16 - End corruption in all forms (WRDM, 2023)

According to West Rand district's District Development Model (DDM) Profile, the Gauteng Province (as well as the district) plans to invest in the creation of new industries, new economic areas, and new cities. The focus of these joint initiatives will be tourism, agriculture, agro-processing and renewable energy projects (CoGTA, 2020). This means diversifying the West Rand's economy away from reliance on mining to include bus manufacturing, agri-business and agro-processing, renewable energy and tourism. The pipeline of concrete projects, pumping over R25 billion worth of investment into the western corridor, includes:

- The expansion of the Busmark bus manufacturing plant;
- The Lanseria Airport expansion and the new Lanseria City Development; and
- The Agro-processing Mega Park and Logistics Hub on the N12 highway and other private sector mega projects.

According to West Rand District Municipality's Spatial Development Framework (SDF), all spatial planning and development management efforts should focus on prioritizing development and investment in accordance with the district's nodal hierarchy. The framework further emphasises the importance of defining a strategic range of well-located activity nodes in the district, with the very specific purpose to guide and direct public and private investment towards these areas (spatial targeting), and to optimise agglomeration benefits to be derived from such clustering of activities. The map below provides a spatial representation of the priority development areas in the West Rand district.

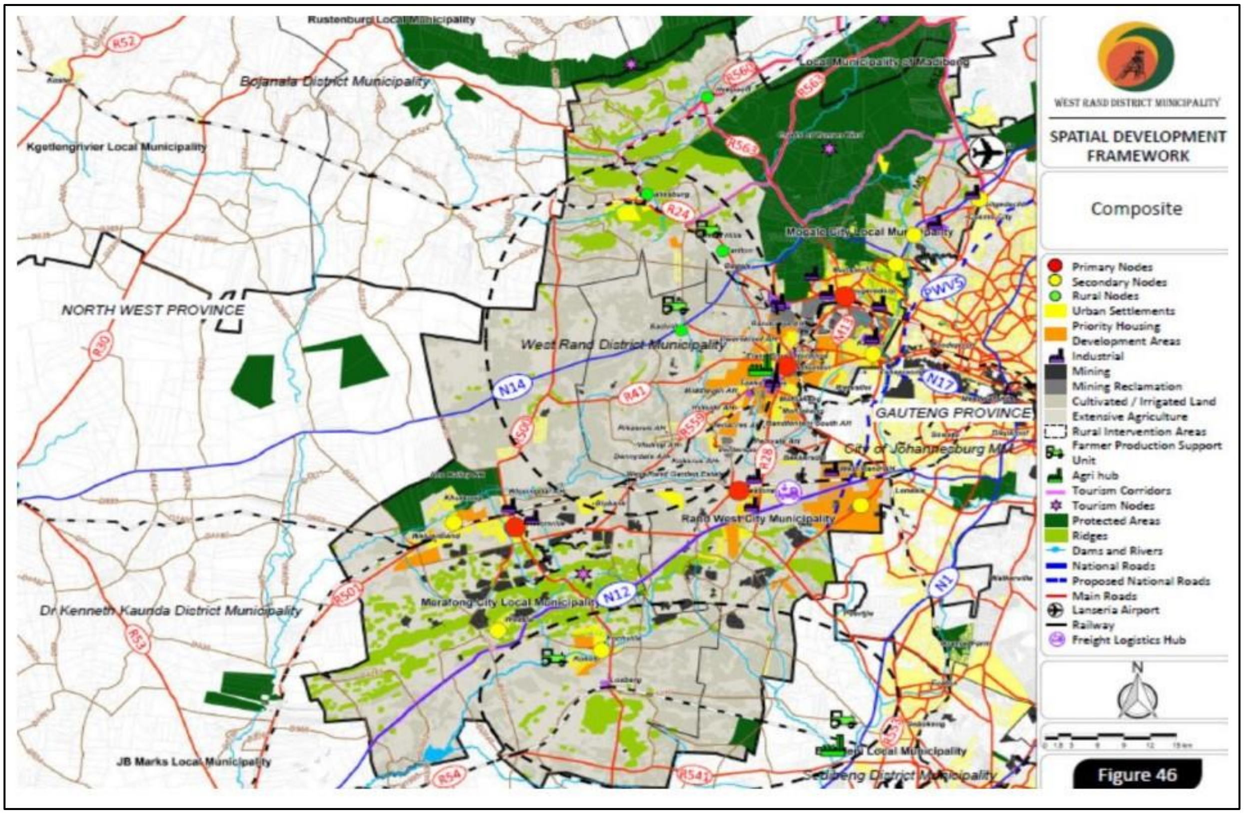

Figure 2: West Rand District Municipality Spatial Development Framework (WRDM, 2017)

The Primary, Secondary and Rural nodes serve as focal points for attracting retail, office and medium to higher density residential uses, as well as commercial and light industrial activity. Activity nodes are also important public transport destinations. In this context, the nodal system also influences the district public transport network as it determines the major destinations to be served by such system and the movement desire lines linking these nodes to one another (WRDM, 2017).

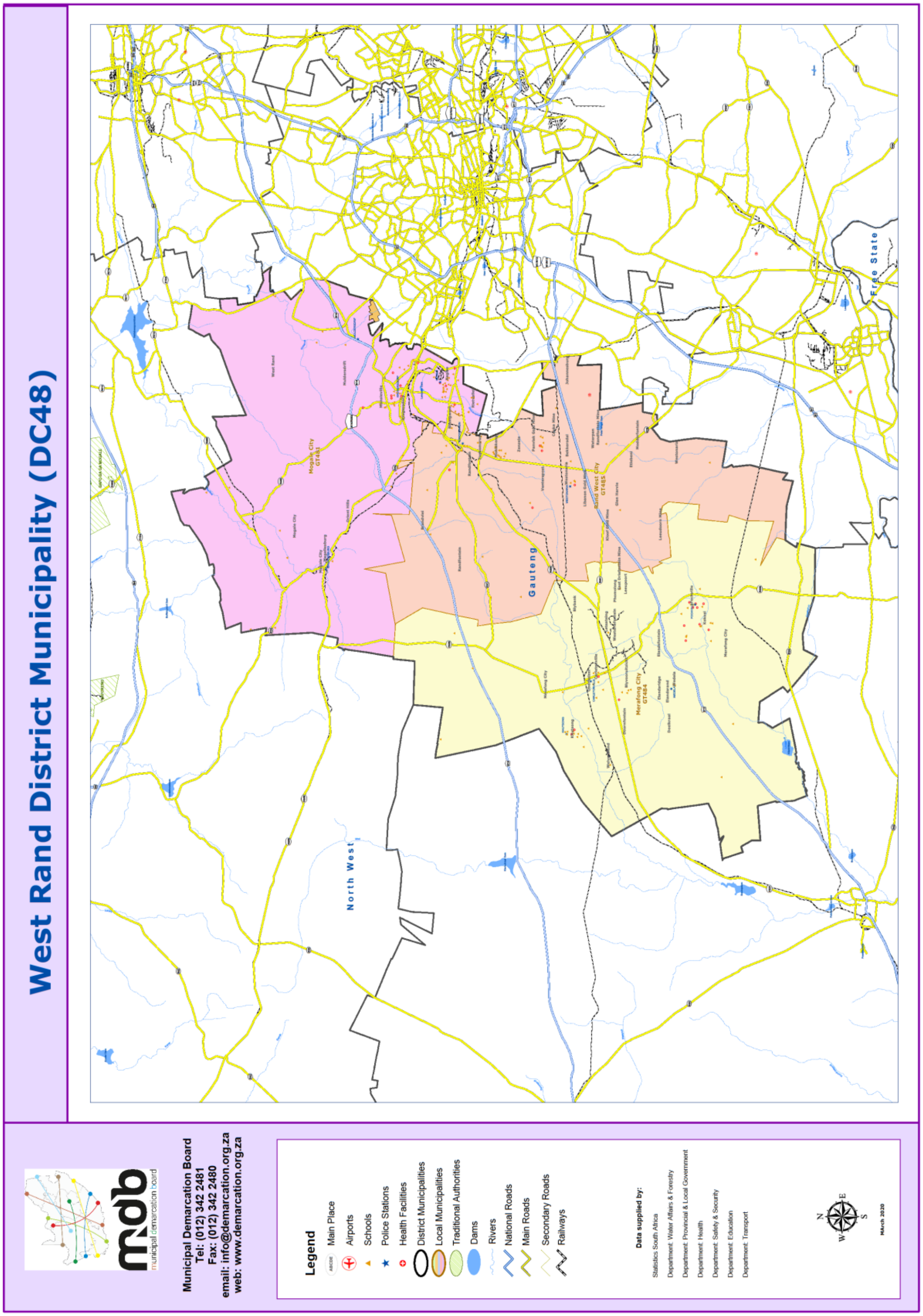

Figure 3: West Rand District Municipality (Municipal Demarcation Board, 2022), with local municipalities shaded in different colours.

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 also set out. Thereafter, the impact of climate on key resources such as water and agriculture are discussed for the local municipalities in the district. Together this information provides an overview of current and future climate risk across the West Rand 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 West Rand District, its local municipalities, and settlements are profiled using a framework which sets out indicators that can be used to profile the multi-dimensional and context-specific inherent vulnerability of settlements and municipalities in South Africa. The framework describes and quantifies, where possible, the inherent vulnerability of people, infrastructure, services, economic activities, and natural resources by setting out context and location-specific indicators that were specifically designed to support vulnerability risk assessments of South African municipalities. Population changes drive vulnerability into the future, and therefore population growth and decline of settlements across the district are projected to 2050. Spatial population projections are integral in determining the potential exposure and vulnerability of a population to hazards.

2.1.1. Municipal vulnerability

Municipal vulnerability is unpacked in terms of four vulnerability indices, each of which are described below and in Table 1, the vulnerability scores are provided for each of the local municipalities in West Rand 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 West Rand 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 (SEVI) and Economic (EcVI) Vulnerability

Table 1: Vulnerability indicators across West Rand District Municipality for 1996 t0 2011

LOCAL MUNICIPALITY	SEVI 1996	SEV 2011	Trend	EcVI 1996	EcVI 2011	Trend	PVI	Trend	EnVI	Trend
Merafong City	2,24	2,83	↗	6,25	6,65	↗	5,60	No Trend	4,48	No Trend
Mogale City	2,36	2,28	↘	4,44	5,67	↗	5,84	No Trend	7,03	No Trend
Rand West City	4,02	3,22	↘	7,75	9,32	↗	5,94	No Trend	6,05	No Trend

Socio-economic vulnerability (SEVI) has decreased (improved) across all local municipalities in West Rand between 1996 and 2011, except Merafong City, the SEVI score of which increased by 0.59 in the same period. However, all the local municipalities have a significantly below national average SEVI scores. Conversely, the economic vulnerability (EcVI) scores of all local municipalities in the district increased (worsened) in the same time period, and exceeded the national average, with Rand West City recording an EcVI score of 9.32 out of 10 (the highest in the province) in 2011. The high economic vulnerability is evident in the declining mining output, which has contributed to West Rand District being home to 9.55 % of the total number of unemployed people in Gauteng, while experiencing an average annual increase of 8.53 % in the number of unemployed people (CoGTA, 2020). All three municipalities in West Rand also recorded above national average physical vulnerability (PVI) scores, alluding to the structural vulnerabilities present in the district. Mogale City and Rand West City recorded high environmental vulnerability (EnVI) scores, alluding to the potential impacts of mining activities, e.g., Acid Mine Drainage (Acid Mine Drainage), on the municipalities' environment (DEA, 2017). The district's EnVI score conveys a high conflict between the need to preserve the natural environment, and accommodate the growth pressures associated with population growth, urbanisation, and economic development.

2.1.2. Settlement vulnerability

The unique set of indicators outlined below highlight the multi-dimensional vulnerabilities of the settlements within the West Rand 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 until 2050.

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 district follows below. Figures 4 to 6 illustrate the multi-dimensional vulnerabilities of the settlements found within Merafong City, Mogale City and Rand West City.

Merafong City

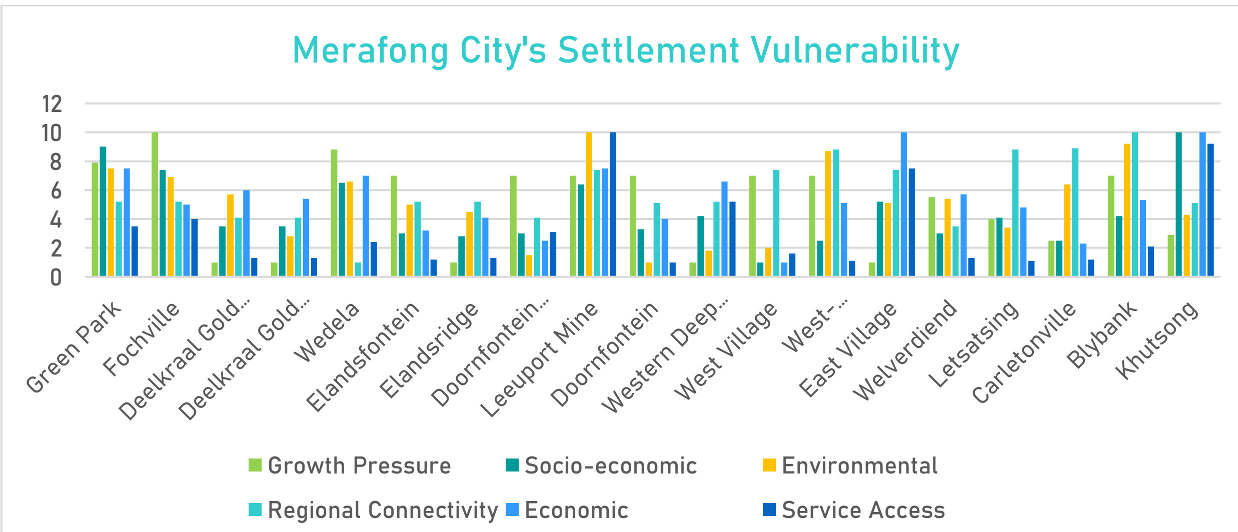

Figure 4: Merafong City Local Municipality's Settlement Vulnerability

The major settlements in this local municipality are Green Park, Fochville, Deelkraal Gold Mine 1 and 2, Wedela, Elandsfontein, Elandsridge, Doornfontein Mine, Western Deep Levels Mine, West-Driefontein Mine, Letsatsing, Carletonville, Blybank and Khutsong. The settlement facing the greatest growth pressure is Fochville. Khutsong is home to a highly socio-economically vulnerable population, while Blybank has the highest regional connectivity vulnerability, therefore indicating the settlement's remoteness in comparison to others found in the Municipality. East Village, as well as Khutsong, have the highest economic vulnerability scores in Merafong City, while Leeuport Mine has the highest service access vulnerability. The latter settlement also has the highest environmental vulnerability score in the municipality, thus alluding to the growing conflict between preserving the environment and accommodating the growth pressures associated with population growth, urbanisation, and economic development.

Merafong City

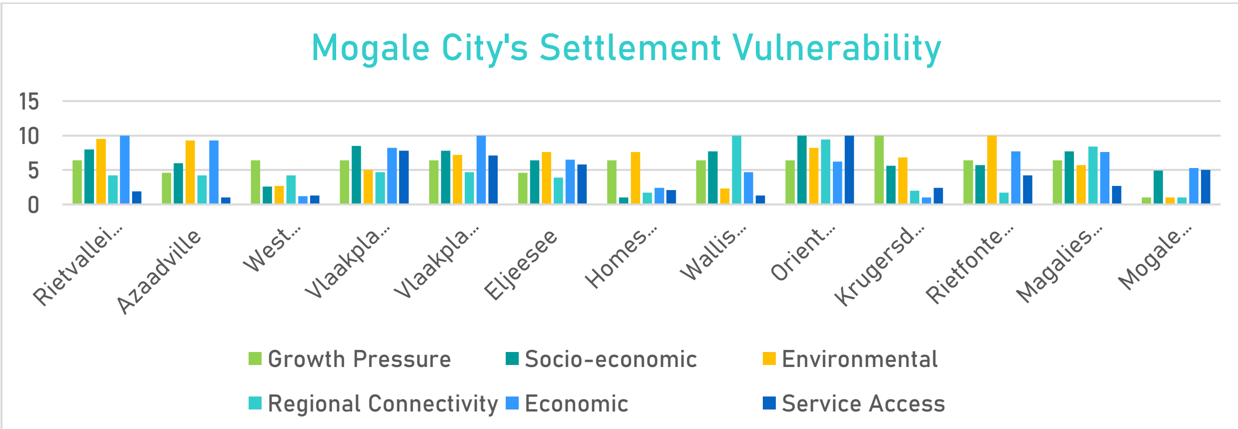

Figure 5: Mogale City Local Municipality's Settlement Vulnerability

The major settlements in this local municipality are Rietvallei Extension 3, Azaadville, West Rand Consolidated Gold Mine, Vlaakplaas 1 and 2, Eljeesee, Homes Haven, Wallis Haven, Orient Hills, Krugersdorp, Rietfontein, Magaliesburg and Mogale City. Krugersdorp is facing the greatest growth pressure, and Orient Hills is home to the most socio-economically vulnerable population. The settlement of Rietfontein GT has the highest environmental vulnerability, an indication of the growing conflict between preserving the natural environment and accommodating growth pressures associated with population growth/urbanisation and economic development, particularly the implications of mining activities on the environment. Wallis Haven has the highest regional connectivity vulnerability, while parts of Vlaakplaas and Rietvallei Ext. 3 have the highest economic vulnerability. Orient Hills also has the highest service access vulnerability in the municipality.

Rand West City

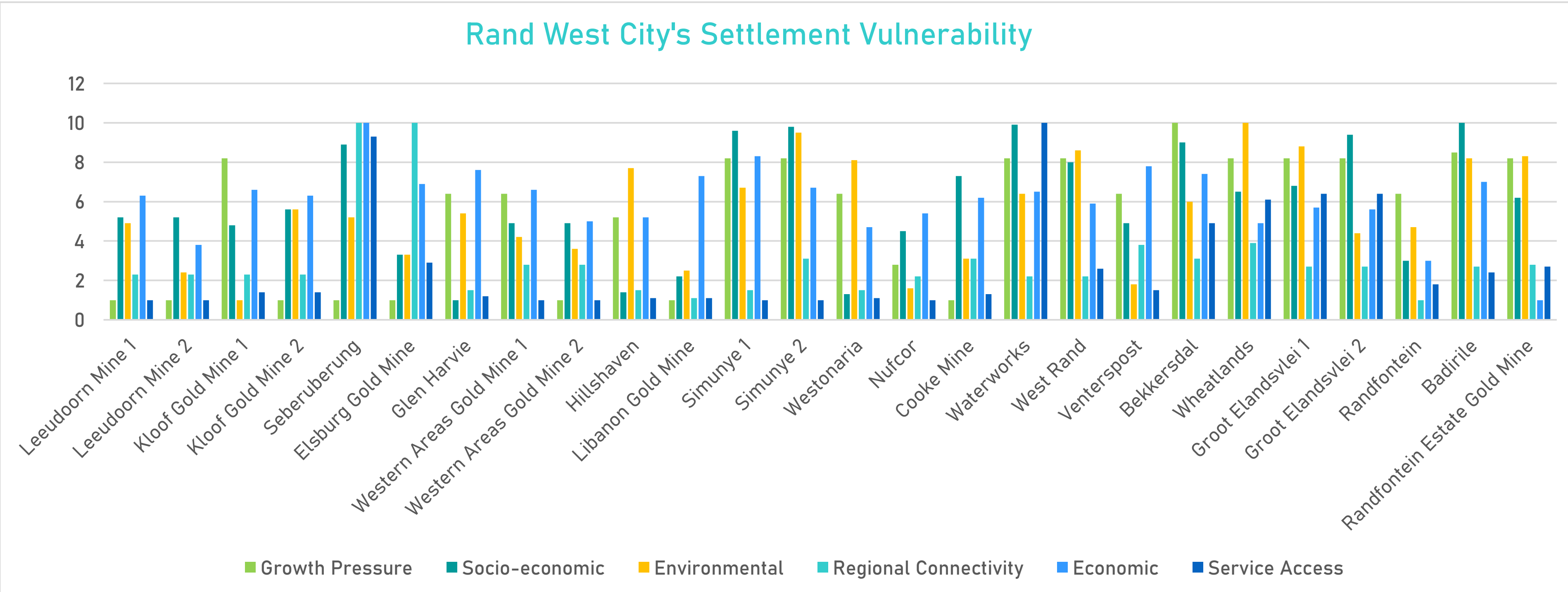

Figure 6:Rand West City Local Municipality's Settlement Vulnerability

The major settlements in this municipality are Leeudoorn Mine 1 and 2, Kloof Gold Mine 1 and 2, Seberuberung, Elsburg Gold Mine, Glen Harvie, Western Areas Gold Mine 1 and 2, Hillshaven, Libanon Gold Mine Simunye 1 and 2, Westonaria, Nufcor, Cooke Mine, Waterworks, West Rand, Venterspost, Bekkersdal, Wheatlands, Groot Elandsvlei 1 and 2, Randfontein, Badirile and Randfontein Estate Gold Mine. The settlement of Bekkersdal is facing the highest growth pressure, while the settlement of Badirile houses the municipalities most socio-economically vulnerable population. Wheatlands has the highest environmental vulnerability, alluding to the growing conflict between preserving the natural environment and accommodating growth associated with urbanisation and economic development. Seberuberung and Elsburg Gold Mine have the highest regional connectivity vulnerability; the former settlement also has the highest economic vulnerability in Rand West City. The settlement of Waterworks has the highest service access vulnerability in the municipality.

2.1.3. Population growth pressure

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

Using the innovative settlement footprint data layer created by the CSIR, which delineates built-up areas, settlement-scale population projections were aggregated up from the 1 x 1 km grids of South African projected population for a 2030 and 2050 medium and high growth scenario. These two population growth scenarios (medium and high) are differentiated based on 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 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 West Rand District Municipality

Population per municipality	2011	Medium Growth Scenario	
		2030	2050
Merafong City LM	197 484	164 146	116 181
Mogale City LM	362 383	475 532	580 924
Rand West City LM	260 992	281 189	277 818
West Rand DM Total	820 859	920 867	974 923

The district's population is projected to increase by approximately 19 % between 2011 and 2050 (which amounts to an additional 155 598 people), under a medium growth scenario. Most of this growth will take place towards the north of the district, particularly in the settlements within Mogale City. Figure 7 depicts the growth pressures that the settlements across the district are likely to experience. The settlements that are likely to experience high growth pressures up to 2050, include Krugersdorp, Azaadville and Wallis Haven. The West Rand Consolidated Gold Mine (located south of Krugersdorp) will likely experience extreme growth pressures, up to 2050. Merafong City is likely to experience a decline in population across all its settlements.

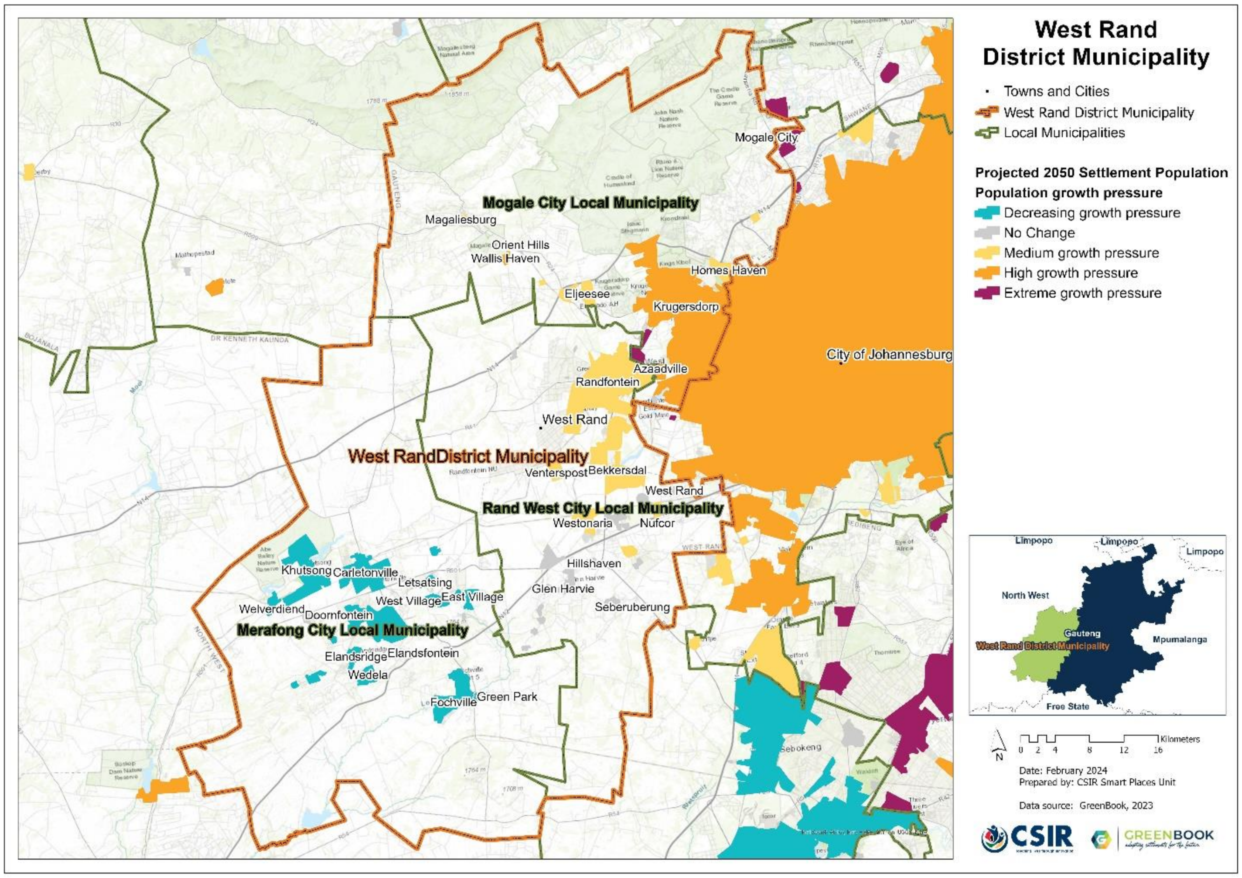

Figure 7: Settlement-level population growth pressure across West Rand District Municipality

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 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 are shown in this case).
b) The projected changes in the variable are subsequently shown, for the time-slab 2021–2050 relative to the baseline period 1961-1990.
c) An RCP 8.5 scenario (low mitigation) is shown.

2.2.1.Temperature

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

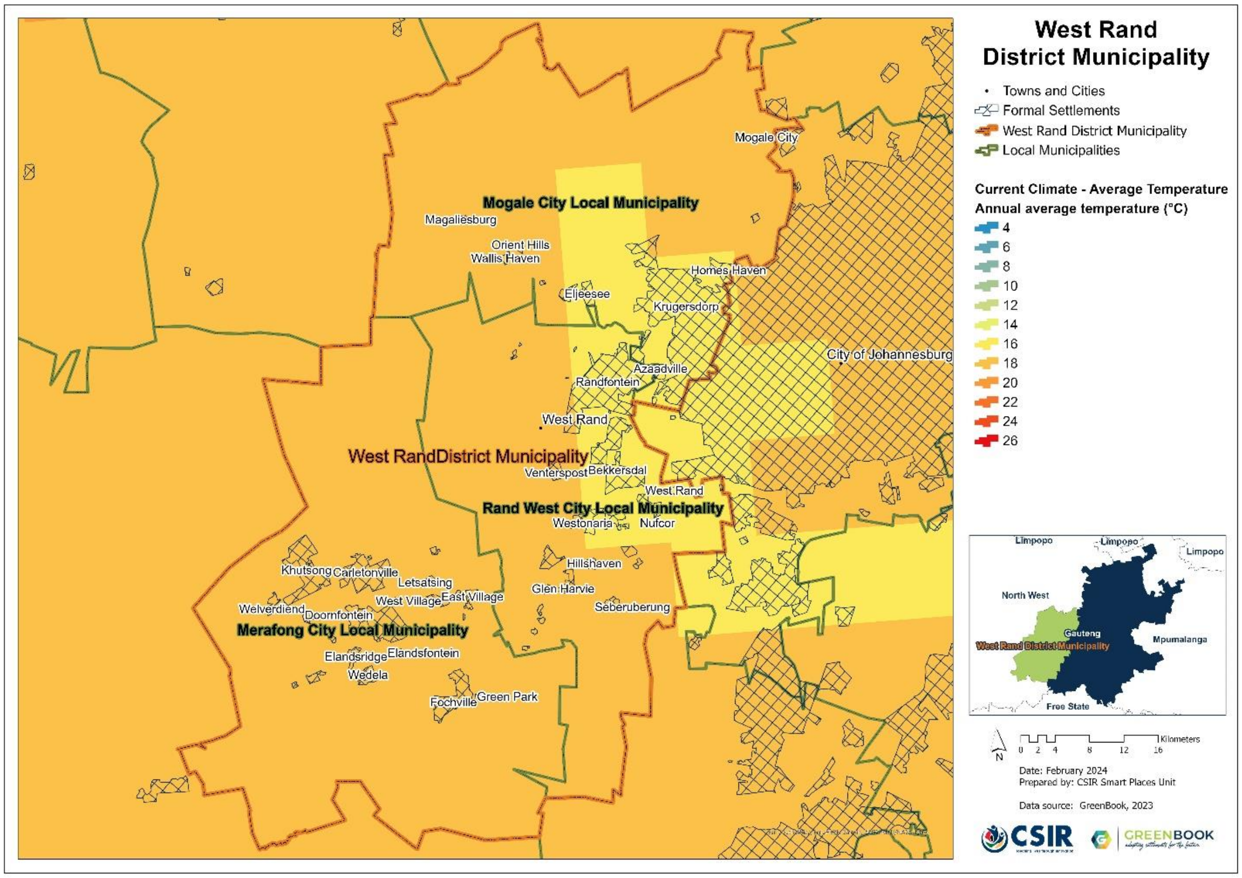

Figure 8: Average annual temperature (°C) for the baseline period 1961-1990 for West Rand District Municipality

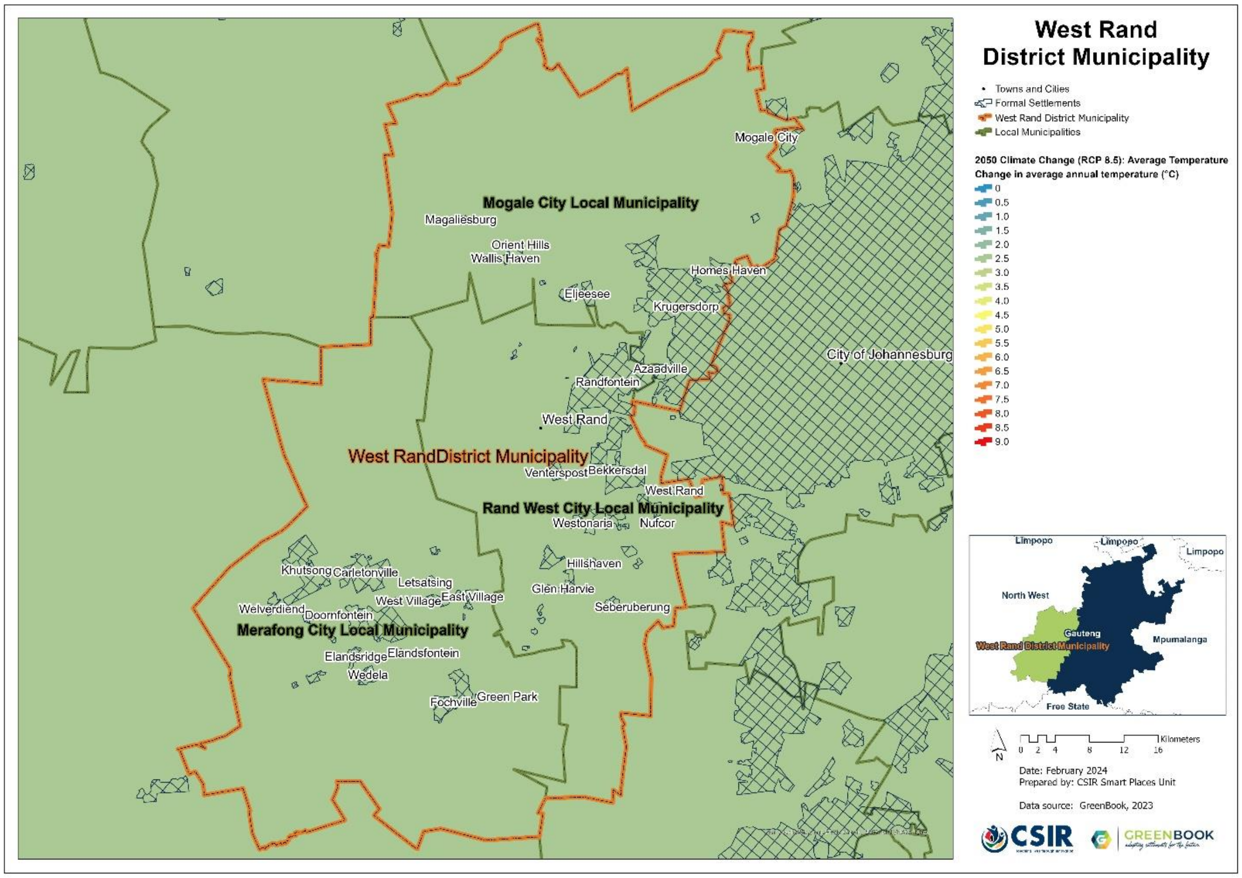

Figure 9: Projected changes in average annual temperature (°C) from the baseline period 1961-1990 to the future period 2021-2050 for West Rand District Municipality, assuming an RCP 8.5 emissions pathway

The WRDM experiences average annual temperatures ranging between 16 and 18 °C, with lower averages found along the lower south eastern parts of Mogale City and the upper north eastern parts of Rand West City LM. The projections show average annual temperature increases of 2.5 °C across the district into the future, under a low mitigation, “business as usual” emissions scenario.

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.

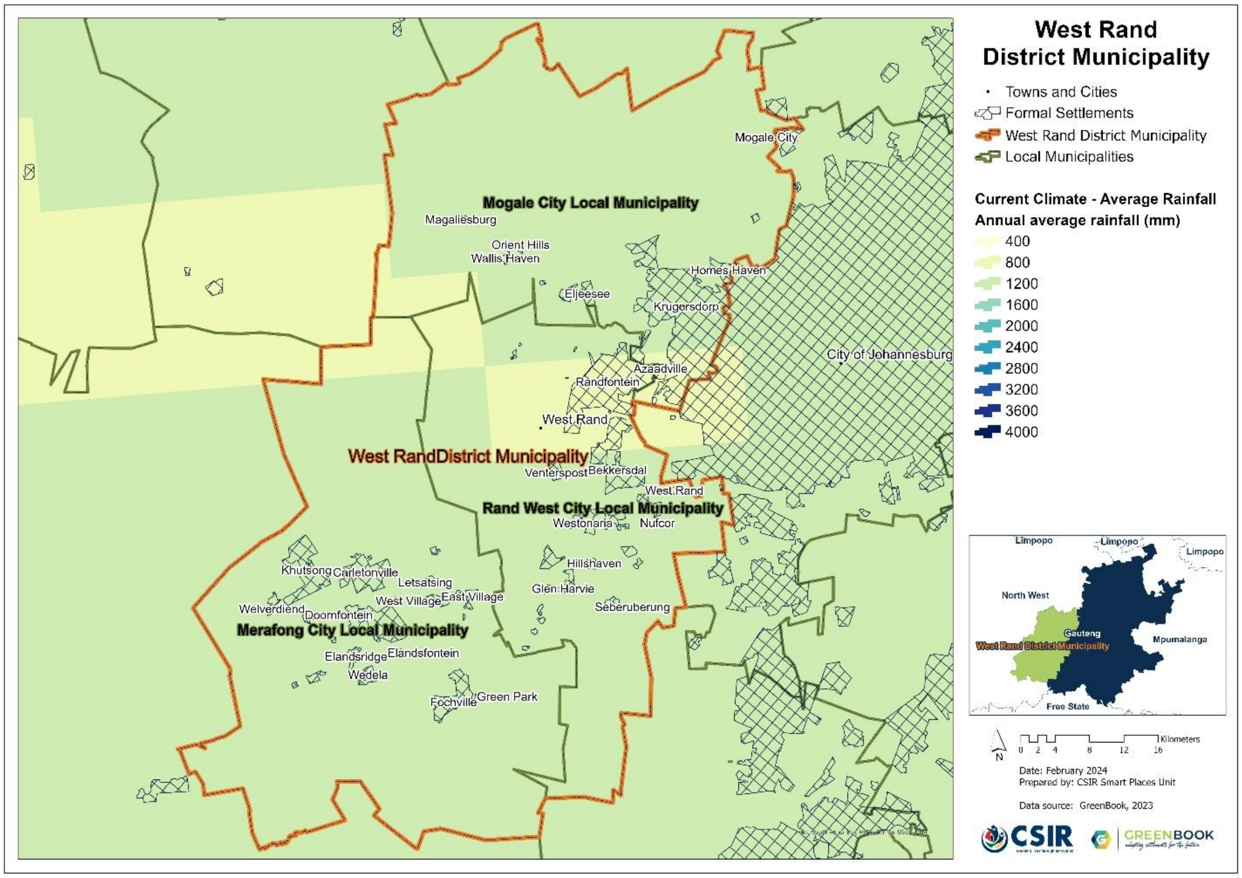

Figure 10: Average annual rainfall (mm) for the baseline period 1961-1990 for West Rand District Municipality

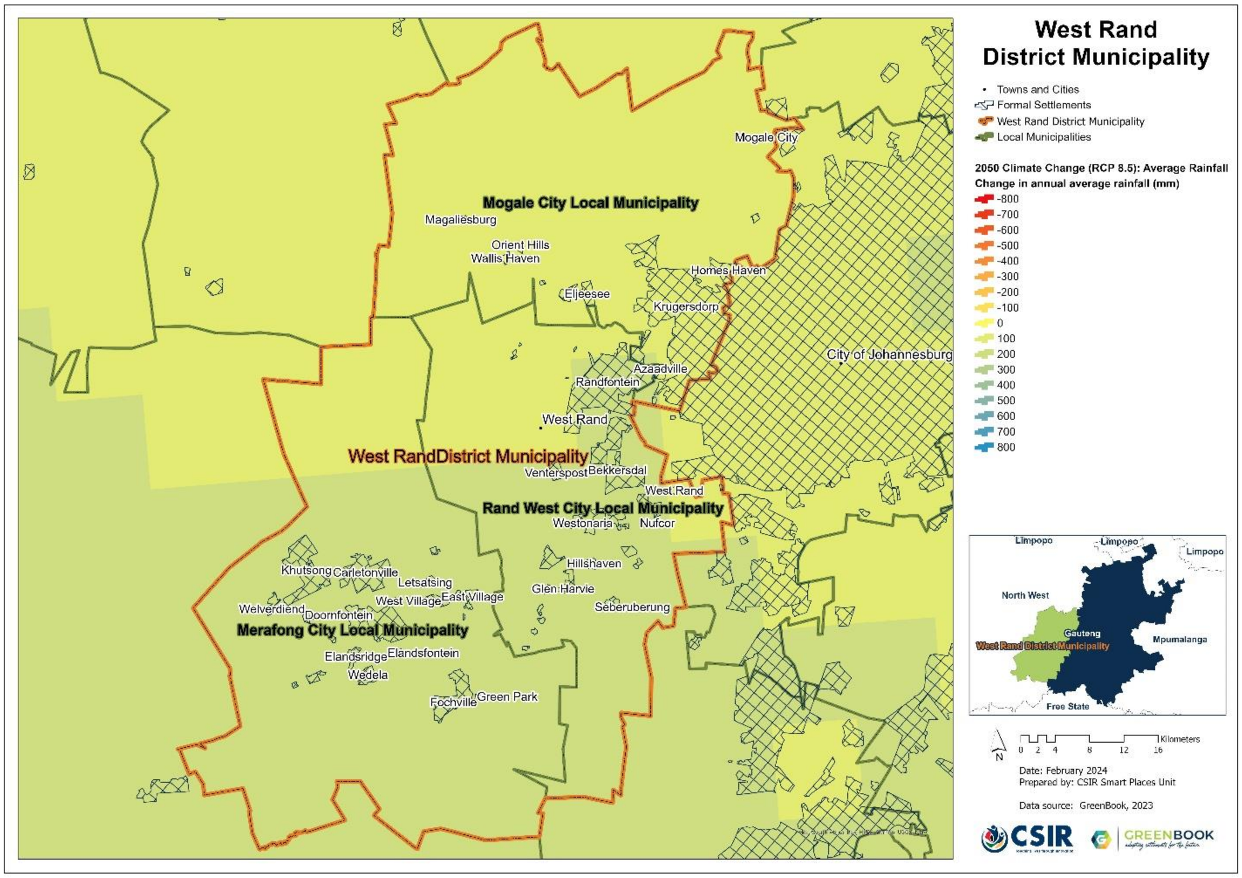

Figure 11: Projected change in average annual rainfall (mm) from the baseline period to the period 2021-2050 for West Rand District Municipality, assuming an RCP8.5 emission pathway

The WRDM experiences current GCM derived average annual rainfall of between 800 and 1200 mm, with lower averages found along the central parts of the district, particularly in Rand West City's settlements of Azaadville, Randfontein and West Rand. Future projections show an average annual rainfall increase of between 100 and 200 mm, with most of the increase expected to occur in the southern parts of the district, under a low mitigation, "business as usual" emissions scenario.

2.3. Climate Hazards

This section showcases information with regards to West Rand 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).

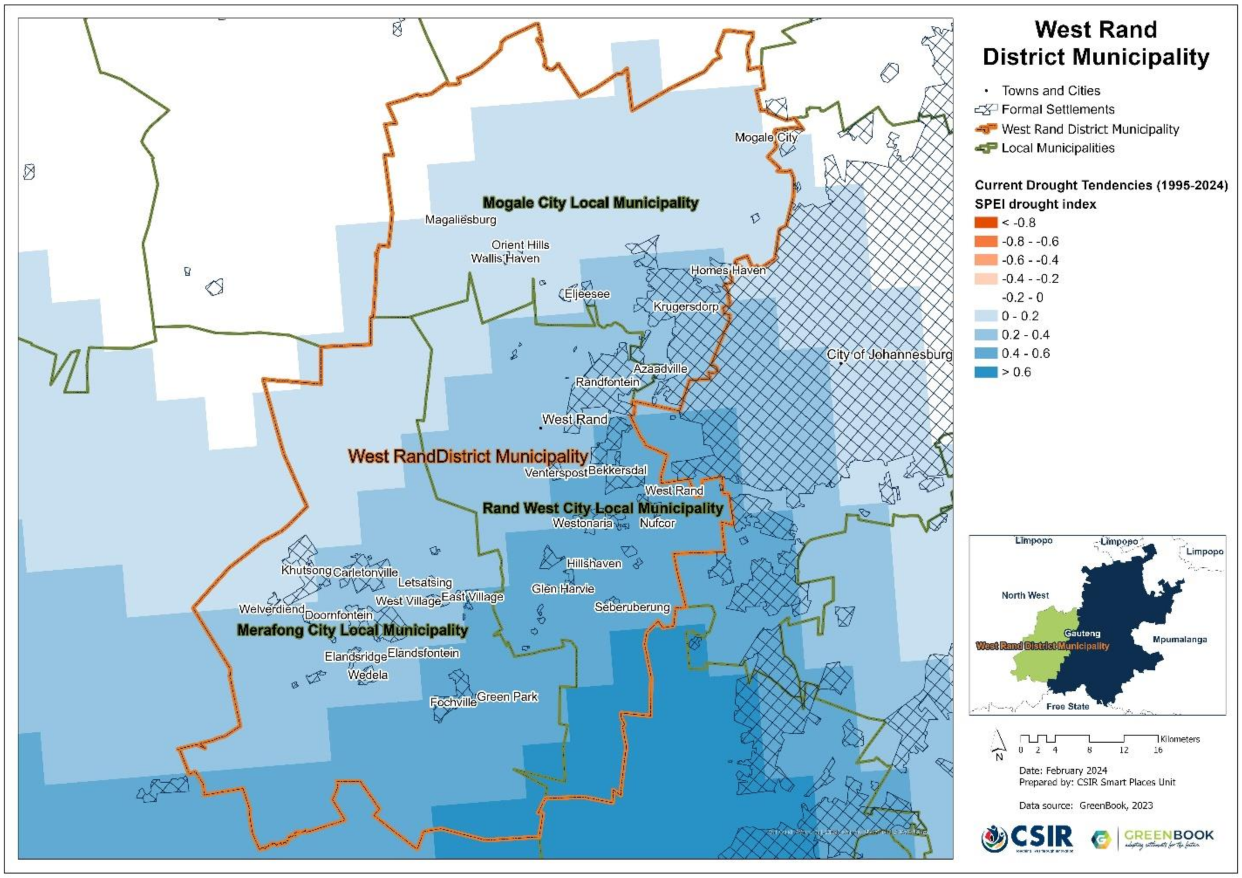

Figure 12: Projected changes in drought tendencies from the baseline period (1986–2005) to the current period (1995-2024) across West Rand District Municipality

Figure 12 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 (RCP 8.5). 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.

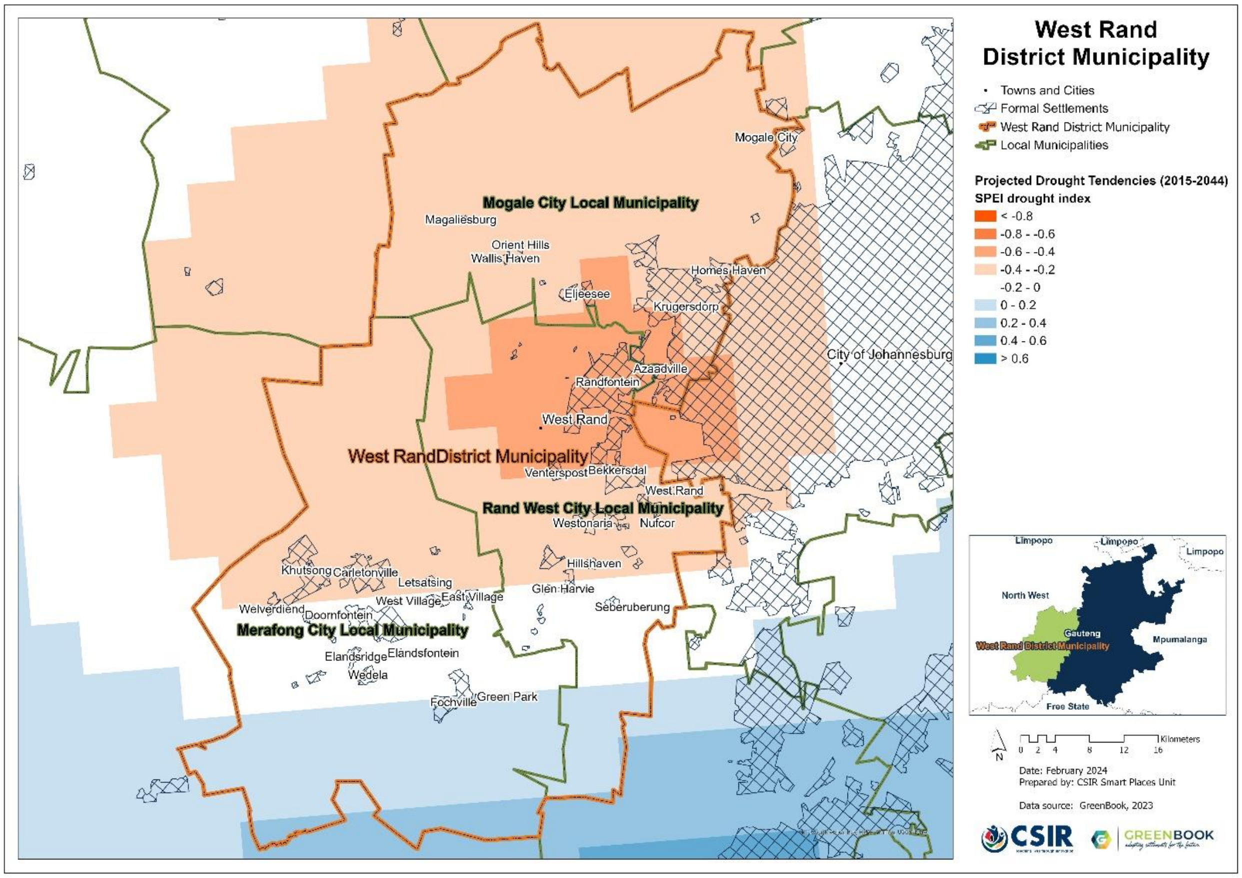

Figure 13: Projected changes in drought tendencies from the baseline period (1986–2005) to the future period 2015-2044 for West Rand District Municipality

Figure 13 depicts the projected change in drought tendencies (i.e., the number of cases exceeding near-normal per decade) for the period 2015–2044 relative to the 1986–2005 baseline period, under the low mitigation, "business as usual" emissions scenario (RCP 8.5). A negative value is indicative of an increase in drought tendencies per 10 years (more frequent than baseline) into the future, and a positive value indicative of a decrease. Figure 14 depicts the settlements that are at risk of increases in drought tendencies.

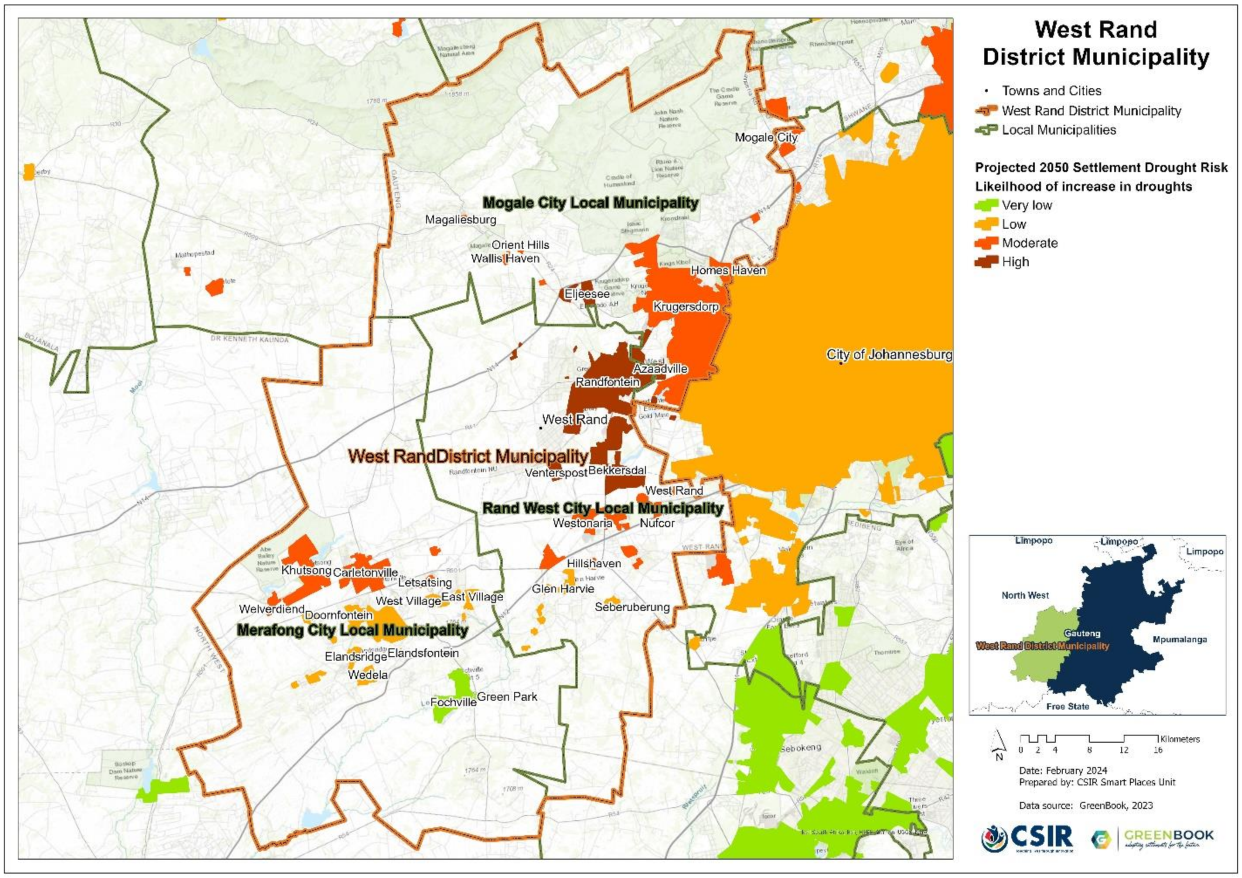

Figure 14: Settlement-level drought risk for West Rand District Municipality

As outlined in Figure 12, at the baseline, large parts of the district are exposed to wetter/high rainfall tendencies. These are projected to decrease, as drought tendencies in the northern and central parts of the district increase, into the future (Figure 13). As a result, most of the settlements in the district face an increased risk of drought into the future (up to 2050), especially those located in the Rand West City LM, including Azaadville, Randfontein, West Rand, Venterspost and Bekkersdal, as well as Eljeesee in Mogale City (Figure 14).

2.3.2. Heat

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.

The GCMs were used to simulate bias-corrected, average annual number of very hot days, defined as days when the maximum temperature exceeds 35° C per GCM grid point for the baseline (current) period of 1961–1990 (Figure 15), and for the projected changes for period 2021–2050 (Figure 16). The annual heatwave days map under baseline conditions (Figure 17) 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 for a period of at least three consecutive days. The projected change in the number of days belonging to a heatwave for the period 2021–2050 (Figure 18), assuming a “business as usual” (RCP 8.5) emissions pathway, is also shown.

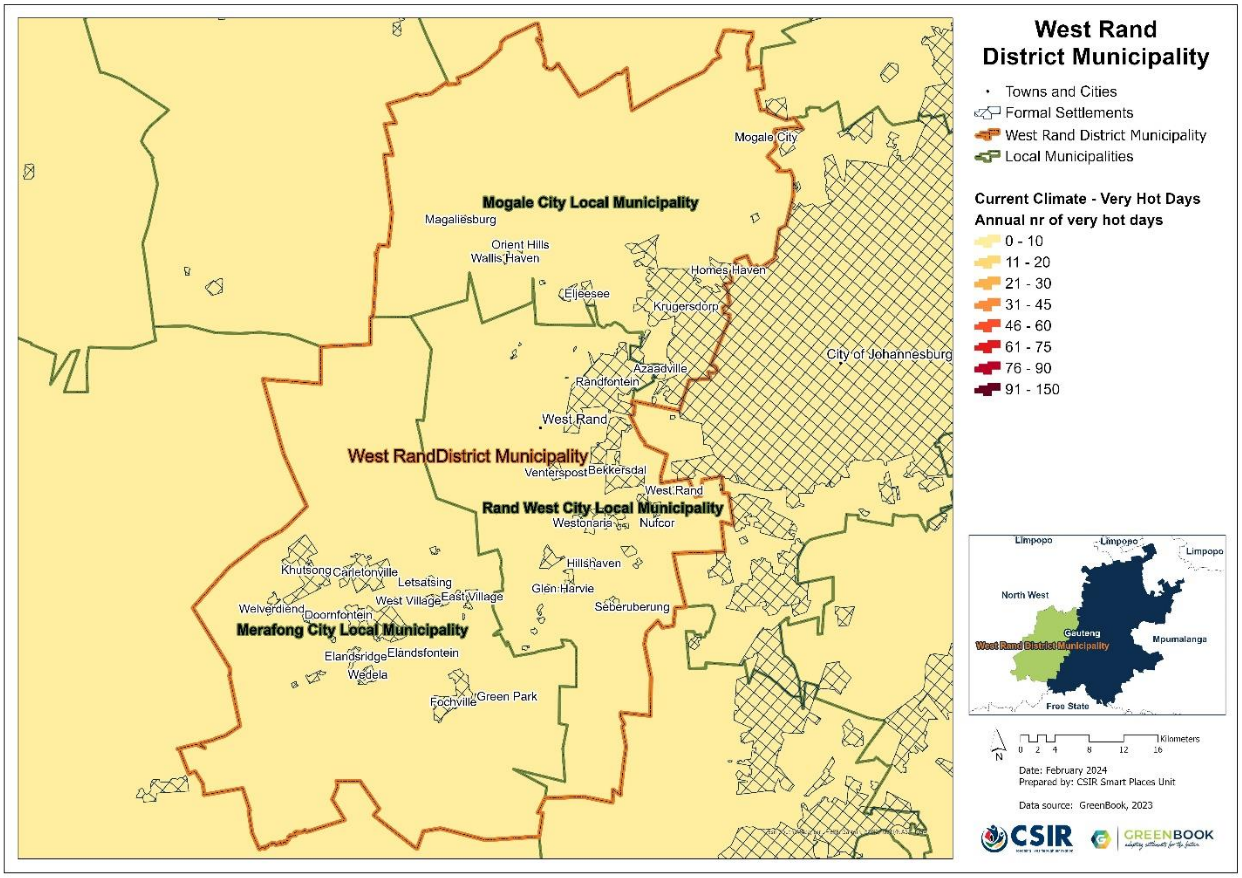

Figure 15: Annual number of very hot days under baseline climatic conditions across West Rand District Municipality, with daily temperature maxima exceeding 35 °C

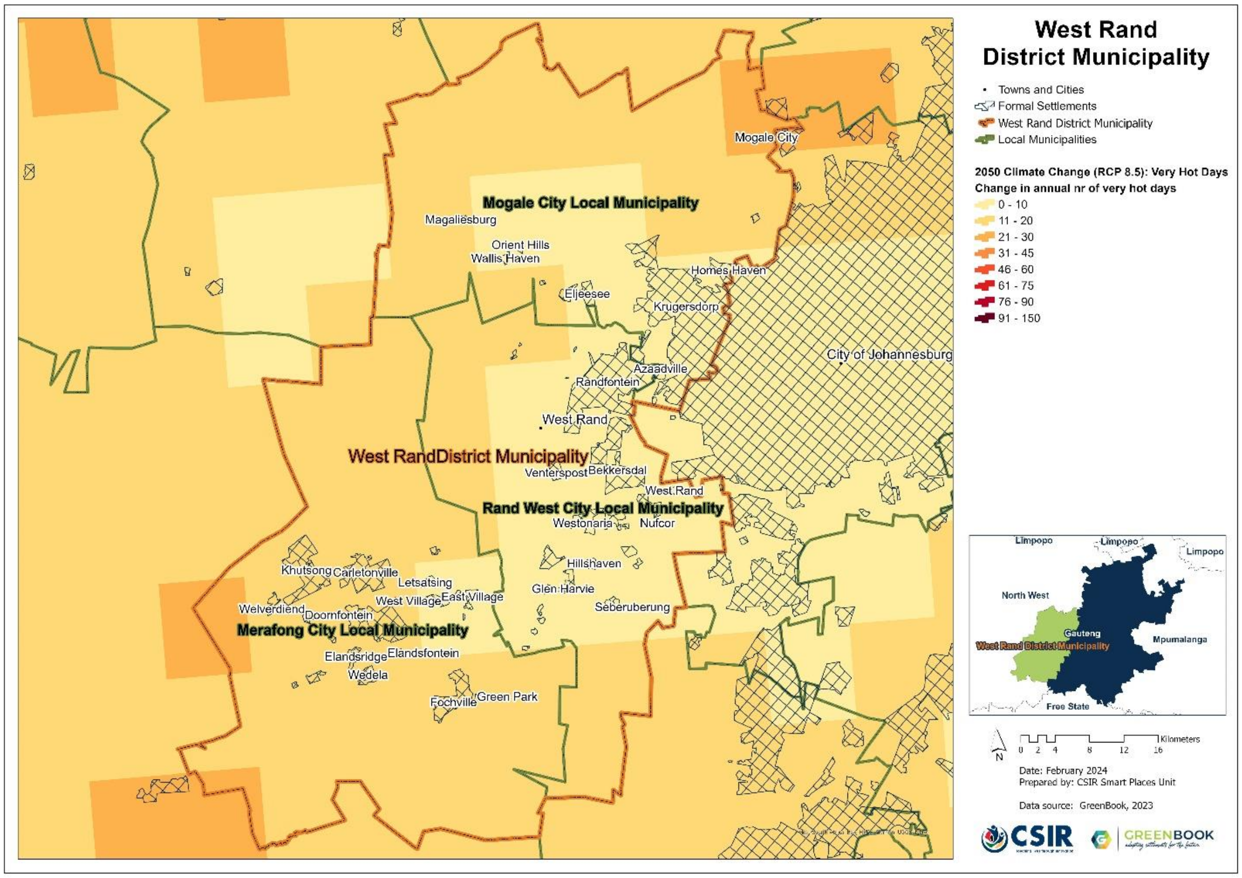

Figure 16: Projected change in annual number of very hot days across West Rand District Municipality, with daily temperature maxima exceeding 35 °C, assuming and RCP 8.5 emissions pathway

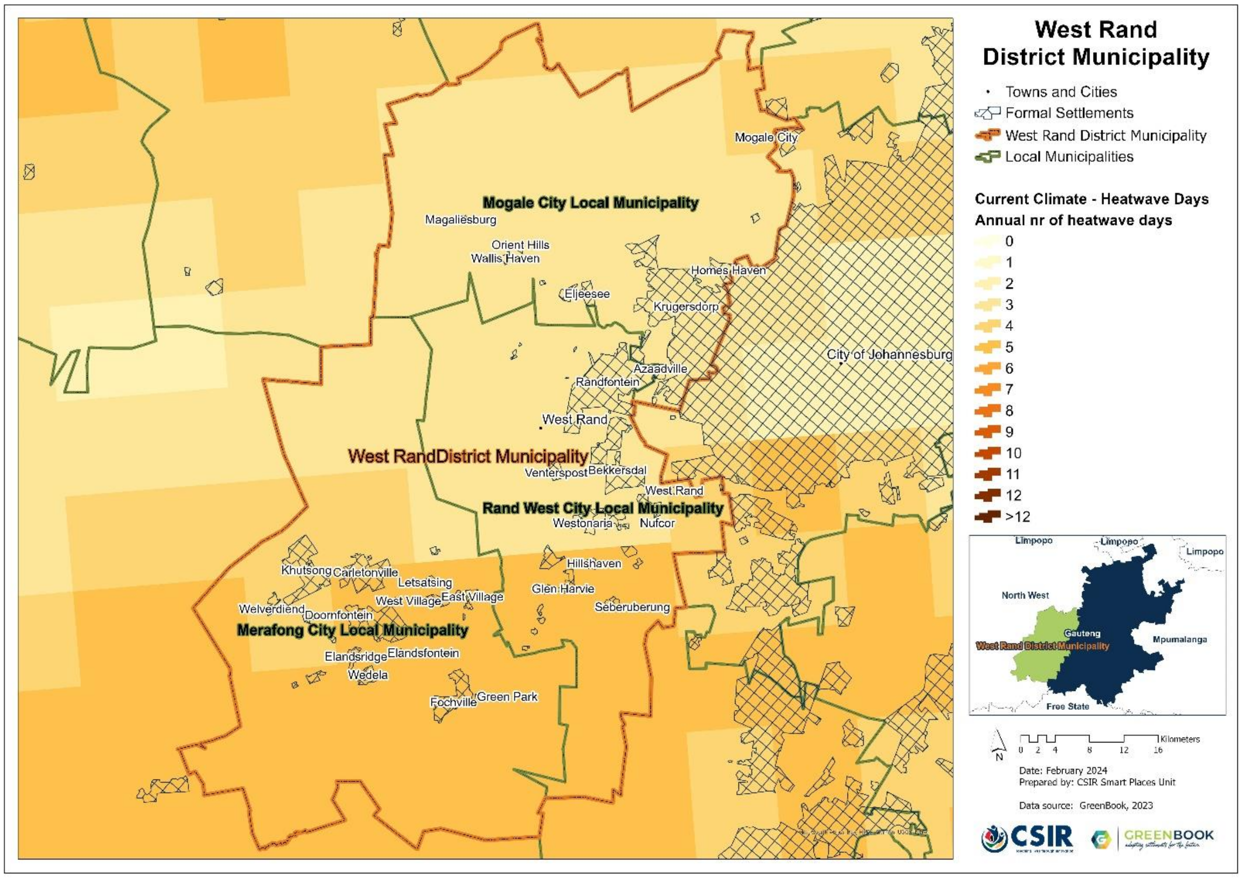

Figure 17: Number of heatwave days under baseline climatic conditions across West Rand District Municipality

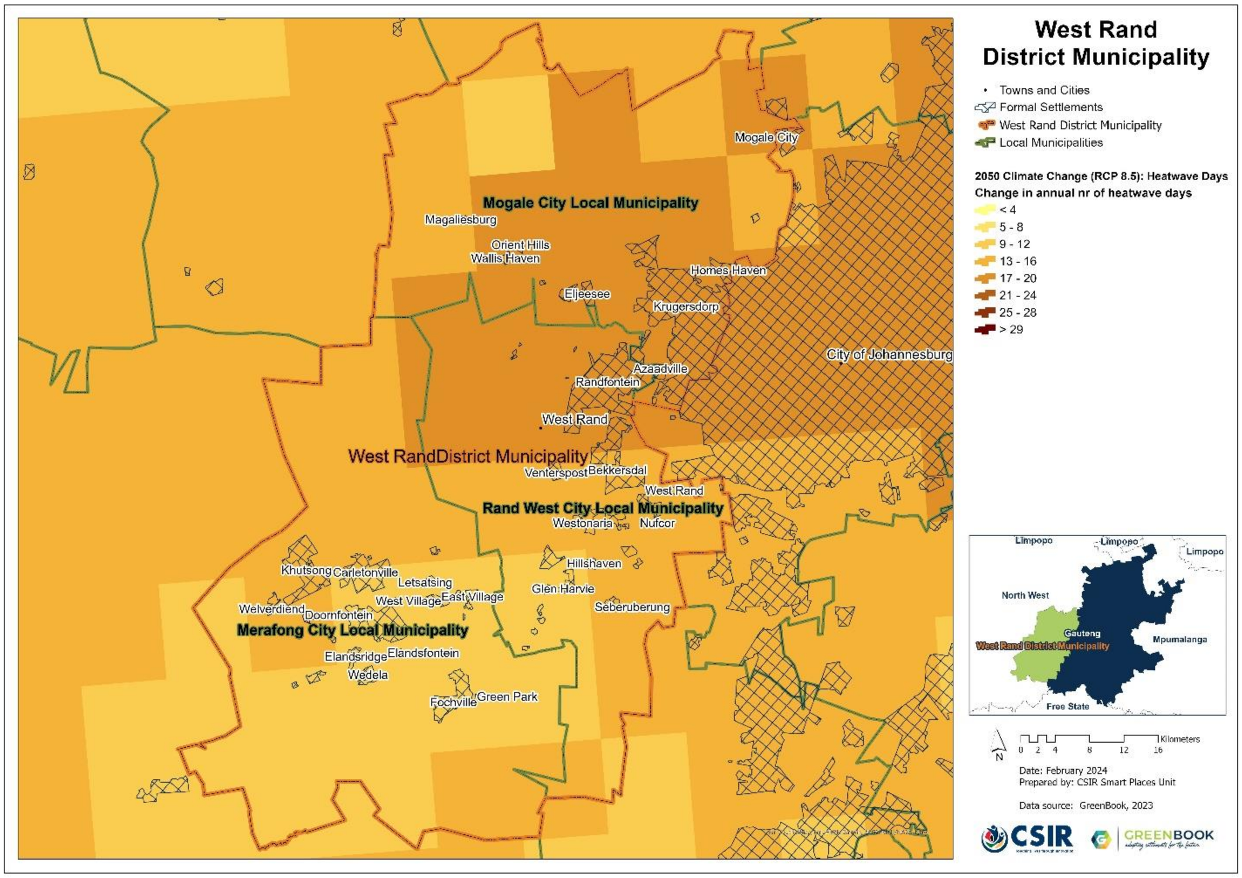

Figure 18: Projected change in annual number of heatwave days across West Rand District Municipality, assuming an (RCP 8.5) emissions pathway

Under baseline climatic conditions, there are no more than 10 very hot days experienced within the district (Figure 15). The number of very hot days are projected to increase by between 0 and 30 into the future, under an RCP8.5 emissions scenario (Figure 16). Most heatwaves days are likely to take place in the southern parts of the district, under baseline conditions (Figure 17), mostly affecting Merafong City LM. Conversely, most of the increase in the number of heatwave days is projected to occur in the northern parts of West Rand, affecting large parts of Mogale City and the northern parts of Rand West City (Figure 18).

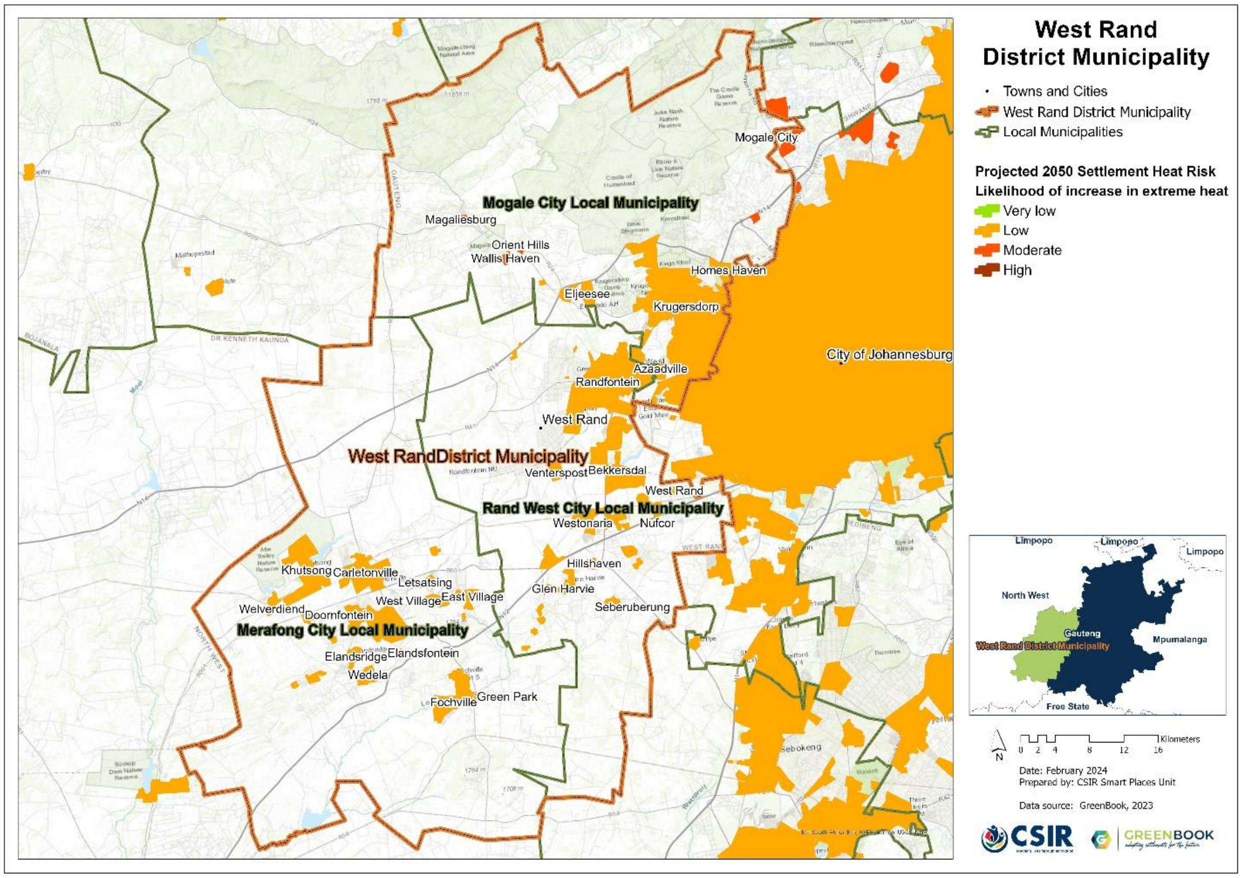

Figure 19: Settlement-level heat risk across West Rand District Municipality

Figure 19 depicts the settlements that are at risk of increases in heat stress. All settlements in West Rand face a low risk of heat stress into the future (2050).

2.3.3. Wildfire

Wildfires occur regularly in South Africa and often cause significant damage. The main reasons for recurring wildfires are that we have climates with dry seasons, natural vegetation that produces sufficient fuel, and people who light fires when 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 'high'. The risks were then summarised for all the settlements within a local authority. Changes in the fire risk in future were accommodated by adjusting either the fire scenarios or the likelihood, or both. Figure 20 depicts the likelihood and the risk of wildfires occurring in the wildland-urban interface (the boundary or interface between developed land and fire-prone vegetation) of the settlement.

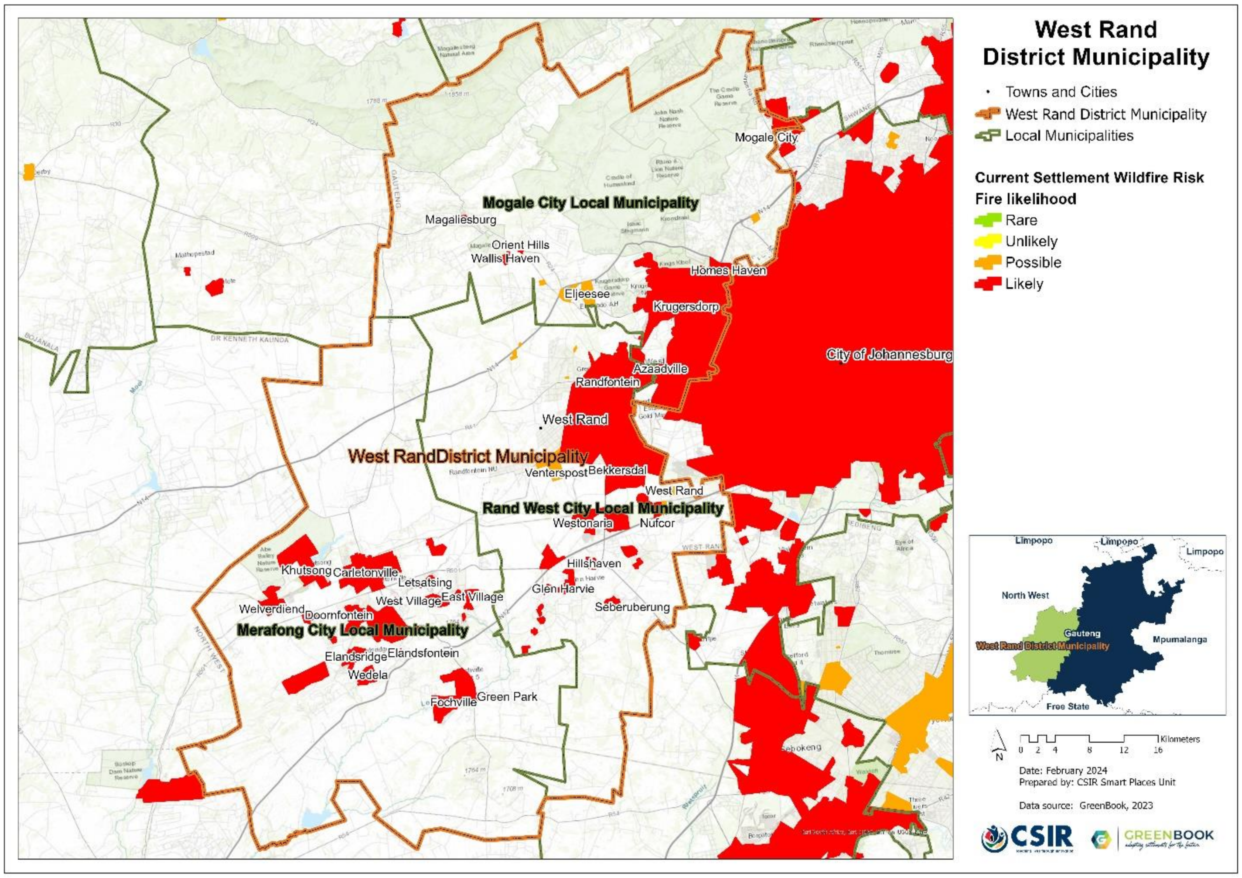

Figure 20: The likelihood of wildfires under current climatic conditions across settlements in the West Rand District Municipality

The projected number of fire danger days for an 8 x 8 km grid-point under an RCP 8.5 "business as usual" emissions scenario was calculated. A fire danger day is described as a day when the McArthur fire-danger index (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 of wildfires is informed by the projected change in the number of fire danger days. Figure 21 depicts the settlements that could be at risk of increases in wildfires by the year 2050.

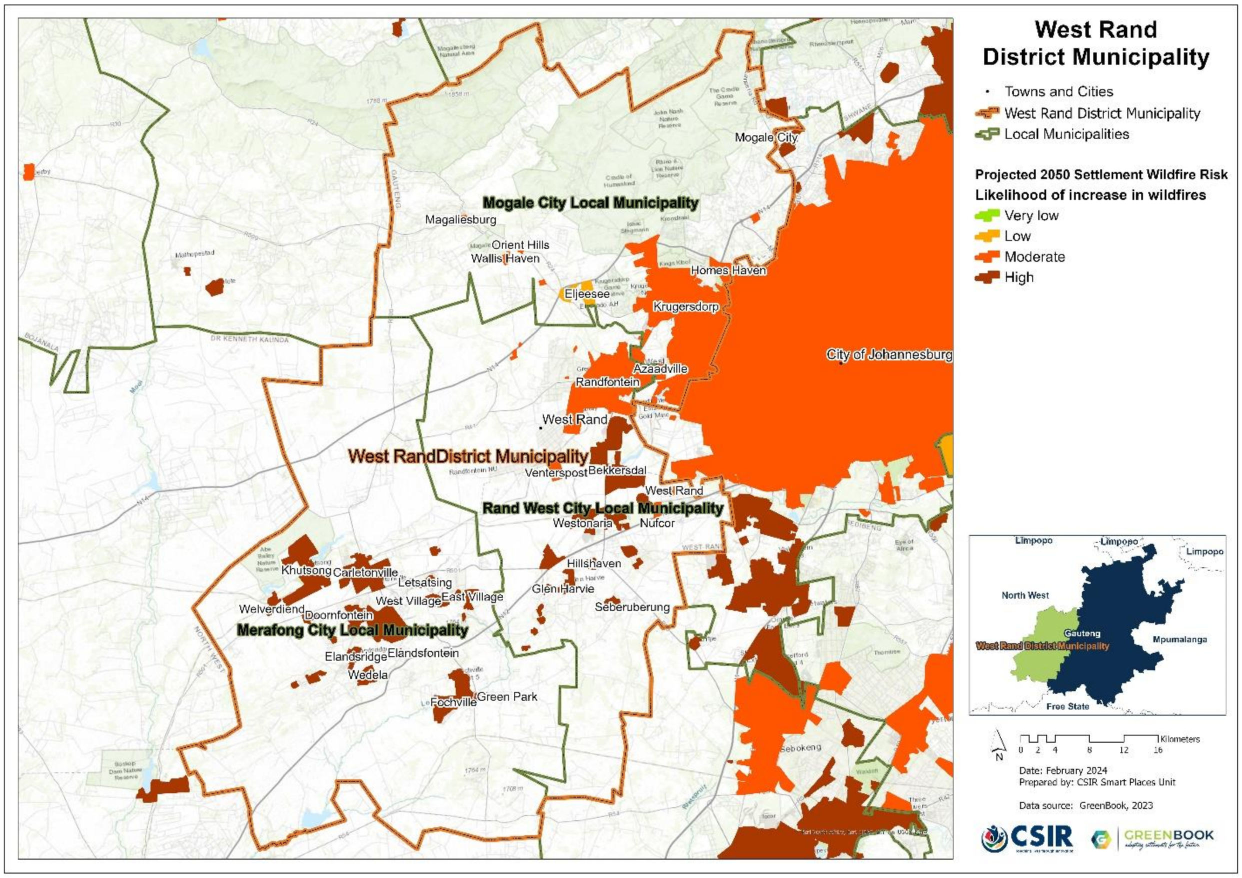

Figure 21: The likelihood of wildfires under projected future climatic conditions across settlements in West Rand District Municipality

All settlements across the district are likely to experience wildfires in their wildland-urban interface (Figure 20). It is projected that all settlements in Merafong City, as well as several settlements scattered in the central parts of Rand West City, face an increased risk of wildfires into the future (Figure 21).

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, 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 settlements that may increase exposure and risk. Additional local and contextual information should be considered to further enrich the information provided here.

Since the magnitude and intensity of rainfall are the main drivers of floods, and rainfall intensity is likely to increase into the future, 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, which considered the flood hazard index and the projected change in extreme rainfall days from 1961-1990 to the 2050s.

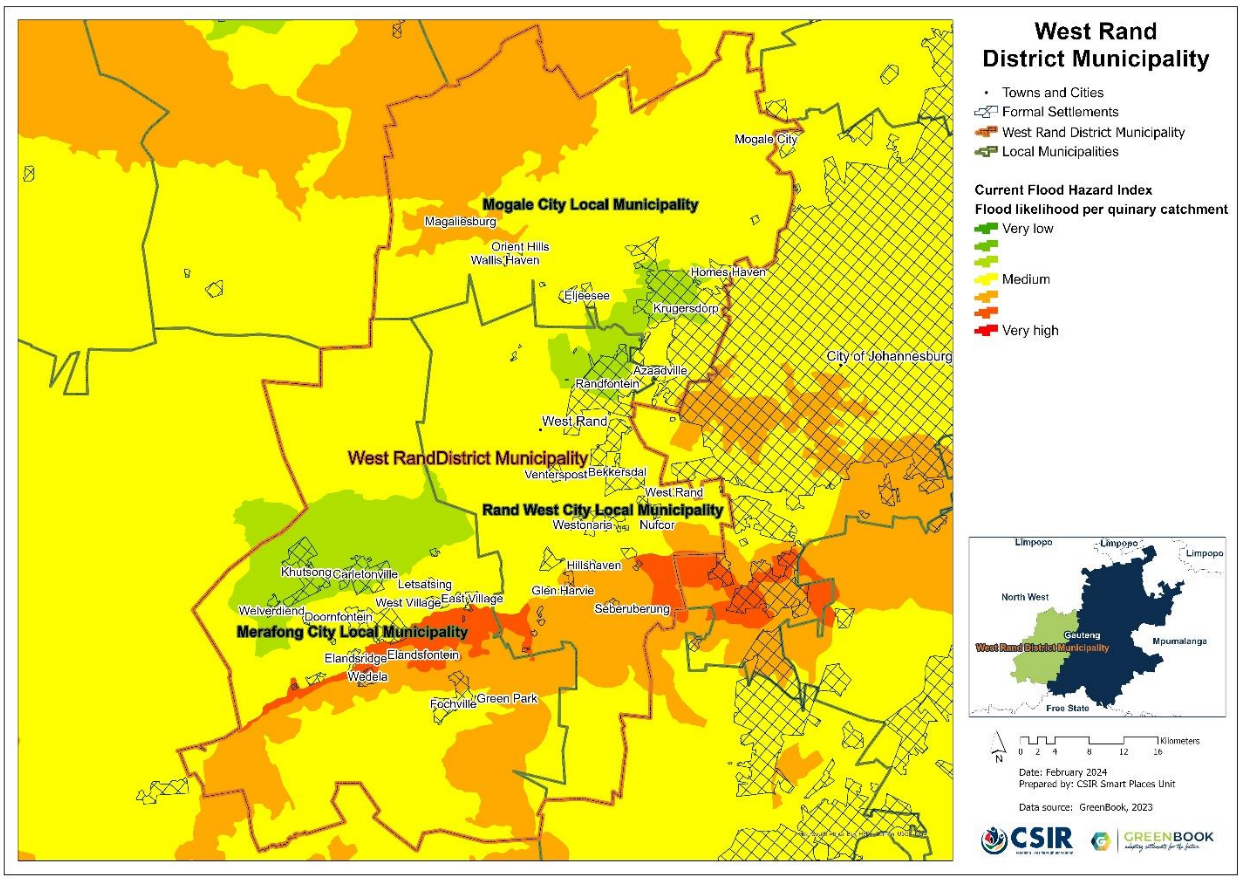

Figure 22: The current flood hazard index across West Rand District Municipality under current (baseline) climatic conditions

Figure 22 depicts the flood hazard index of the 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 some variation of the flood hazard index across the district. Most parts of the district have a medium flood hazard index, with pockets of low, high, and very high flood hazard index.

Figure 23 depicts the projected change into the future in 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 those under the current rainfall extremes. A value of more than 1 indicates an increase in extreme daily rainfalls. Slight increases (</= 5) in the number of extreme rainfall days are expected over most parts of the district. The settlements in the north of Mogale City are projected to have the smallest change in the number of extreme rainfall days in the West Rand District.

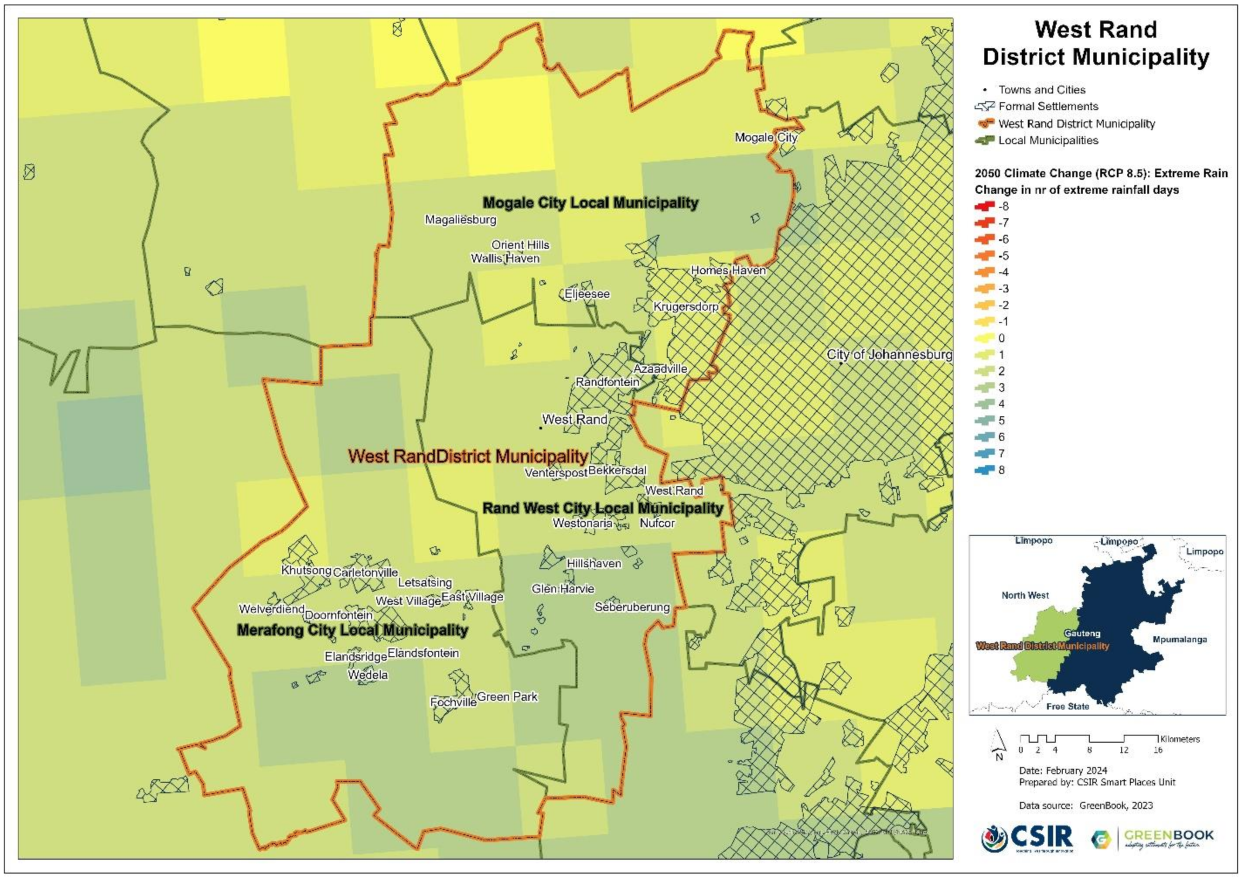

Figure 23: Projected changes into the future in extreme rainfall days across West Rand District Municipality

Model projections of precipitation manifest uncertain due to several factors, including model sensitivity to spatial resolution at which processes are resolved. At 8 X 8km horizontal resolution, for example, some processes (such as convective systems) that contribute to rainfall are not adequately resolved by the climate models. The precipitation projections therefore could reflect uncertainty in some locations since fine-scale processes that contribute to precipitation and its extremes are not captured. When the modelling ensemble approach used in the online GreenBook is considered, and the 10^{th}, 50^{th} and 90^{th} percentiles, per grid point, agree on the directional change relative to the reference period, the signal is considered well developed and conclusive. In the case where the respective model percentiles show conflicting signs, the model ensemble manifest uncertainty and therefore reflect low confidence on which future model realisation/outcome is more likely. It is therefore critical to consider the ensemble distribution uncertainty when devising long-term adaptation strategies.

Figure 24 depicts the settlements that are at increased risk of flooding under an RCP 8.5 low mitigation (worst case of greenhouse gas emissions) scenario. The settlements of Glen Harvie and Hills Haven in Rand West City are amongst those facing a high risk of flooding into the future, while the majority of settlements could face a low to moderate flood risk.

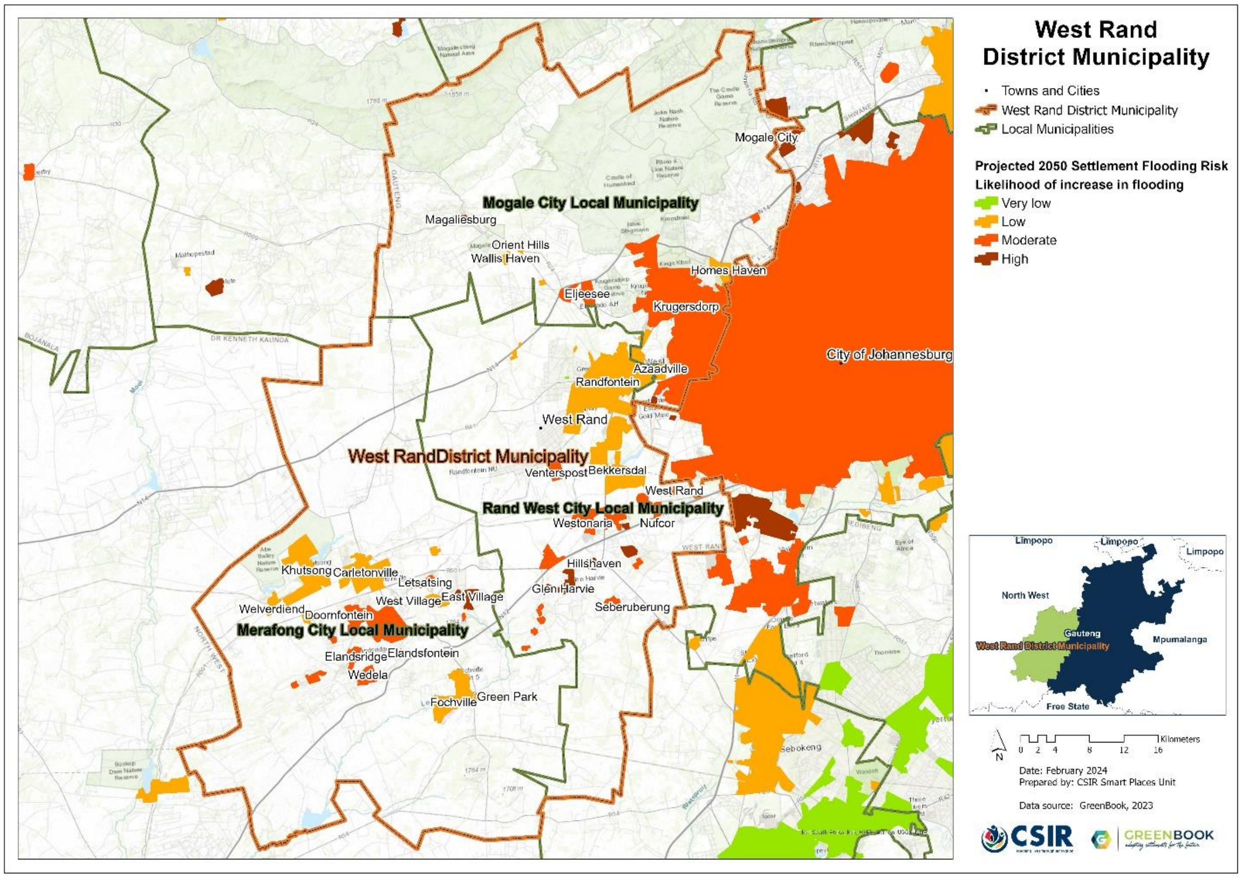

Figure 24: Flood risk into a climate change future at settlement level across West Rand District Municipality.

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 West Rand District Municipality.

2.4.1. Water resources and supply vulnerability

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

Figures 25 to 27 indicate the catchment(s) related to the Local municipalities in the district. The quaternary catchments serving the district include the Limpopo and Vaal Primary Catchments.

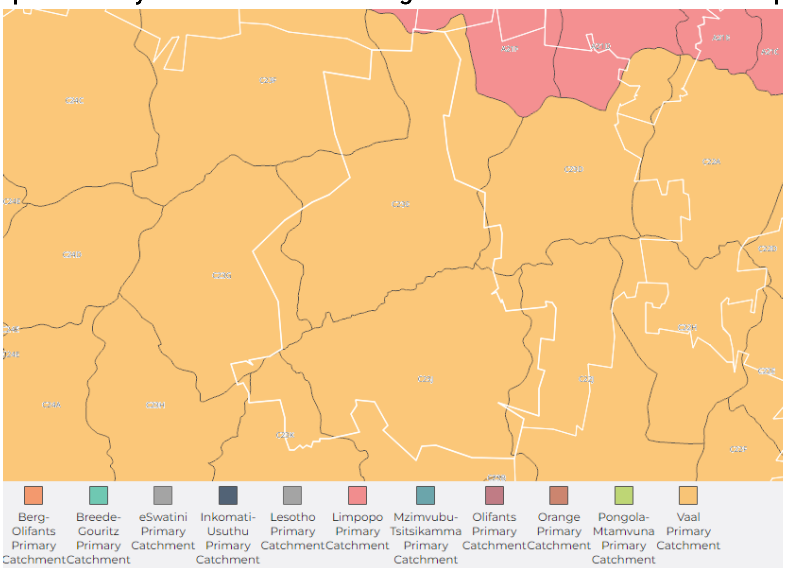

Figure 25: Quaternary catchments found in Merafong City Local Municipality

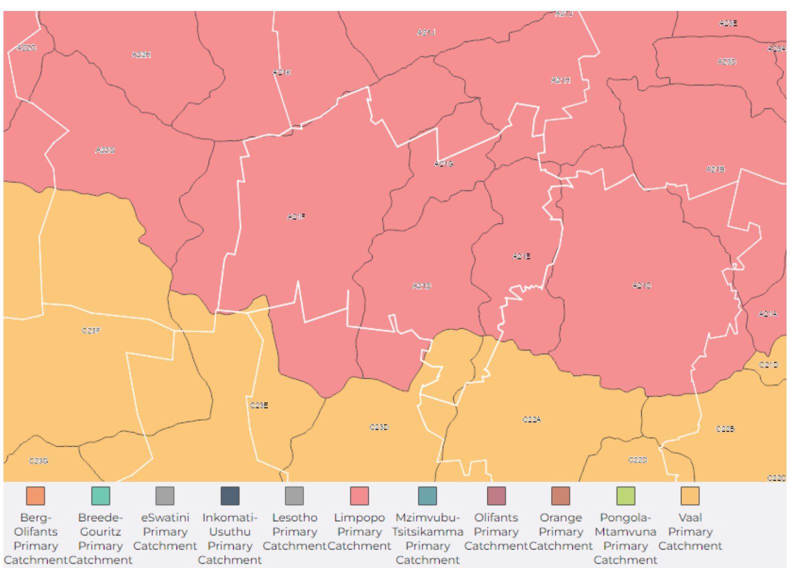

Figure 26: Quaternary catchments found in Mogale City Local Municipality

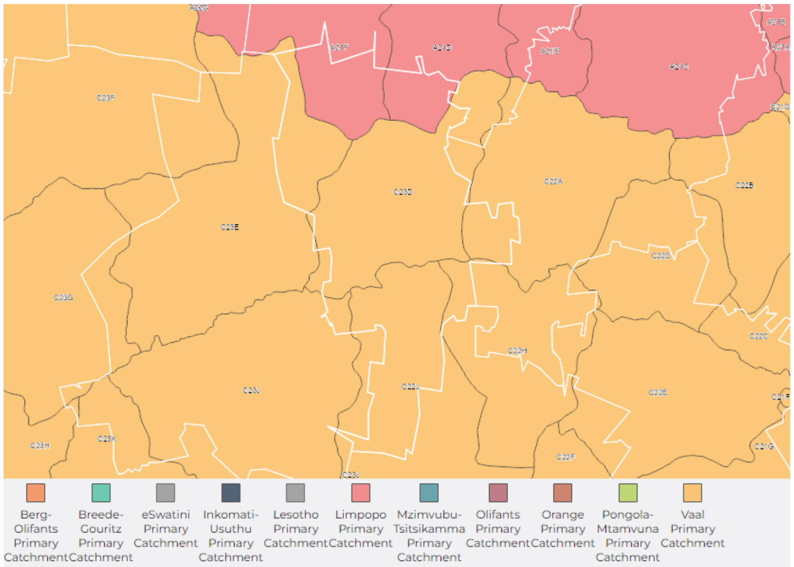

Figure 27: Quaternary catchments found in Rand West City Local Municipality

Figure 28 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 West Rand District, most of the settlements to the north are surface water dependent, and others to the south rely on a combination of surface water and groundwater sources.

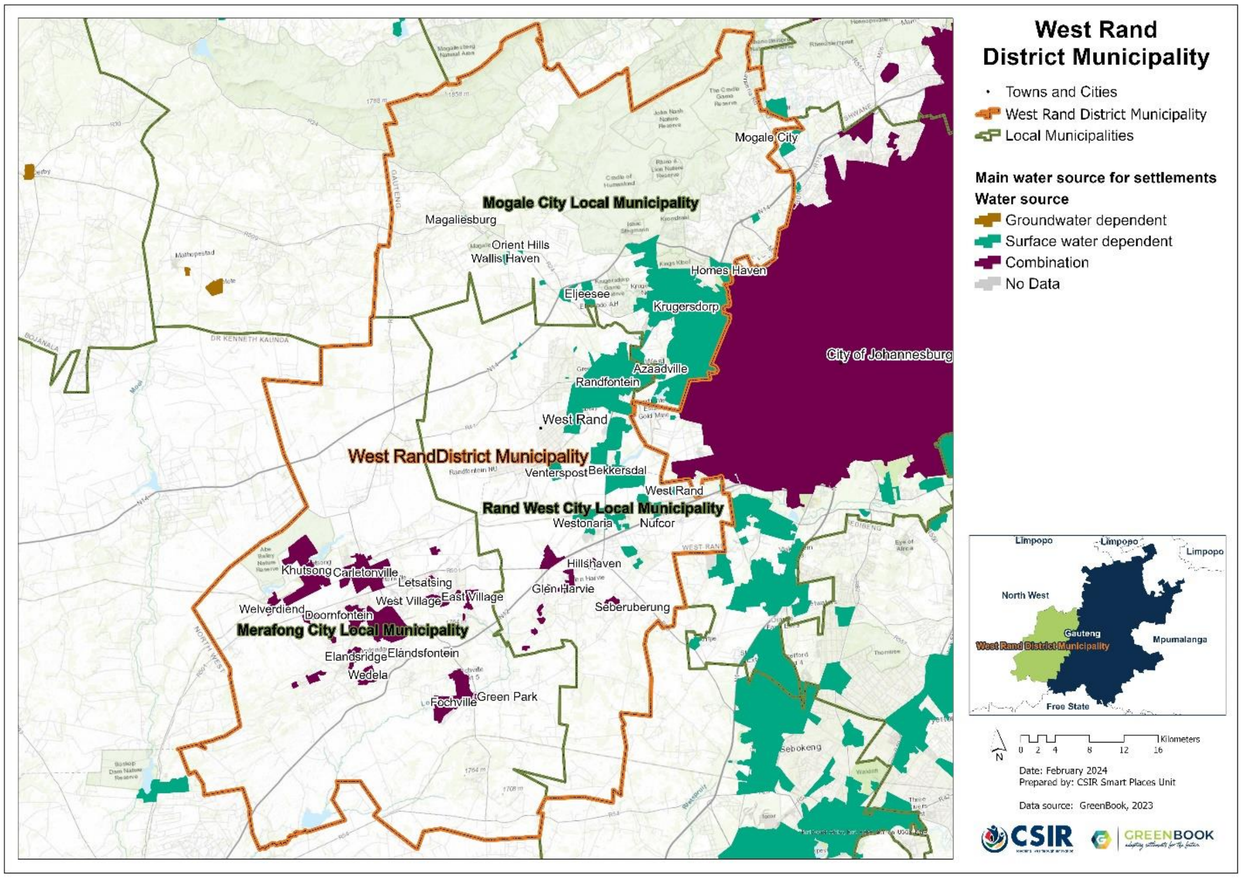

Figure 28: Main water source for settlements in the West Rand District Municipality

Figure 29 indicates the occurrence and distribution of groundwater resources across the district Municipality, showing distinctive recharge potential zones, while Figure 30 indicates the projected change in groundwater potential. Figure 31 indicates which 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 into the future.

There is moderate to high groundwater recharge potential across the district. The projected changes in groundwater recharge potential across the district (Figure 29), are just as varied, with decreases in groundwater potential projected for some areas scattered across the district and increases (and significant increases) projected for other areas in the district (Figure 30). No settlement in the WRDM faces a high risk of groundwater depletion into the future (Figure 31).

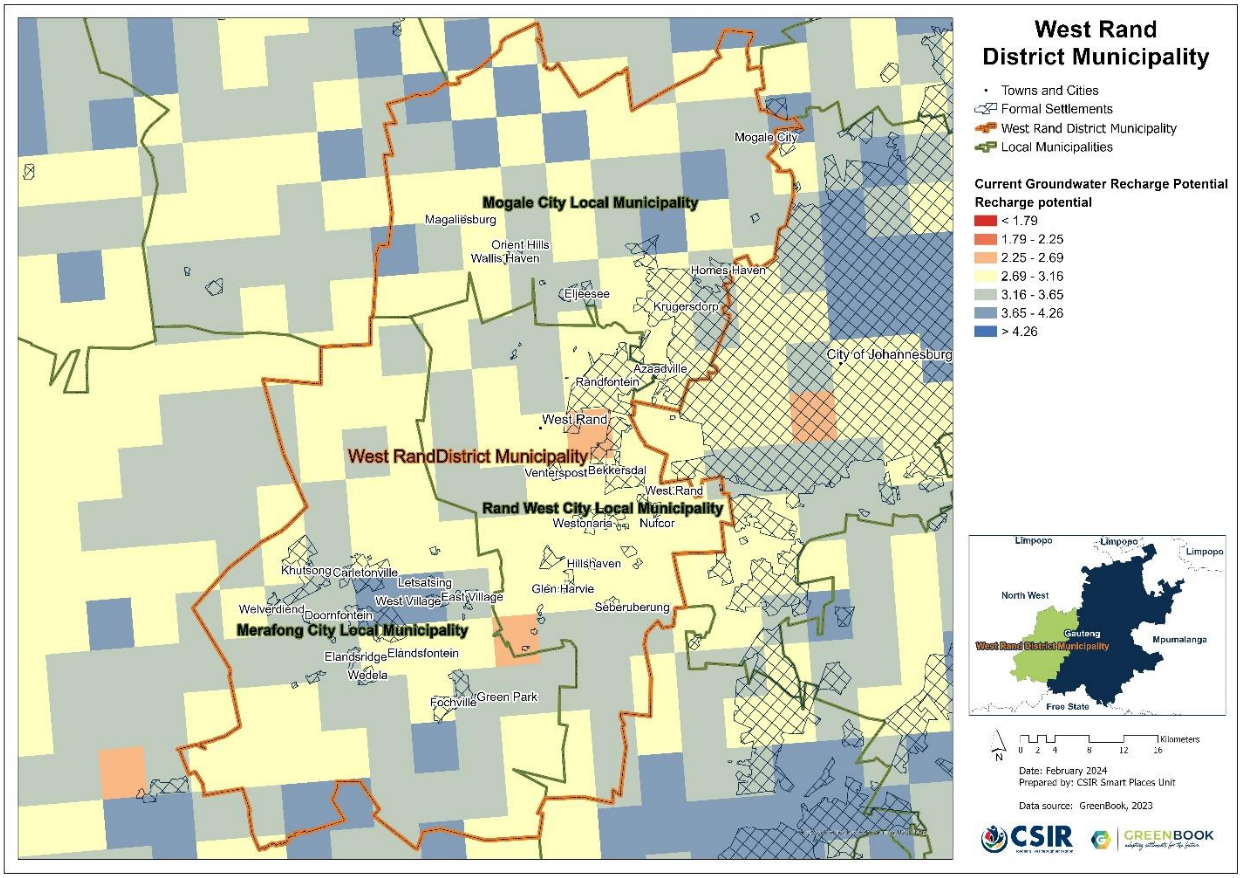

Figure 29: Groundwater recharge potential across West Rand District Municipality under current (baseline) climatic conditions

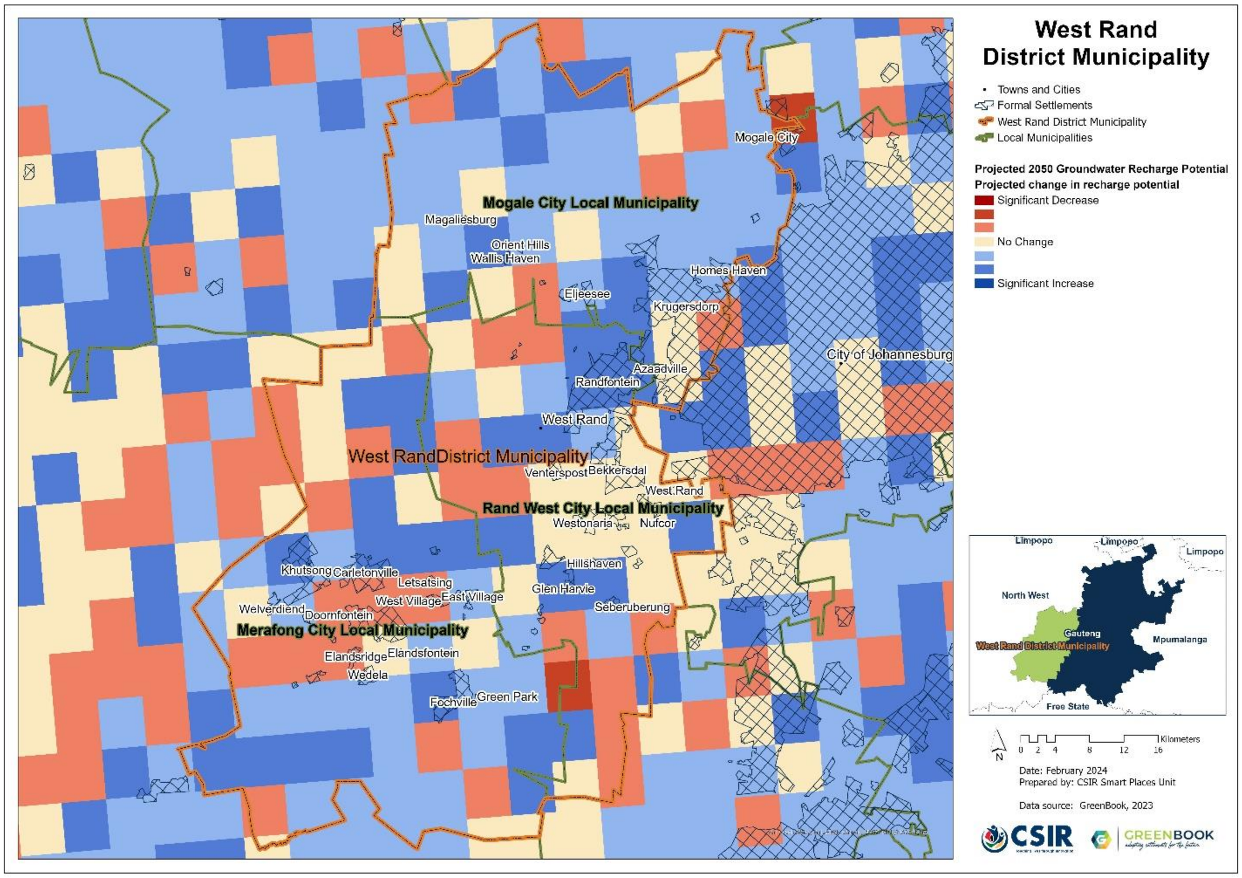

Figure 30: Projected changes in groundwater recharge potential from baseline climatic conditions to the future across West Rand District Municipality

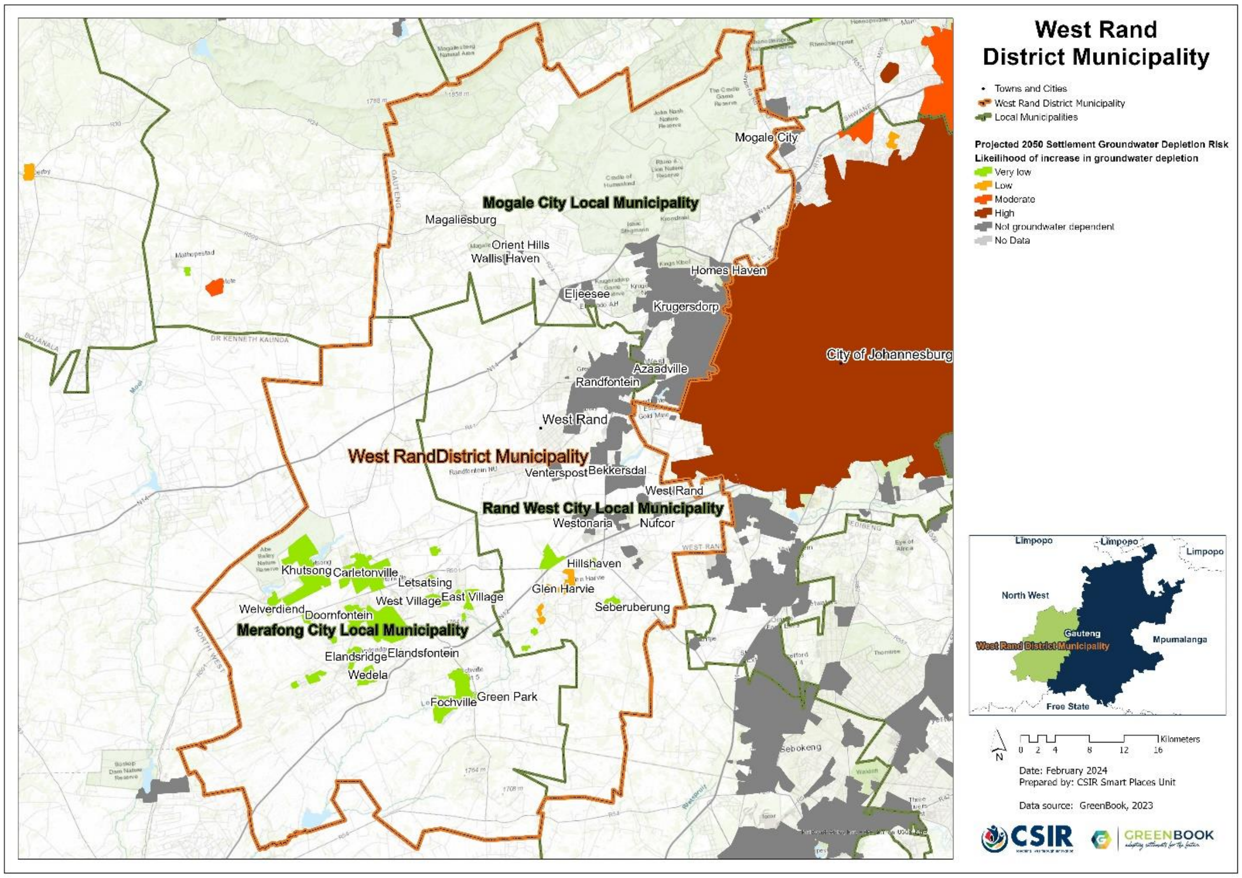

Figure 31: Groundwater depletion risk at settlement level across West Rand District Municipality

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

Local Municipality	Water Demand per Capita (l/p/d)	Water Supply per Capita (l/p/d)	Current Water Supply Vulnerability
Merafong City	No data	No data	No data
Mogale City	181.45	181.45	1
Rand West City	238.39	282.06	0.85

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.

Merafong City

No water supply vulnerability data is available for the Merafong City LM on the GreenBook website.

Mogale City

Water supply vulnerability currently amounts to 1, meaning that water demand per capita is equal to the current supply (see Table 3). The municipality's water supply vulnerability is projected to increase to between 1.14 and 1.75 into the future (2050), due to a decrease in mean annual precipitation, as well as an increase in mean annual evaporation and population growth.

Rand West City

Water supply vulnerability is currently moderate (see Table 3) with supply meeting the demand, and not projected to increase into the future due to population decline, as well as an increase in mean annual runoff and regional urban water supply.

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

Together with the Mining sector, the AFF sector contributed 28.6 % to the district's Gross Value Added (GVA) in 2016 (CoGTA, 2020). The district has a lot of agricultural potential, considering the large number of holdings situated in the region (although these pockets are rarely used for agricultural purposes due to the high mining activity in the area) (DRDLR, 2016). Therefore, the potential impact of climate change and climate hazards on agriculture is notable considering the contribution this sector makes to the local economy and its potential to support the livelihoods of local residents.

Below, the main agricultural commodities for each local municipality within the district is 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" greenhouse gas emissions scenario.

Merafong City

In the Merafong City LM, the AFF sector contributes 0.61 % to the local GVA, which is a contribution of 0.13 % to the national GVA for the AFF sector. Of the total employment, 2.5 % is within the AFF sector. The main agricultural commodities are chicken, maize for grain and pigs. Climate projections show a generally hotter and wetter climate, with more extreme rainfall events. For chickens, the projected climate could result in increased production costs (as increased investment costs may be required in ventilation and cooling) to maintain optimal seasonal temperatures and reduce the risk of heat stress. Heat stress on birds could reduce body weight gain, reproduction efficiency and egg quality. The projected climate may also result in potential increase in maize yield for the near future. However, towards 2050, heat stress can negatively impact on production. For pigs, warm and humid conditions could negatively affect reproductive efficiency and health.

Mogale City

In the Mogale City LM, the AFF sector contributes 1.32 % to the local GVA, which is a contribution of 0.52 % to the national GVA for the AFF sector. Of the total employment, 5.45 % is within the AFF sector. The main agricultural commodities are chicken eggs. Climate projections show a generally hotter and wetter climate, which could result in increased production costs (as increased investment may be required in ventilation and cooling) to maintain optimal seasonal temperatures and reduce the risk of heat stress. Heat stress on birds will reduce body weight gain, reproduction efficiency and egg quality.

Rand West City

In the Rand West City LM, the AFF sector contributes 0.77 % to the local GVA, which is a contribution of 0.21 % to the national GVA for the AFF sector. Of the total employment, 2.92 % is within the AFF sector. The main agricultural commodities are maize for grain, chicken eggs, and milk and cream. Climate projections show a generally hotter and wetter climate, with more extreme rainfall events, which could result in a potential increase in maize yield for the near future. However, towards 2050, heat stress can negatively impact on production. For chicken eggs, the projected climate could result in increased production costs (as increased investment may be required in ventilation and cooling) to maintain optimal seasonal temperatures and reduce the risk of heat stress. Heat stress on birds could also reduce body weight gain, reproduction efficiency and egg quality. For milk and cream, hot and moist conditions may result in the increased spread of cattle disease and parasites. Furthermore, the potential increase in heat stress could negatively affect conception rates, milk yield and milk quality.

3. Recommendations

The greatest risks faced across the West Rand district are increased temperatures, drought and wildfire, with the risk of heat extremes and intense rainfall becoming greater towards 2050. The district currently has abilities present within the district. District officials confirmed this during the first engagement when they made reference to the increasing burden of new mega-developments on the district's limited and aging infrastructure (the mega-development applications also allude to the increased exposure of people to the anticipated climate hazards in the future). West Rand also has very high economic vulnerability (EcVI) due to its heavy reliance on one sector, i.e., mining, which has been on the decline for several years. This has major implications for those who rely on the sector for employment (bearing in mind that the majority of the district's labour force is employed in this sector) and revenue. Two thirds of district have above national average environmental vulnerability (EnVI), pointing towards the conflict between preserving the natural environment and accommodating the growth pressures associated with urbanisation and economic development. In the case of West Rand, this conflict largely manifests in the form of decanting water in mines that are no longer in operation, as well as the resultant AMD that is threatening the survival and quality of some of the district's most critical natural resources, especially surface and groundwater resources.

In addition to these risks and vulnerabilities, several settlements in the Mogale City LM, including Krugersdorp and Azaadville, will likely experience high growth pressures up to 2050, while the West Rand Consolidated Gold Mine area (located north of Krugersdorp) will likely experience extreme growth pressures, also up to 2050 – thus alluding to an increase in the exposure of people and their assets to the anticipated climate hazards. This trend was also confirmed by the district during the first engagement, when representatives raised the importance of considering the implications of the multiple mega-developments planned in and around Mogale City, for infrastructure expansion and services provision, seeing that the district already struggles to meet current demands. In an effort to diversify the economy, the district also indicated plans to expand and diversify the local economy by shifting its reliance from mining to agriculture and tourism. While both sectors emerge ass key avenues for promoting economic growth, creating jobs, and reducing the district's economic vulnerability – it will become increasingly imperative to climate-proof and build the sectors' resilience to the impacts of climate change, in an effort to protect investments.

Therefore, in response to these climate risks 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 temperatures (which increase evaporation and reduce runoff, thus reducing the amount of water captured and stored for future consumption), drought tendencies and population growth will have on the West Rand District's future water supply – developing comprehensive strategies for water resource management is crucial. As part of these

strategies, the WRDM and its municipalities 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 protect natural resources and ecosystems: Considering West Rand's high environmental vulnerability (EnVI), particularly the impact of mining activities on the district's natural resources – it is critical to protect the natural resources and ecosystems in the district. Protecting and restoring natural ecosystems such as wetlands and riparian areas, will enhance West Rand'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 could be taken 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 reduce the exposure and vulnerability of human systems to climate change and extreme weather events: To minimise the damage, disruption and loss stemming from the unavoidable impacts of climate change, it is essential to reduce the exposure and vulnerability of elements found in human systems (i.e., lives, livelihoods, assets, and human settlements) present in the West Rand 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. This goal also aims to reduce the district's socioeconomic and physical vulnerability, as well as the exposure its human systems to key climate-related hazards.

4. To develop climate-resilient, low-carbon, diverse and inclusive local economies, particularly within the mining, tourism and agricultural sectors, that are socially responsible, environmentally sustainable and that provide job opportunities for unskilled, semi-skilled and skilled local residents: Considering the Gauteng Province's (and the West Rand district's) plans to diversify the district's economy by expanding the agricultural and tourism sectors, it is important that these plans to expand and diversify the economy are carried out in a low-carbon manner, with the intention of having both sectors contribute towards building West Rand's resilience to climate change impacts, while simultaneously creating diverse and inclusive local economies within the district, that provide job opportunities for residents with all types of skills levels. In so doing, the district is able to meet most of its development priorities as captured in the IDP, i.e.,

particularly development priorities 1,2,3,5,6,7,9,10 and 12 – while simultaneously meeting relevant climate response objectives captured in this plan. The agricultural sector, in particular, has various opportunities for expansion at its disposal, especially within the West Rand district municipal area. Moreover, the fact that agricultural development, investment and beneficiation forms part of the district's core objectives (see WRDM's pipeline projects outlined in the district's DDM profile and the rural nodes identified in the district's SDF; as summarised in section 3.1.1 of this plan), means that it will be to the benefit of those who rely on the sector for employment, sustenance and economic development (i.e., revenue and wealth generation), to increase its resilience to the impacts of climate change. This can be done by providing farmers with (i) access to resilient crop varieties and efficient irrigation systems; (ii) training in sustainable farming techniques; (iii) financial risk management tools; and (iv) market opportunities, i.e., to help the agricultural sector withstand shocks and stresses such as climate change impacts, market fluctuations, and pest outbreaks.

These goals should be pursued with the understanding that the West Rand District's climate risks are likely to increase due to climate change. Hence, any actions taken need to remain adaptable to the evolving risks over time. Furthermore, while these recommended goals are not exhaustive, they can be enhanced by strategies tailored to the specific needs of the WRDM. The key to success lies in integrating these goals and the principles behind them into all aspects of municipal decision-making and operations, as well as in actively engaging communities in these initiatives.

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