Lejweleputswa 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
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
LDM	Lejweleputswa District Municipality
DEA	Department of Environmental Affairs
DM	District Municipality
DRR	Disaster Risk Reduction
DWS	Department of Water and Sanitation
EcVI	Economic Vulnerability Index
EnVI	Environmental Vulnerability Index
GCM	General circulation model
GRiMMS	Groundwater Drought Risk Mapping and Management System
GVA	Gross Value Added
GDP	Gross Domestic Product
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
l/p/d	Litres Per Person Per Day
LM	Local Municipality
MAR	Mean Annual Runoff
mm	Millimetre
NDMC	National Disaster Management Centre
PVI	Physical Vulnerability Index
RCP	Representative Concentration Pathways
SCIMAP	Sensitive Catchment Integrated Modelling and Prediction
SDF	Spatial Development Framework
SEVI	Socio-Economic Vulnerability Index
SPI	Standardised Precipitation Index
SPLUMA	Spatial Planning and Land Use Management Act, 2013 (Act No. 16 of 2013)
THI	Temperature Humidity Index
WMAs	Water Management Areas
WMO	World Meteorological Organisation
WRYM	Water Resources Yield Model

WUI	Wildland-Urban Interface

Glossary of Terms

Adaptation actions	A range of planning and design actions that can be taken by local government to adapt to the impacts of climate change, reduce exposure to hazards, and exploit opportunities for sustainable development (CSIR, 2019).
Adaptation planning	The process of using the basis of spatial planning to shape built-up and natural areas to be resilient to the impacts of climate change, to realise co-benefits for long-term sustainable development, and to address the root causes of vulnerability and exposure to risk. Adaptation planning assumes climate change as an important factor while addressing developmental concerns such as the complexity of rapidly growing urban areas, and considers the uncertainty associated with the impacts of climate change in such areas – thereby contributing to the transformational adaptation of urban spaces. Adaptation planning also provides opportunities to climate proof urban infrastructure, reduce vulnerability and exploit opportunities for sustainable development (National Treasury, 2018; Pieterse, 2020).
Adaptive capacity	"The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2022, p. 2899).
Climate change adaptation	"In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects" (IPCC, 2022, p. 2898).
Climate change mitigation	"A human intervention to reduce emissions, or enhance the sinks, of greenhouse gases (GHGs)" (IPCC, 2022, p. 2915). The goal of climate change mitigation is to achieve a reduction of emissions that will limit global warming to between 1.5°C and 2°C above preindustrial levels (Behsudi, A, 2021).

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

Resilience	"The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation" (IPCC, 2022, pp. 2920–2921).
Sensitivity	"The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)" (IPCC, 2022, p. 2922).
Vulnerability	Vulnerability is defined as the "propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including, sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2022, p. 2927). Vulnerability refers to the characteristics or attributes of exposed elements, i.e., elements that are exposed to potential climate-related hazards. Vulnerability is a function of sensitivity and (coping or adaptive) capacity (Pieterse et al., 2023).

1. Introduction

This Climate Risk Profile report, as well as the accompanying Climate Change Adaptation Plan, were developed specifically for Lejweleputswa District Municipality (LDM), 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.

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.

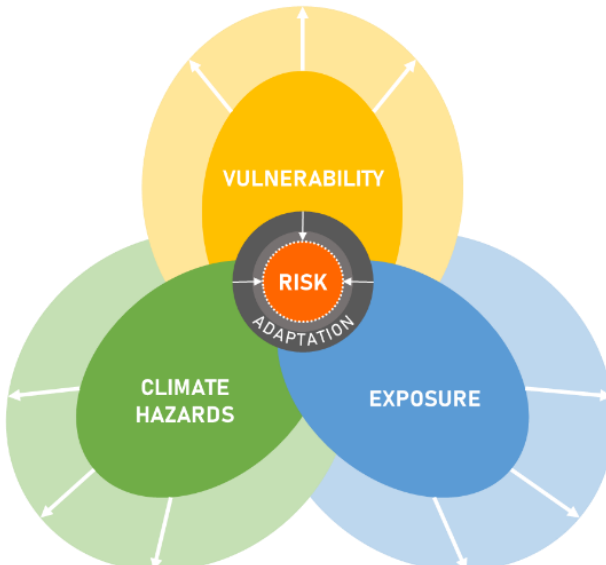

Figure 1: The interaction between the various components of risk, indicating the opportunity to reduce risk through adaptation (based on IPCC, 2014 and IPCC, 2021)

To understand climate risk across the municipal area, the exposure of settlements to certain climate hazards and their vulnerability are unpacked. In this Climate Risk Profile report multiple vulnerability indices are provided on the municipal and settlement level, as well as variables for the current and future projected climate. Climate-related hazards such as drought, heat extremes, wildfire and flooding and the impact of climate on key resources are also set out for the district and its municipalities.

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

1.2. Policy framework

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

Furthermore, the National Climate Change Response White Paper – which outlines the country's comprehensive plan to transition to a climate resilient, globally competitive, equitable and low-carbon economy and society through climate change adaptation- and mitigation, while simultaneously addressing the country's key priorities, including job creation, poverty reduction, social equality and sustainable development, amongst others – identifies local governments as critical role players that can contribute towards effective climate change adaptation through their various functions, including "[the] planning [of] human settlements and urban development; the provision of municipal infrastructure and services; water and energy demand management; and local disaster response, amongst others." (Republic of South Africa, 2011, p. 38). The Climate Change Bill (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 that district intergovernmental forum to serve as a Municipal Forum on climate change that coordinates climate response actions and activities in its respective municipality. 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 Lejweleputswa District Municipality is one of four District Municipalities in the Free State Province. The Lejweleputswa District Municipality (DC 18) is located in the northwestern part of the Free State and is about 32 287 square km². Lejweleputswa, meaning 'grey rock', describes the area with a rich history in gold prospecting and mining. Lejweleputswa is a category C municipality and shares a boundary with North West Province to its north west, Fezile Dabi and Thabo Mofutsanyana District Municipalities to its east, Mangaung Metropolitan Municipality and Xhariep District Municipality to its south, and the Northern Cape Province to its west. Lejweleputswa District consists of the following five local municipalities namely Masilonyana, Tokologo, Tswelopele, Matjhabeng and Nala.

Some local contextual statistics to consider:

- The district has a total population of 679 746 (StatsSA, 2022), which is the third largest in the province after Thabo Mofutsanyana and Mangaung DMs.
- The district hosts 189 807 households, with an average household size of 3.6 people.
- Young children (0-14 years) make up 27.5% of the total population. The working-age population (15-64 years) accounts for 65.9%, while the elderly (65+ years) constitute 6.6%. The district's dependency ratio is reported at 51.7%.
- Education indicators reveal that 4.4% of individuals aged 20 and above have no formal schooling, while 8.6% have attained higher education qualifications.
- Formal dwellings dominate the housing landscape, representing 88.2% of the housing stock.
- Sanitation and waste management services are accessible, with 86.2% of formal dwellings equipped with flushing toilets connected to sewerage, and 66.5% receiving weekly refuse disposal services. Moreover, 53.5% of households enjoy access to piped water within their dwellings, while 94.7% have electricity for lighting.

The mining sector is the primary economic driver in the district, encompassing 46.5% of the economic activities as noted in the Lejwleputswa Annual Report of 2021. Following closely behind, community services account for 14.2 percent, with trade trailing at 11 percent. In the smaller municipalities of Nala, Tswelopele, and Tokologo, the economic landscape looks different. In Tswelopele, agriculture is the biggest economic sector at 36.9% as of 2014. In Nala, government services take the lead, claiming 24% of the economic pie in 2014, and Tokologo sees agriculture as the predominant sector with 24.6% in the same year.

A significant portion of Lejweleputswa, approximately 47%, is designated as natural habitat. Within this expanse, the Bloemhof Dam Nature Reserve spanning 632ha and the Sandveld Nature Reserve covering 24 883.5ha are formal protected areas within the District Municipality. Additionally, wetlands cover 37 304.9ha (5.7%) of Lejweleputswa's total area. The municipality is also home to numerous ecological aquatic areas vital for supporting endangered and aquatic species, with the Agri Park in Wesselsbron serving as a notable Ecological Support Area, predominantly characterised by aquatic environments and species. Protected and conservation areas are strategically situated throughout the Lejweleputswa District Municipality, with key concentrations around Bloemhof, Erfenis, and Allemanskraal Dams.

Rivers flowing through and in close proximity to the district municipality play a major role in providing water to Lejweleputswa. The Vaal, Modder, Vals, Sand and Vet rivers are essential sources of water supply in Lejweleputswa. The Bloemhof, Erfenis and Allemanskraal Dams provide drinking water to rural towns, the communities and farmers in the district municipality.

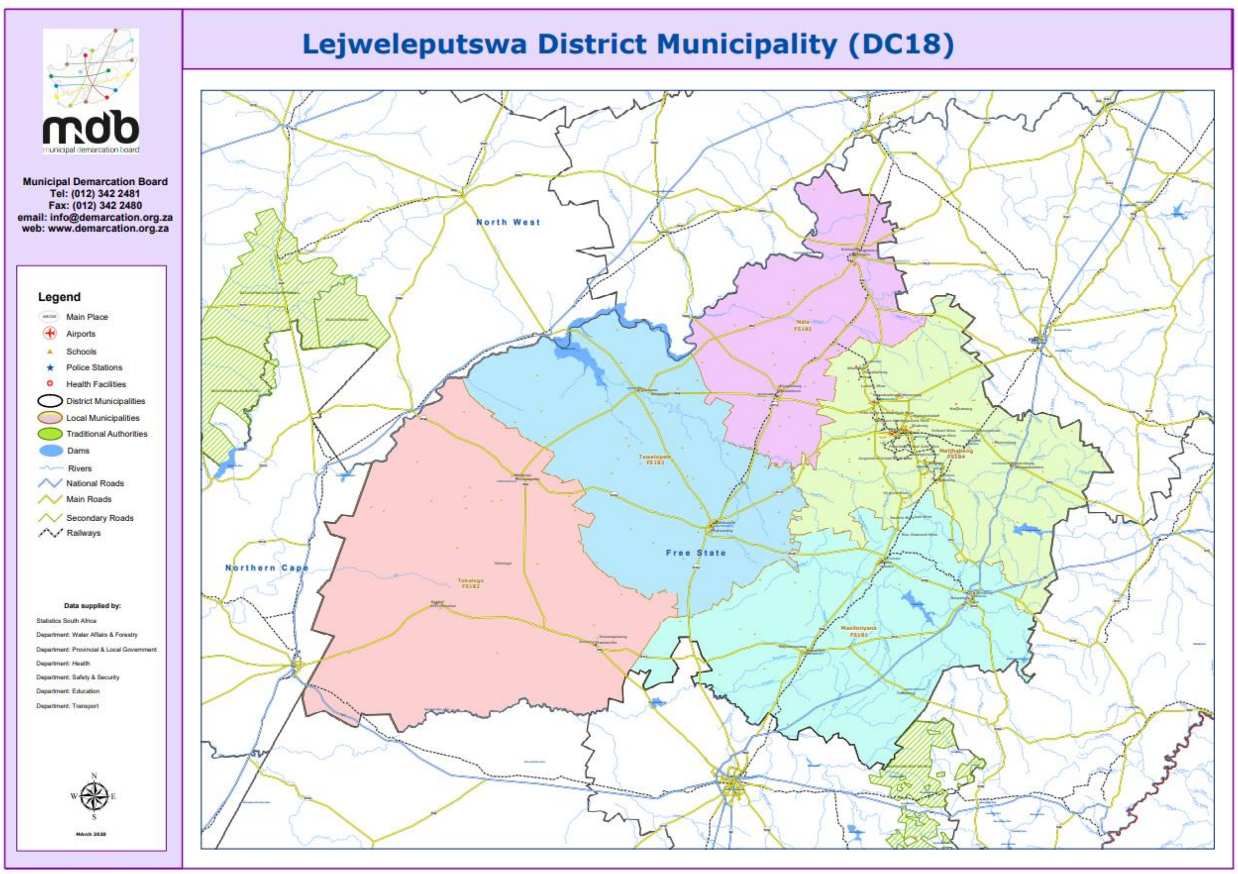

Figure 2: Lejweleputswa District Municipality (Municipal Demarcation Board, 2022), with local municipalities shaded in different colours

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 Lejweleputswa 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 Lejweleputswa 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 Lejweleputswa 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 Lejweleputswa 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 Lejweleputswa District Municipality for 1996 to 2011

LOCAL MUNICIPALITY	SEVI 1996	SEV 2011	Trend	EcVI 1996	EcVI 2011	Trend	PVI	Trend	EnVI	Trend
Masilonyana	6.7	5.8	↘	7.4	8.7	↗	5.3	N/A	2.6	N/A
Tokologo	7.3	6.4	↘	6.4	4.8	↘	5.5	N/A	2.9	N/A
Tswelopele	7.2	6.1	↘	6.2	6.9	↗	5.9	N/A	2.7	N/A
Matjhabeng	5.3	4.2	↘	7.7	9.9	↗	5.3	N/A	3.9	N/A
Nala	7.0	6.0	↘	5.3	6.1	↗	5.3	N/A	3.5	N/A

As outlined in Table 1 all LMs in the district had decreased (improved) socio-economic vulnerability between 1996 and 2011. Nala LM has the highest socio-economic vulnerability in the district and is ranked 16th out of 19 municipalities in the Free State Province. When considering household composition, education and health, access to basic services and safety and security Nala LM has a high proportion of households vulnerable to external stressors. All LMs in the district apart from Tokologo LM experienced an increase (worsening) in economic vulnerability for the period 1996 to 2011. Matjhabeng LM had the biggest decline in economic vulnerability and has the highest economic vulnerability in the province (19th out of 19). Matsilonyana has the second highest economic vulnerability in the province. The high economic vulnerability scores in these LMs means they are highly susceptibility to external shocks and may make take longer to recover from natural disasters (e.g. floods and droughts), global economic crises (e.g.

recession) and pandemics such as COVID-19. Physical vulnerability scores fall within the same range across the district and indicates infrastructure condition and accessibility. Tswelopele LM has the highest score in the district and is ranked 15th out of the 19 municipalities in the Free State. In terms of ecological vulnerability, scores are relatively low for the district, with the Matjahabeng LM having the highest score and ranked 13th out of the 19 municipalities in the Free-State.

2.1.2. Settlement vulnerability

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

Masilonyana Local Municipality

The major built-up areas in this municipality are Tshepong, Verkeerdevlei, Brandfort, Makeleketle, Winburg, Theunnisen, Leeubult Mine1, Leeubult Mine2. The settlement of Tshepong is facing the greatest growth pressure in the municipality, this is combined with a high socio-economically vulnerable population, high economic pressures and poor service access. Makeleketle has the second highest socio-economically vulnerable population in the municipality. Makeleketle and the Winburg settlement has poorest regional connectivity in the municipality. Theunnisen has the third high socio-economically vulnerable population in the LM this is combined with poor service access.

Tokologo Local Municipality

The major built-up areas in this municipality are Dealesville 2, Tswaraganang, Boshof and Hertzogville. Dealesville 2 is facing the greatest growth pressure in the municipality along with high environmental pressures. Hertzogville has the highest socio-economically vulnerable population in the LM and is also faced with poor service access and regional connectivity. Tswaranganang has high economic pressures. while Boshof is faced with high ecological pressures.

Tswelopele Local Municipality

The major settlements in this municipality are Bultfontein FS, and Hoopstad. Both settlements in the municipality are faced with high economic pressure and poor service access. Hoopstad has the greatest growth pressure, combined with poor regional connectivity and high environmental pressures. Bultfontein FS has the highest socio-economically vulnerable population in the municipality.

Matjahabeng Local Municipality

The major built-up areas in this municipality are Meloding, Odendaalsrus, Allanridge, Thabong, Kutloamong, Nyakallong, Virginia, Hennenman, Venersburg, Phomolong, Mmamahabane with smaller built-up areas of Saaiplaas Gold Mine, Vigina Gold Mine, Whites, Jabulani, Kutloanong and Loraine Gold Mine. Meloding has the greatest growth pressure in the municipality, this is coupled with high economic and environmental pressure, and the third highest socio economically vulnerable population. Ventersburg has the highest social-economic vulnerability combined with poor regional connectivity and poor service access. Phomolong is faced with low service access, high socio-economic vulnerability and the second highest growth pressure in the municipality. Welkom has the third highest population growth in the LM. Kutloanong has poor service access, a high socio-economically vulnerable population and high environmental pressure which indicates some conflict in preserving the natural environment and accommodating growth pressures such as population growth and economic development. Loraine Gold Mine has poor service access. While Allanridge has the second highest socio-economic vulnerable population and is faced with poor service access and high environmental pressures.

Nala Local Municipality

The major settlements in this municipality are Wesselbron, Balkfontein and Bothaville. Bothaville has the greatest population growth pressure in the municipality along with a high socio-economically vulnerable population and high environmental pressure which indicates some conflict in preserving the natural environment and accommodating growth pressures such as population growth, urbanisation and economic development. Wesselbron is faced with high economic and environmental pressure, high socio-economic vulnerability and low service access. The Balkfontein settlement has low regional connectivity.

2.1.3. Population growth pressure

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

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

Population per municipality	2011	Medium Growth Scenario	
		2030	2050
Masilonyana	59 857	64 308	70 426
Tokologo	28 984	29 352	30 838
Tswelopele	47 624	44 644	42 557

Matjahabeng	406 957	431 230	465 279
Nala	81 198	72 017	65 211
Lejweleputswa DM Total	624 620	641 551	674 311

The District's population is projected to increase by 7.95% between 2011 and 2050, under a medium growth scenario. Most of this growth will take place in the settlements within Matjahabeng LM which is also the most populous municipality in the DM. Figure 4 depicts the growth pressures that the settlements across the district are likely to experience. Settlements within Tswelopele and Nala LMs are expected to have decreasing growth pressure, whereas the main settlements within the Tokologo, Masilonyana and Matjhabeng LMs are expected to have medium growth pressure.

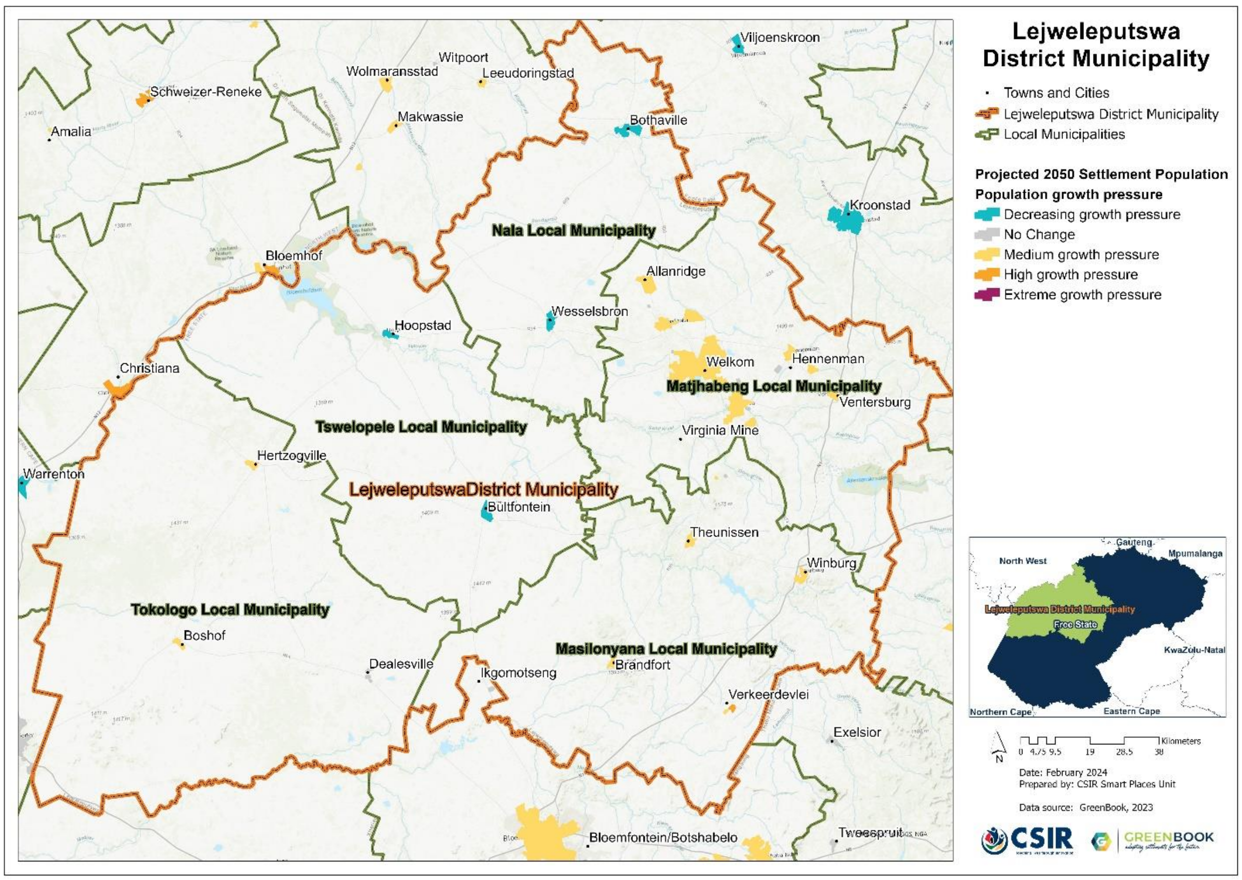

Figure 3: Settlement-level population growth pressure across Lejweleputswa District Municipality

2.2. Climate

An ensemble of very high-resolution climate model simulations of present-day climate and projections of future climate change over South Africa has been performed as part of the GreenBook. The regional climate model used is the Conformal-Cubic Atmospheric Model (CCAM), a variable-resolution Global Climate Model (GCM) developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). CCAM runs coupled to a dynamic land-surface model CABLE (CSIRO Atmosphere Biosphere Land Exchange model). GCM simulations of the Coupled Model Inter-Comparison Project 5 (CMIP5) and the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), obtained for the emission scenarios described by Representative Concentration Pathways 4.5 and 8.5 (RCP 4.5 and RCP 8.5) were first downscaled to 50 km resolution globally. The simulations span the period 1960–2100. RCP 4.5 is a high mitigation scenario (assuming a reduction in CO_2 emissions into the future), whilst RCP 8.5 is a low mitigation scenario (assuming "business as usual" emissions).

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

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

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

For each of the climate variables discussed below:

a) The simulated baseline (also termed "current" climatological) state over South Africa calculated for the period 1961–1990 is shown (note that the median of the 6 downscaled GCMs 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 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.

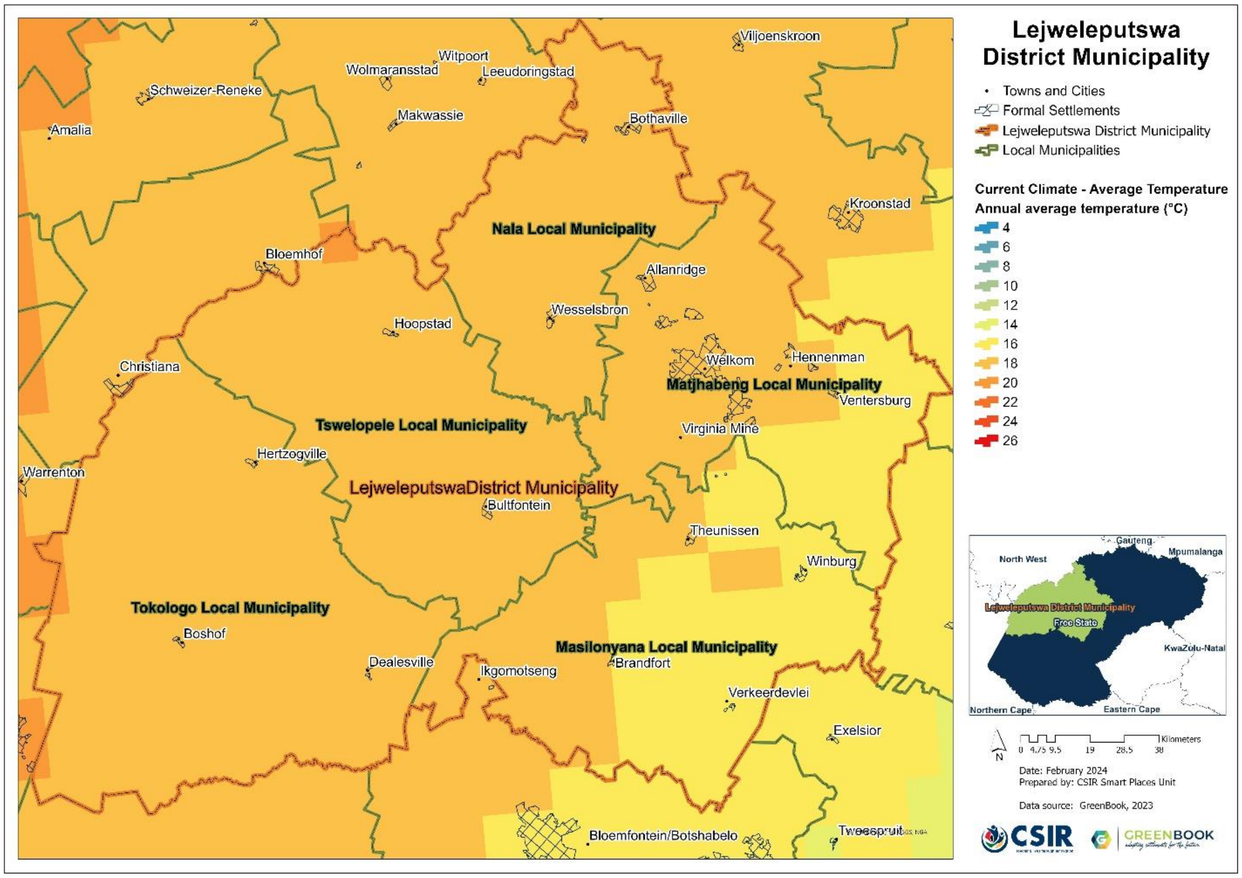

Figure 4: Average annual temperature (°C) for the baseline period 1961-1990 for Lejweleputswa District Municipality

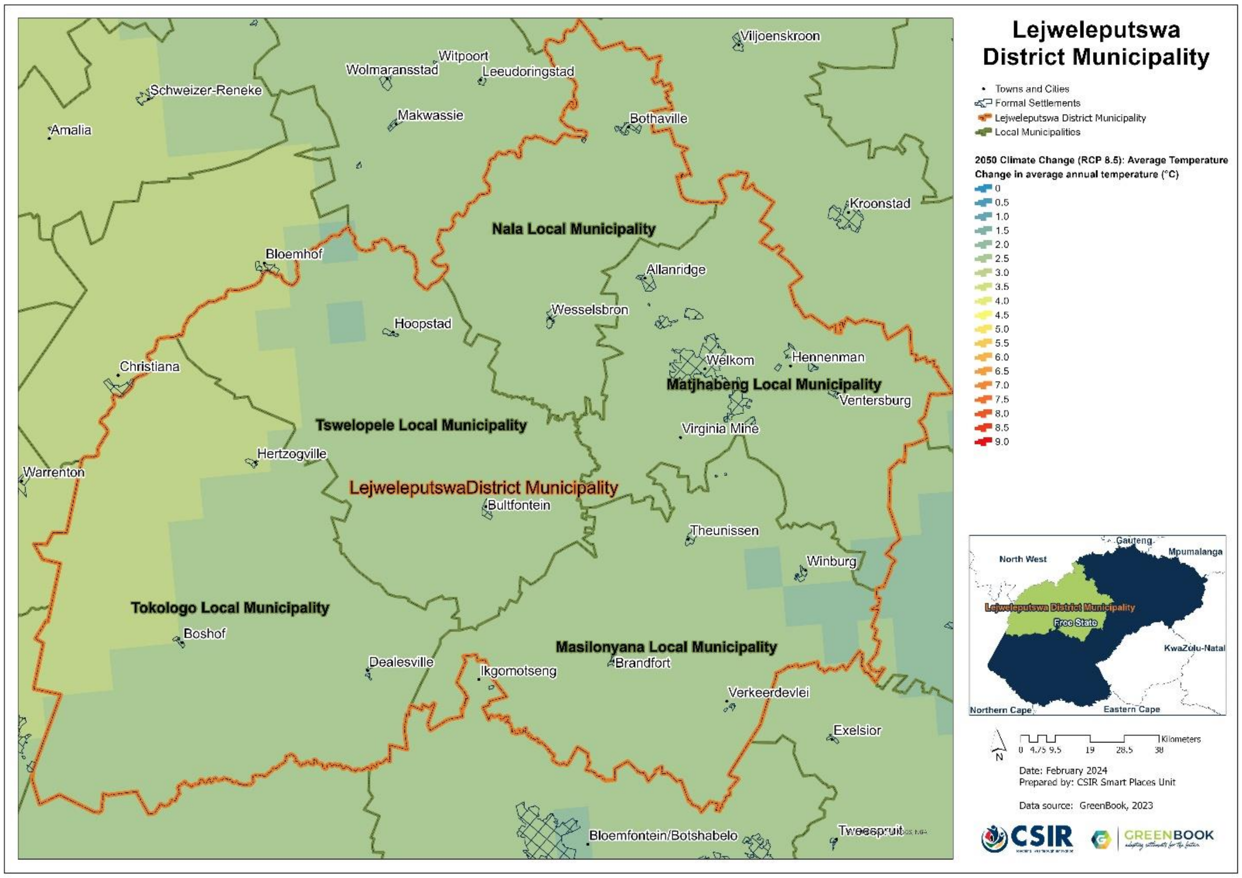

Figure 5: Projected changes in average annual temperature (°C) from the baseline period 1961-1990 to the future period 2021-2050 for Lejweleputswa District Municipality, assuming an RCP 8.5 emissions pathway

The Lejweleputswa DM experiences an average annual temperature of 16.99°C across the district. Future climate projections show average annual temperature increases between 2.35 to 3.47°C across the district. The projected increase in temperature is relatively uniform across the district.

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.

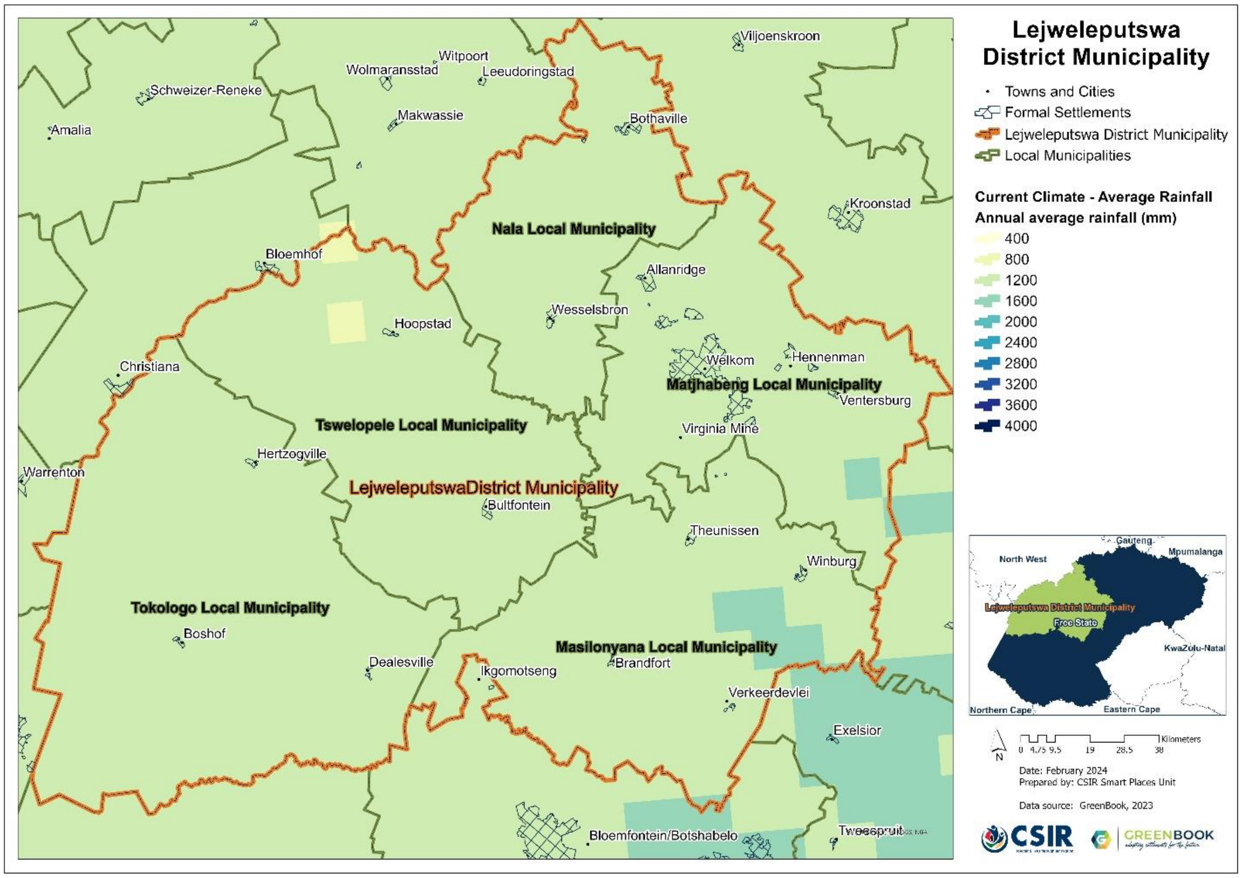

Figure 6: Average annual rainfall (mm) for the baseline period 1961-1990 for Lejweleputswa District Municipality

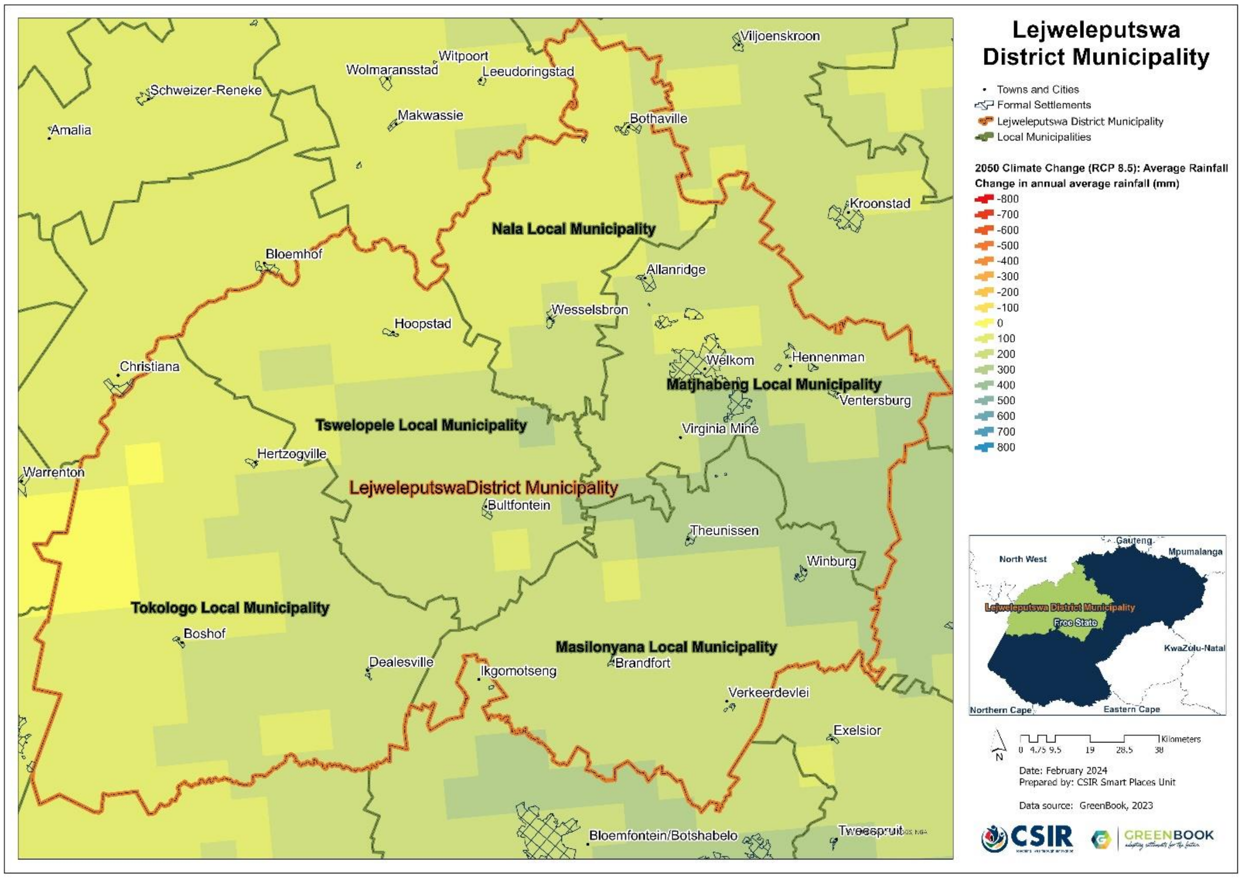

Figure 7: Projected change in average annual rainfall (mm) from the baseline period to the period 2021-2050 for Lejweleputswa District Municipality, assuming an RCP8.5 emission pathway

As displayed in Figure 6 the average annual rainfall under baseline condition for LDM ranges between 1200 and 1600 mm. The projected future change in average annual rainfall (Figure 7) is expected to range between 88.16mm to 253.94mm. The large variation in the range of change in rainfall across the LMs of the district suggests significant uncertainty regarding the magnitude of the change in annual rainfall. The projected changes represent anything from a relatively modest increase (88.16mm) in some areas to a substantial increase (253.94mm) in rainfall for parts of the Masilonyana and Matjhabeng LMs. A change in annual rainfall within this wide range could have significant implications for water availability, agriculture, ecosystems, and various socio-economic activities.

2.3. Climate Hazards

This section showcases information with regards to Lejweleputswa 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).

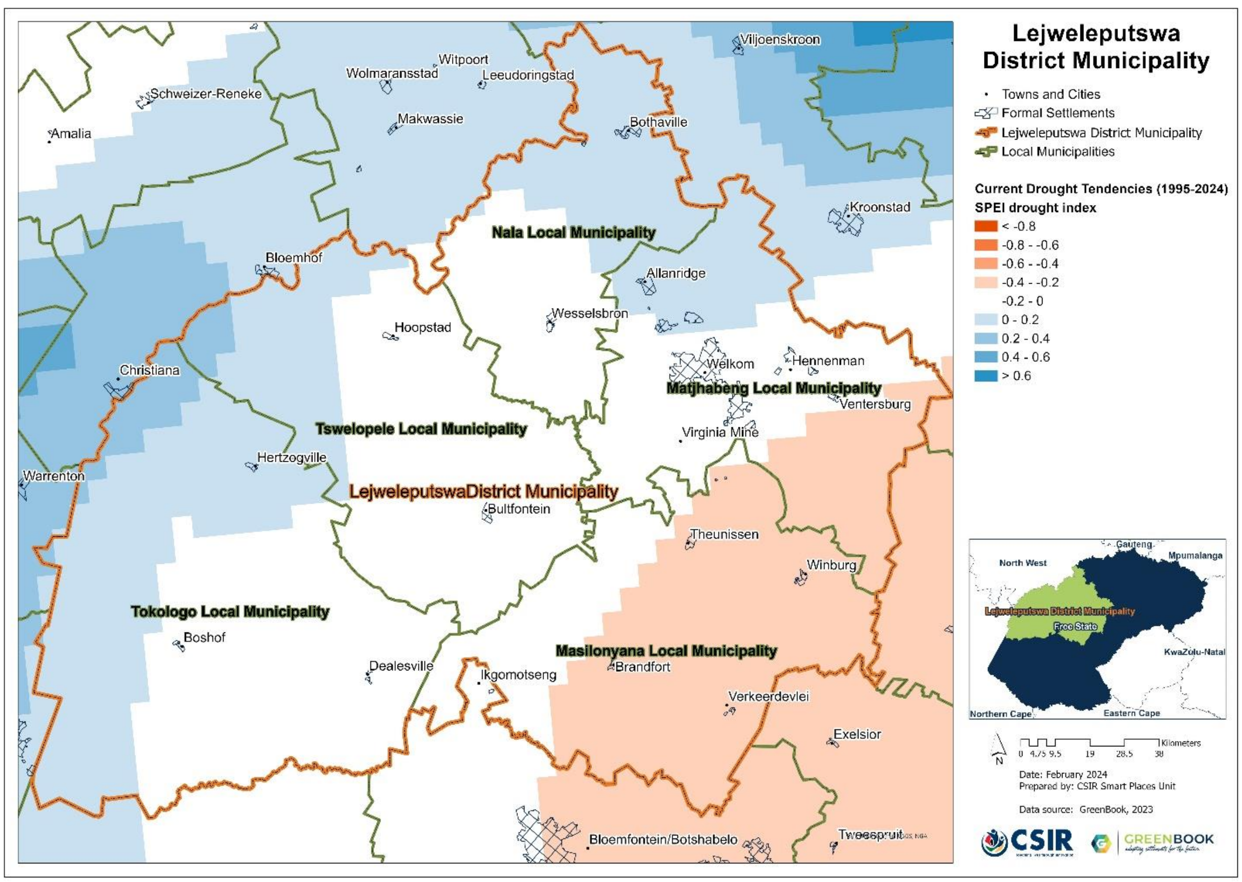

Figure 8: Current drought tendencies from the baseline period (1986-2005) to the current period (1995-2024) across Lejweleputswa District Municipality

Figure 8 depicts the current 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.

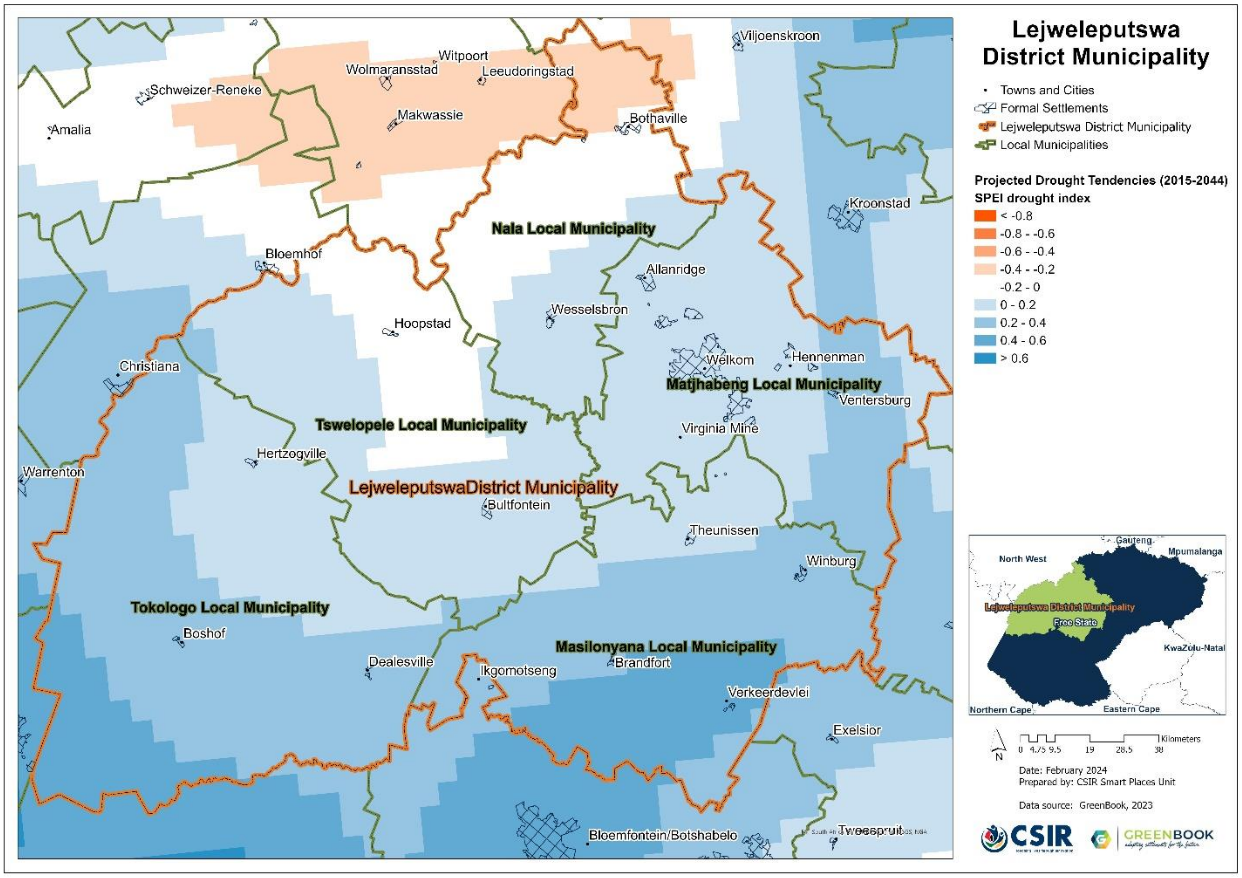

Figure 9: Projected changes in drought tendencies from the baseline period (1986–2005) to the future period 2015-2044 for Lejweleputswa District Municipality

Figure 9 depicts the projected change in drought tendencies (i.e., the number of cases exceeding near-normal per decade) for the period 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 10 depicts the settlements that are at risk of increases in drought tendencies.

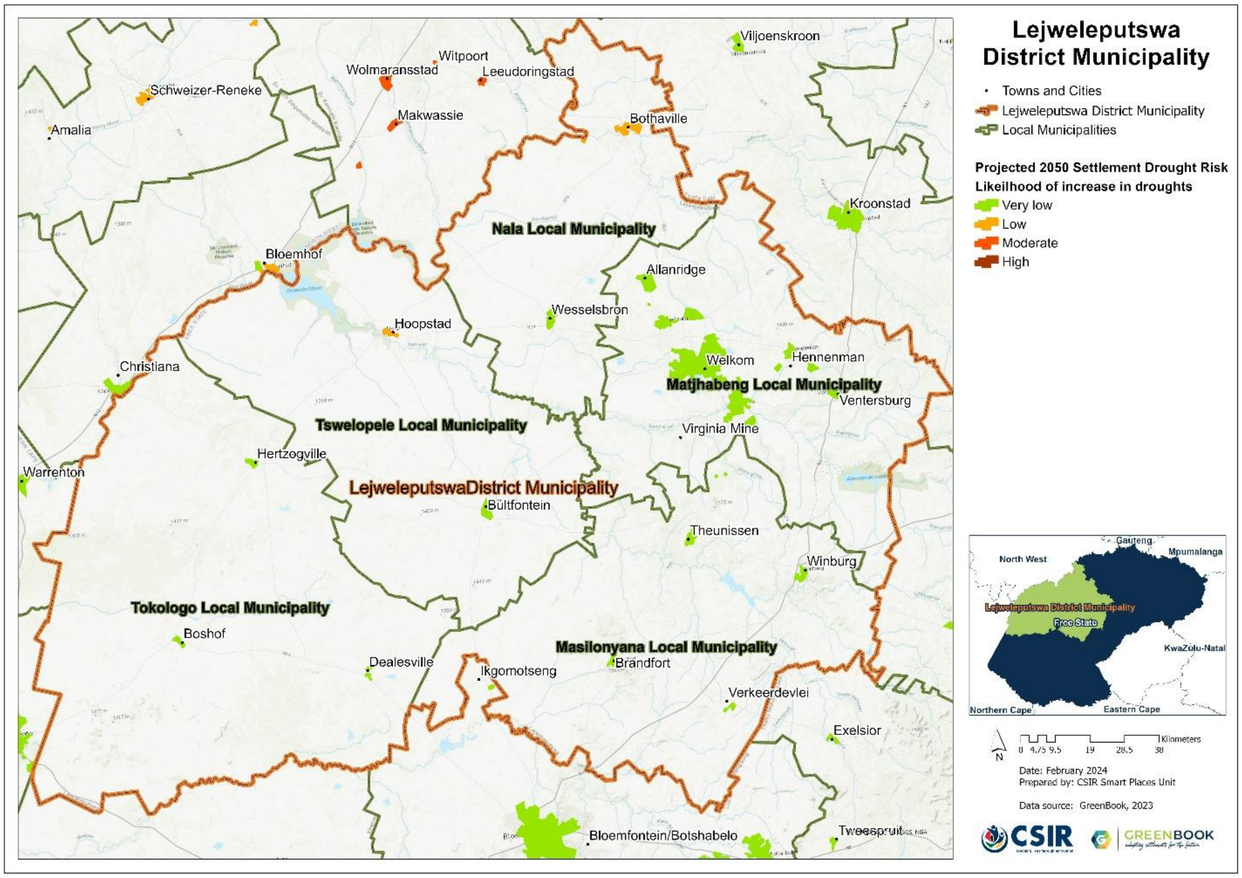

Figure 10: Settlement-level drought risk for Lejweleputswa District Municipality

As displayed in Figure 8 the current drought tendencies ranges between -0.4 to -0.2 for large parts of Masilonyana LM and the lower parts of Matjhabeng LM which suggests a relatively mild level of precipitation deficit. This can be interpreted as slightly less precipitation in these LMs than what was expected for the period 1995-2024. The central part of the district which includes large parts of Tokologo, Tswelopele, Nala and Matjhabeng LMs' current drought tendencies range between -0.2 to 0.2 this is an indication of near normal conditions. Future prediction of drought tendencies (Figure 9) indicates wetter conditions with the SPI ranging between 0.2 to 0.4 for large parts of Tokologo LM, and parts of Masilonyana and Matjhabeng LM which implies that there is a slight excess of precipitation compared to what is typically expected for the period. The lower parts of the Tokologo and Masilonyana LMs have SPI scores ranging between 0.4 to 0.6 indicating a larger increase in precipitation. The central part of the district has SPI scores ranging between 0 to 0.2. This range indicates that the precipitation level is neither significantly above nor significantly below normal. It's essentially in the middle ground, suggesting that conditions are fairly typical for the given time scale. The settlements of the Lejweleputswa DM have a very low likelihood of increase in droughts.

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, 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 (Figure 11), and for the projected changes for period 2021–2050 (Figure 12). The annual heatwave days map under baseline conditions (Figure 13) depicts the number of days (per 8x8 km grid point) where the maximum temperature exceeds the average maximum temperature of the warmest month of the year at that location by 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 14), assuming a "business as usual" (RCP 8.5) emissions pathway is also shown.

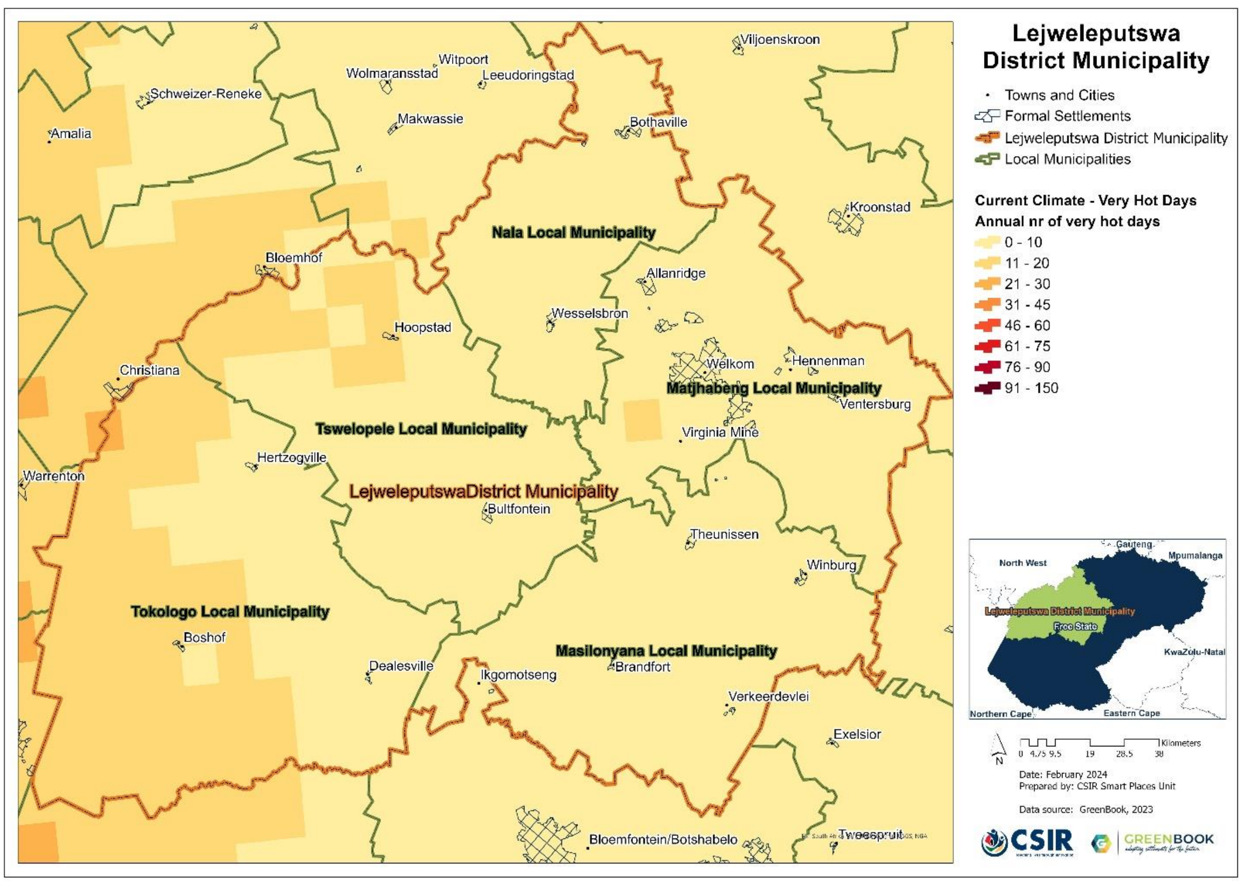

Figure 11: Annual number of very hot days under baseline climatic conditions across Lejweleputswa District Municipality with daily temperature maxima exceeding 35°C

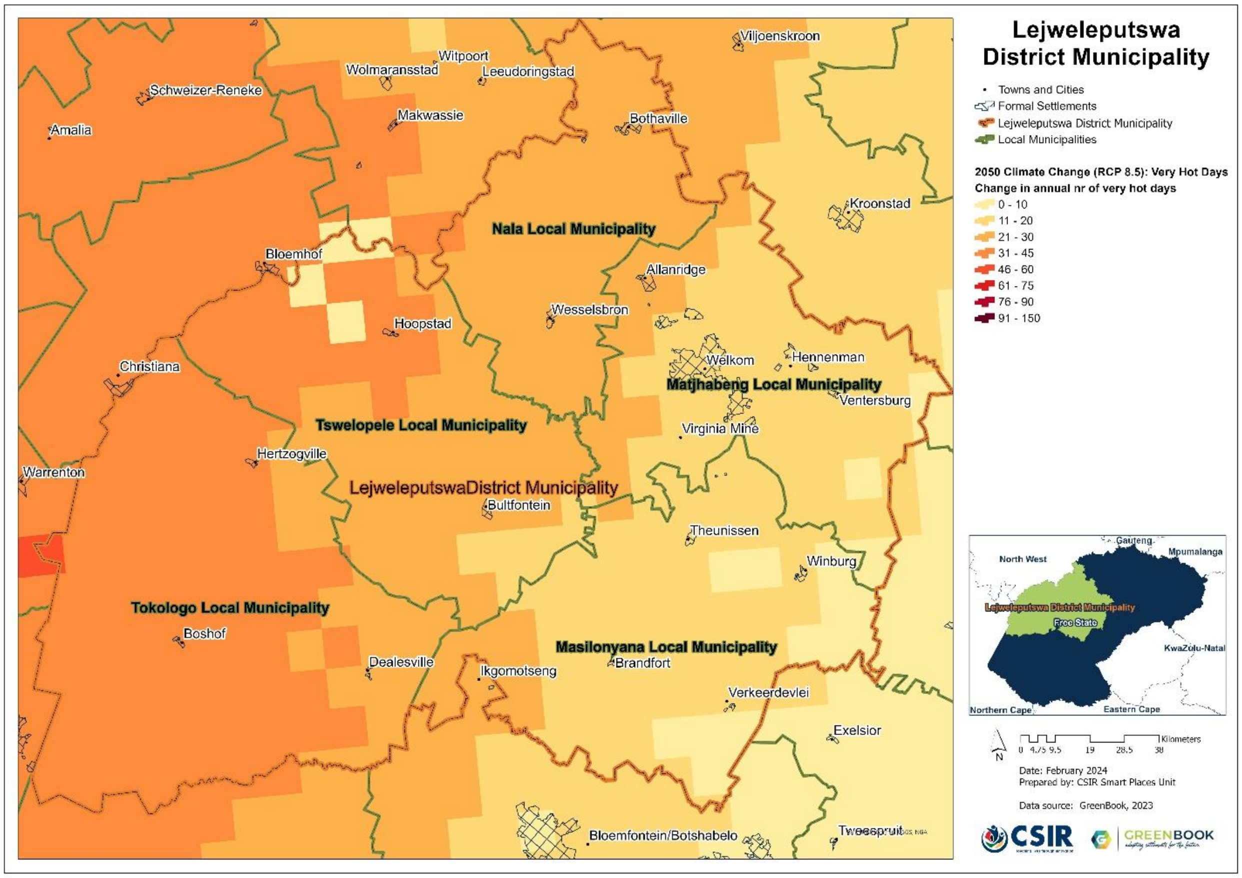

Figure 12: Projected change in annual number of very hot days across Lejweleputswa District Municipality with daily temperature maxima exceeding 35°C , assuming and RCP 8.5 emissions pathway

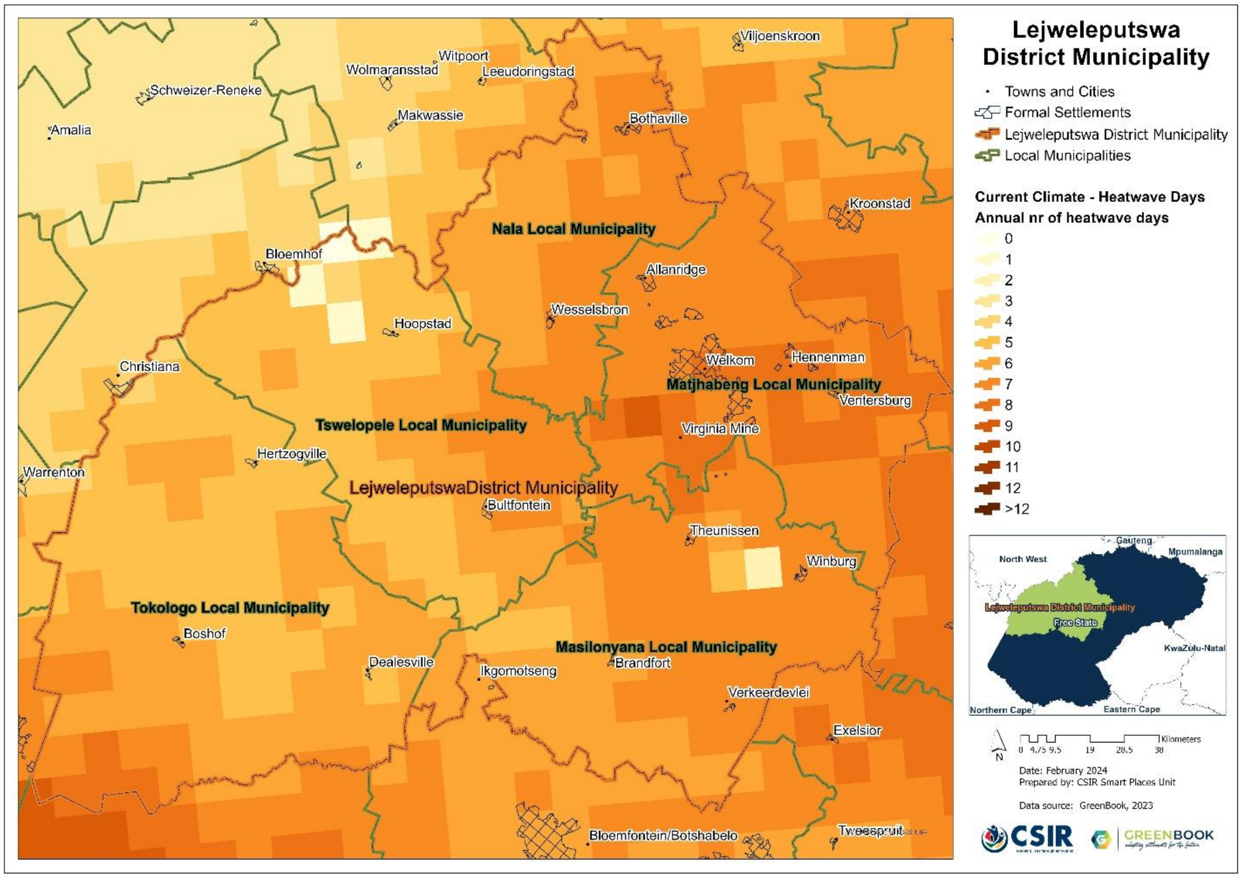

Figure 13: Number of heatwave days under baseline climatic conditions across Lejweleputswa District Municipality

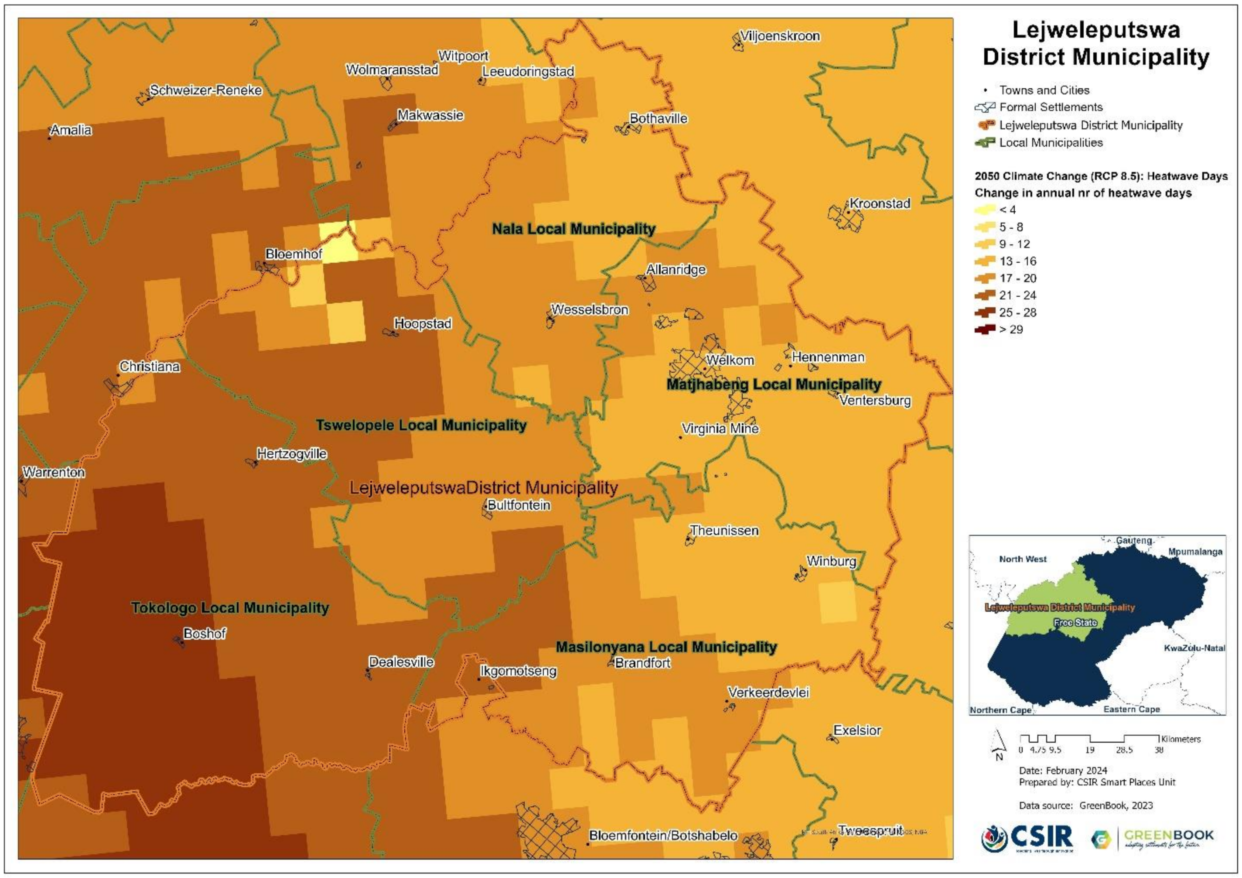

Figure 14: Projected change in annual number of heatwave days across Lejweleputswa District Municipality, assuming an (RCP 8.5) emissions pathway

As displayed in Figure 11 the number of very hot days under current conditions ranges between 0 to 10 days for most of the LM with 11 to 20 days of very hot days experienced in parts of the Tokologo and Tswelopele LMs. The projected change in annual number of very hot days is expected to increase across the Lejweleputswa district (Figure 12). Tokologo LM is expected to have the highest increase in very hot days in the district with the number of very hot days expected to increase to between 24.86 to 46.90 days. In the Masilonyana LM the number of very hot days is expected to range between 1.18 to 32.46 days. In Tswelopele LM number of hot days is expected to range between 0 to 42.86 days across the LM. In Matjhabeng LM the number of hot days is expected to range between 8.94 to 33.76 days per annum. Whilst in Nala LM the number of hot days is expected to increase to between 19.70 to 38.16 days per annum. The current annual number of heatwave days range between 2 to 8 days per annum. Future projections show an increase in heatwave days for the district between 9 to 28 days per annum.

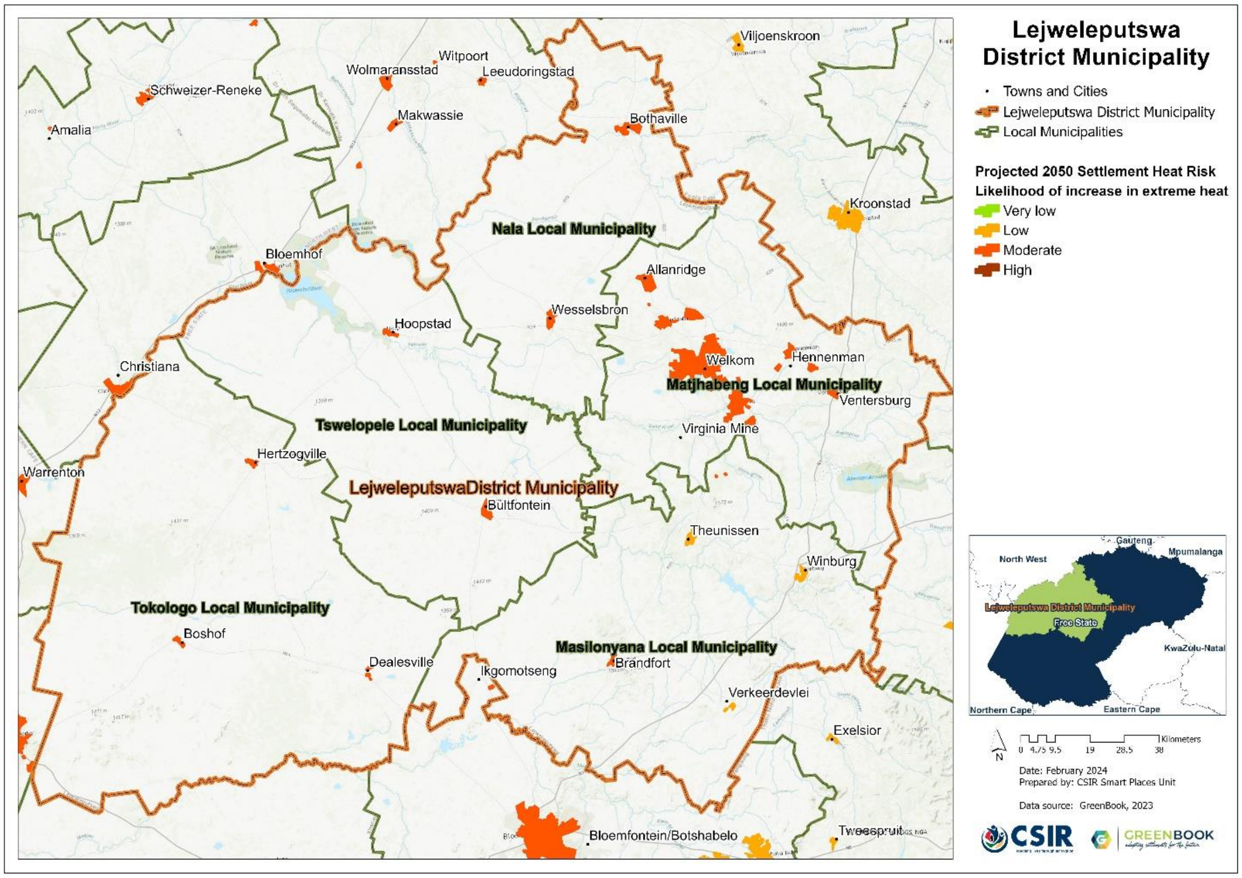

Figure 15: Settlement-level heat risk across Lejweleputswa District Municipality

Figure 15 depicts the settlements that are at risk of increases in heat stress. The majority of settlements in the District are expected to have a moderate increase in extreme heat with low heat risk projected for the settlements of Verkeerdevlei, Winburg and Theunissen and Winburg in the Mailonyana LM.

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 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.

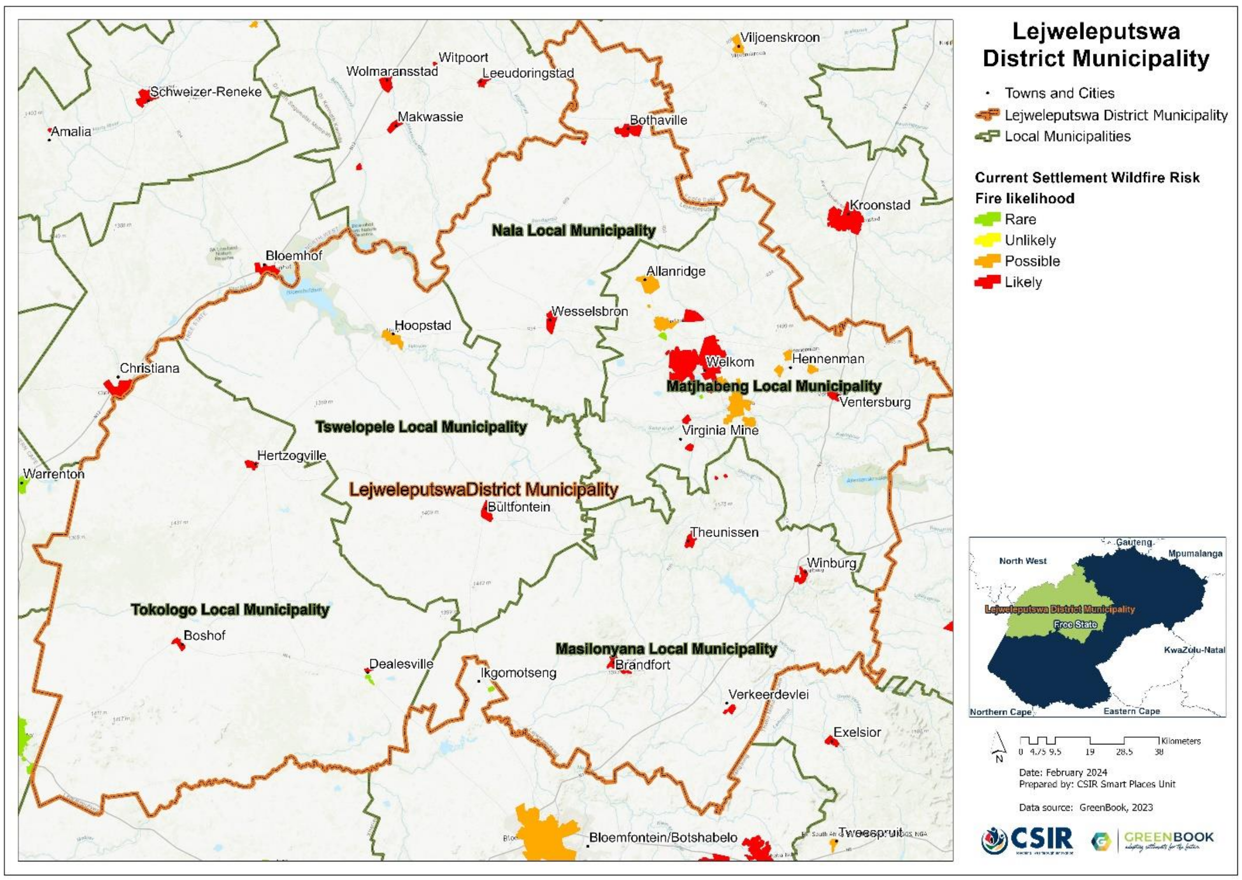

Figure 16 The likelihood of wildfires under current climatic conditions across settlements in Lejweleputswa District Municipality

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 17 depicts the settlements that could be at risk of increases in wildfires by the year 2050.

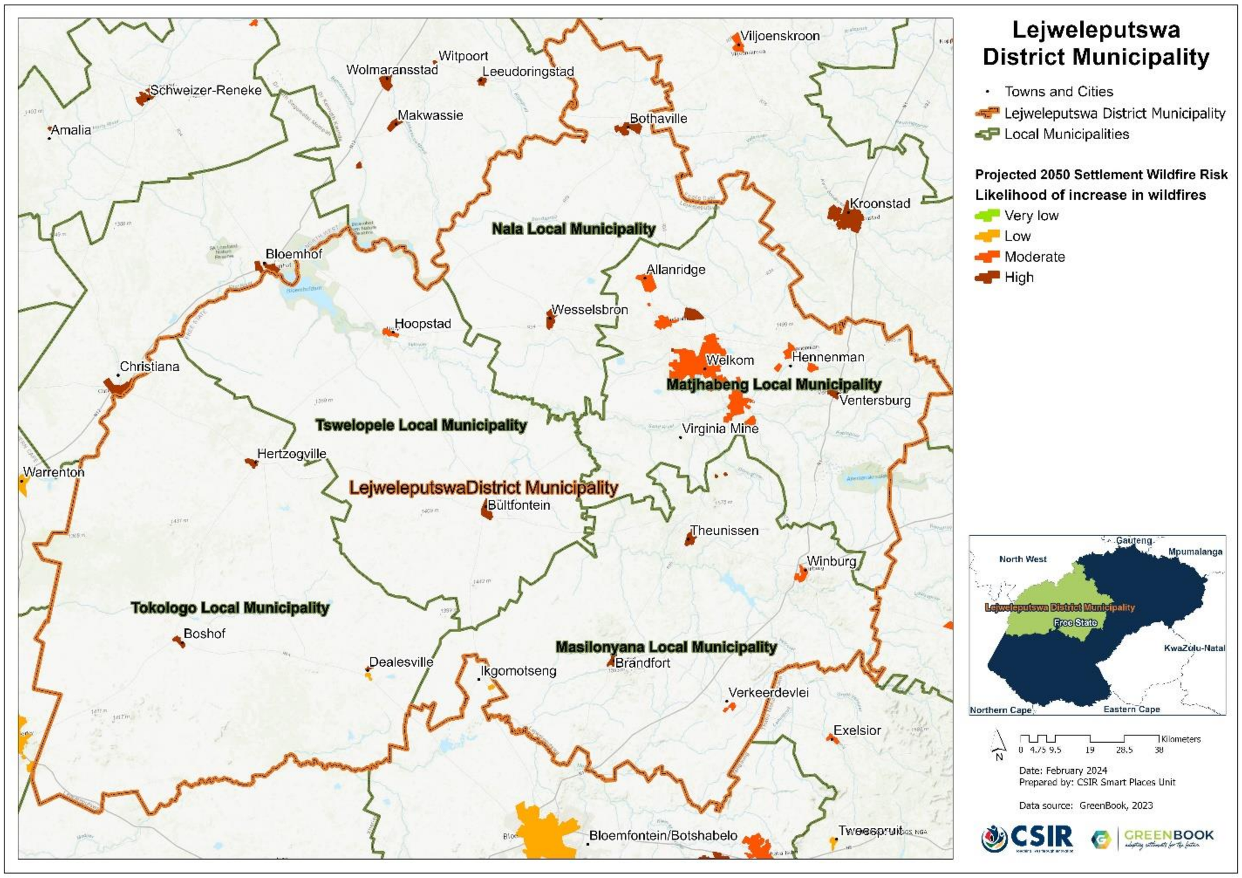

Figure 17: The likelihood of wildfires under projected future climatic conditions across settlements in Lejweleputswa District Municipality

The current settlement wildfire risk is possible to likely for settlements across the district. The projected 2050 settlement wildfire risk is moderate for most settlements in Matjhabeng LM to high wildfire risk for settlements of Boshof, Hertzogville, Bultfontein, Theunissen, Wisselsbron and Brandford

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.

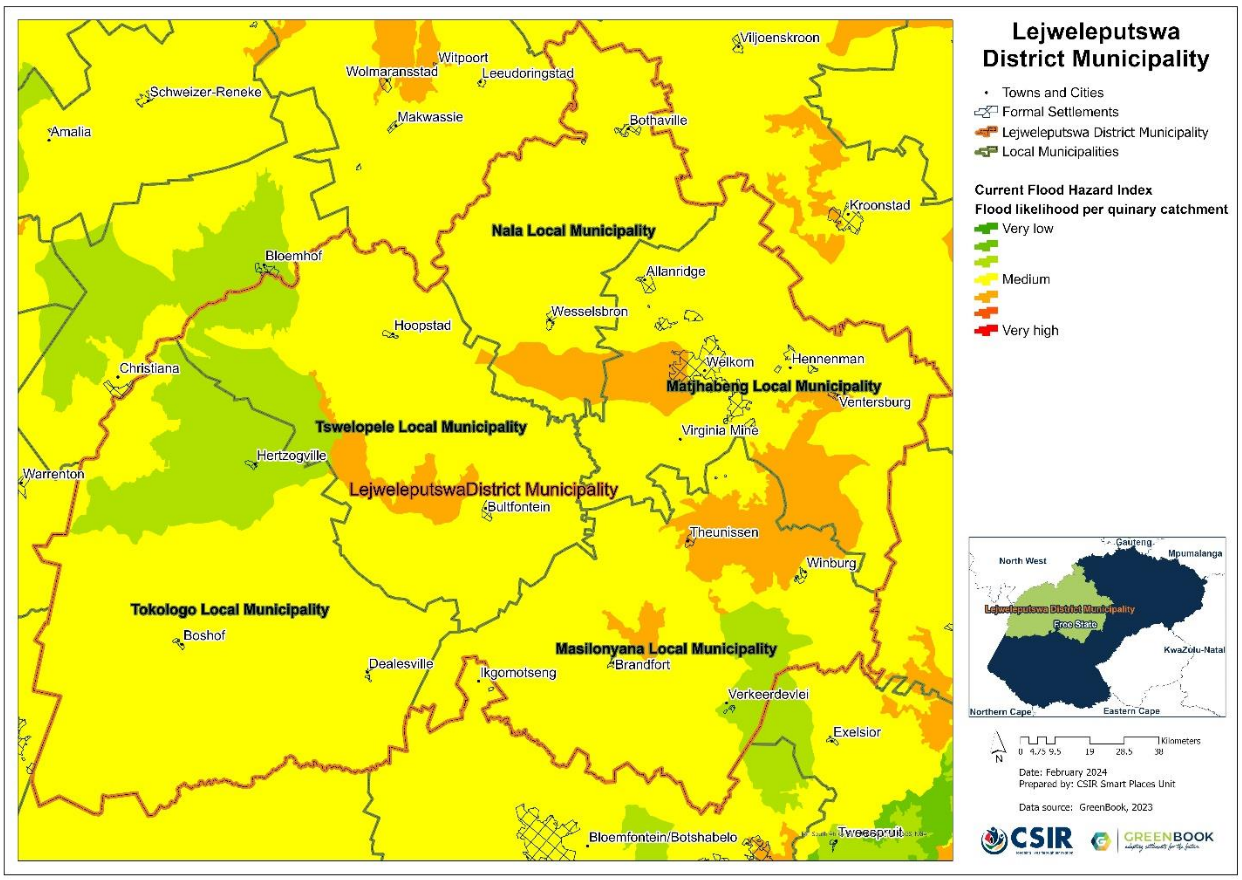

Figure 18: The current flood hazard index across Lejweleputswa District Municipality under current (baseline) climatic conditions

Figure 18 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. Majority of the LMs in the district have a medium flooding hazard, with medium high flood hazard in parts of Tswelopele, Masilonya and

Matjhabeng and Nala LMs. Low flood hazard occurrence is predicted for the upper parts of Tokolog LM and parts of Masilonyana.

Figure 19 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. The predicted change in the number of extreme rainfall days is variable across the district and ranges between a slight decrease in number of extreme rainfall days as well as increases in extreme rainfall days in some parts of the district. This indicates a degree of variability and uncertainty in the future trend of extreme rainfall events. The biggest increase in extreme rainfall days is predicted for parts of Masilonyana and Matjahabeng LMs with increases of up to 4 days, while Tswelopele and Nala LMs are predicted to have extreme rainfall days of up to 2 days. This can lead to more days with heavy precipitation, potentially causing challenges such as increased flooding, waterlogging, and damage to infrastructure. Certain parts of the district are also expected to have a decrease in rainfall days, with highest decrease predicted for parts of Tokologo LM of -1.6 days which suggests a slight decrease in the number of extreme rainfall days.

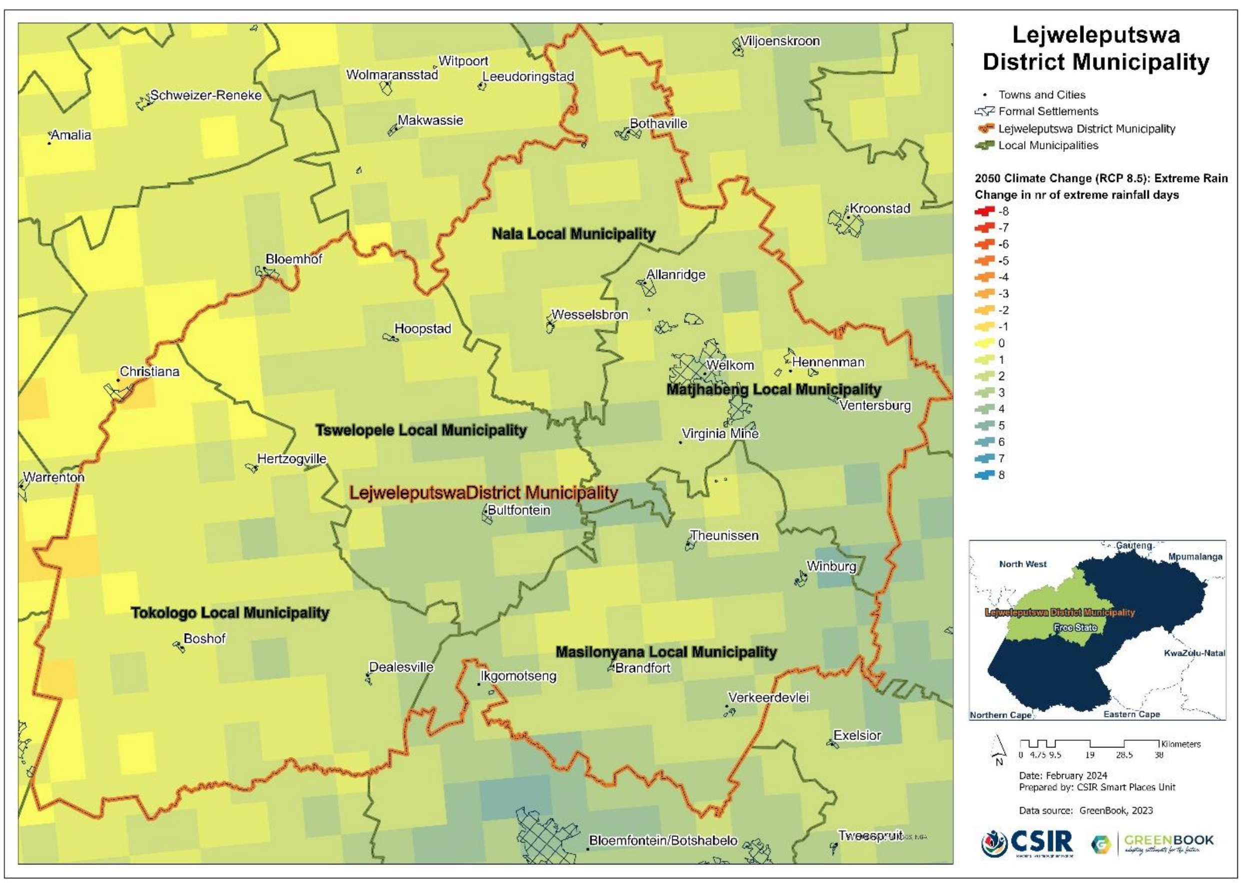

Figure 19: Projected changes into the future in extreme rainfall days across Lejweleputswa District Municipality

Model projections of precipitation manifest uncertain due to several factors, including model sensitivity to spatial resolution at which processes are resolved. At 8x8 km 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 10th, 50th and 90th 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 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. Majority of settlements across the district have very low to low likelihood of increased flooding, with Theunissen, Winberg and Ventersburg having a moderate likelihood of increased flooding.

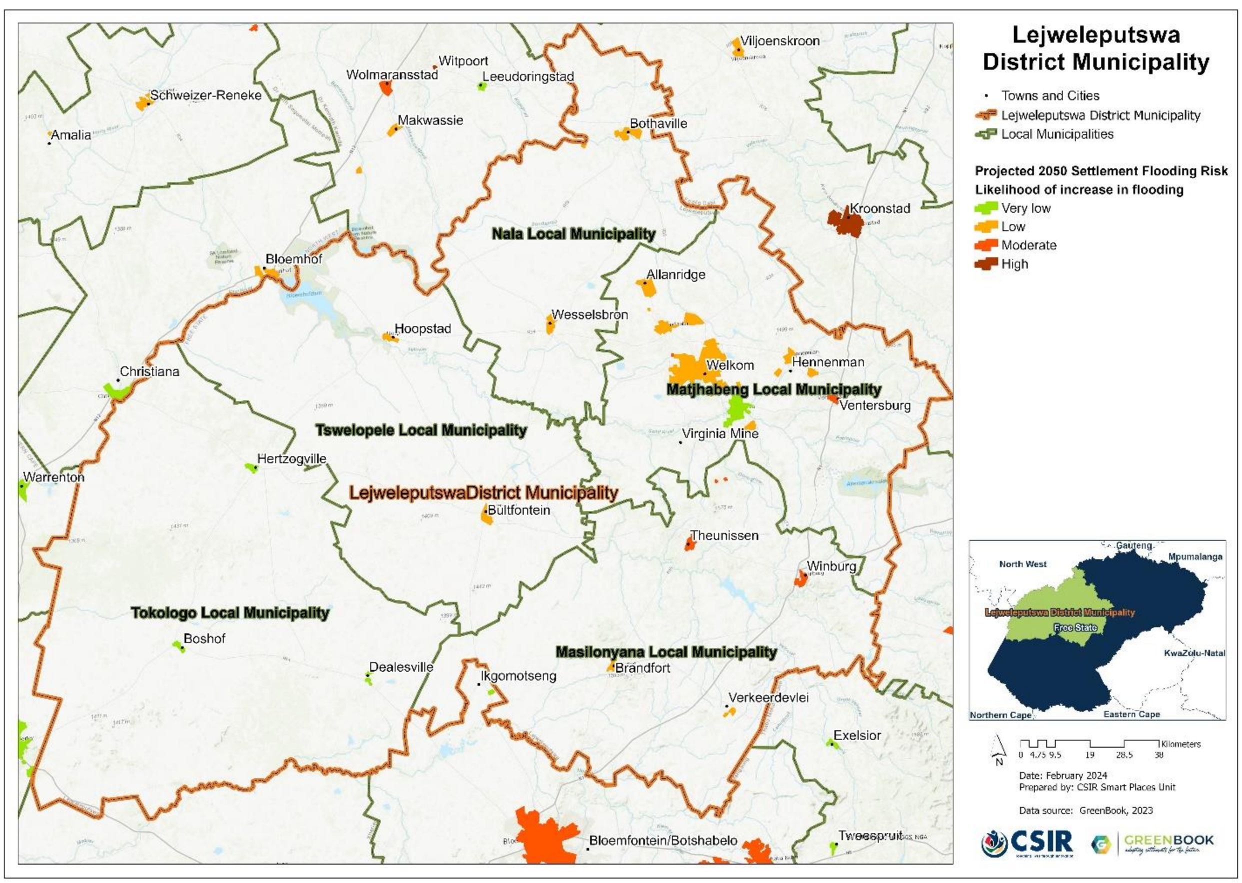

Figure 20: Flood risk into a climate change future at settlement level across Lejweleputswa District Municipality.

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 Lejweleputswa 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.

Figure 21 indicates the catchment(s) related to the district. The quaternary catchments serving the district include the Orange and Vaal Primary Catchments.

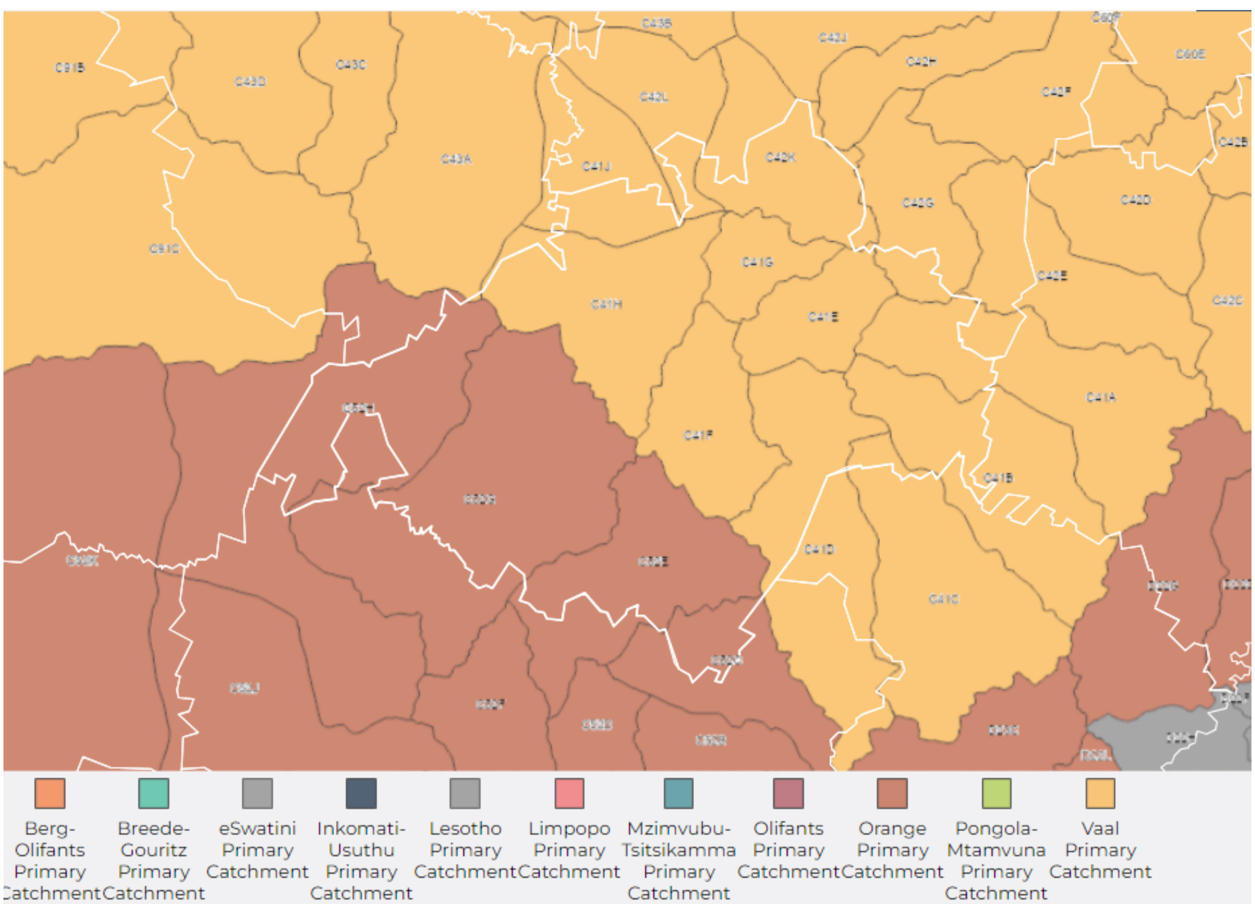

Figure 21: Quaternary catchments found in Lejweleputswa District Municipality

Figure 22 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 Lejweleputswa District, most towns are surface water dependent with Boshof and Hetzogville in Tokologo LM and Verkeerde Vlei in Masilonyana LM relying on groundwater.

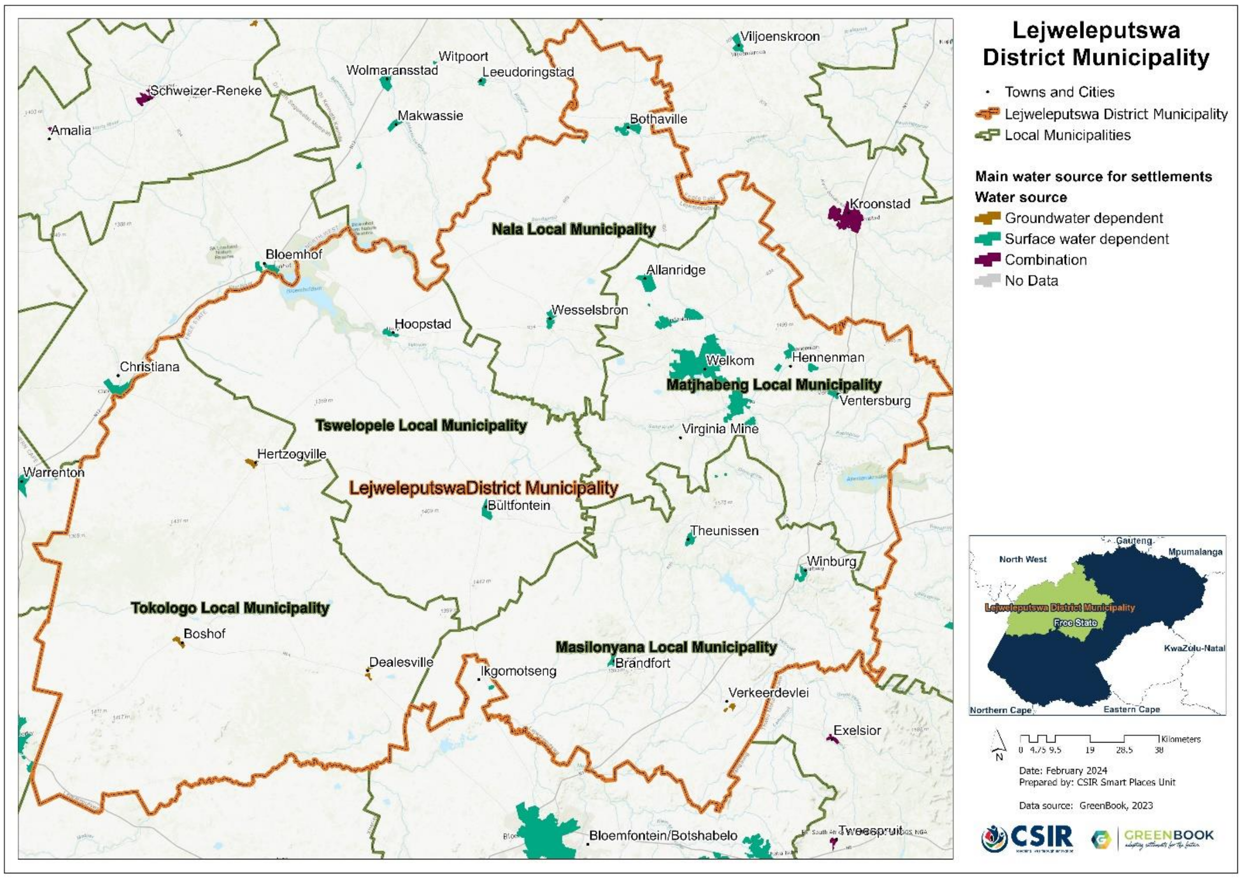

Figure 22: Main water source for settlements in the Lejweleputswa District Municipality

Figure 23 indicates the occurrence and distribution of groundwater resources across the District Municipality, showing distinctive recharge potential zones, while Figure 24 indicates the projected change in groundwater potential. Figure 25 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.

Groundwater recharge potential is moderate in Tokologo and Tswelopele LMs and high in Masilonyana, Matjhabeng and Nala LMs. The projected change in recharge potential shows no change in Tokologo and Tswelopele LMs, with increase in recharge potential for rest of the district.

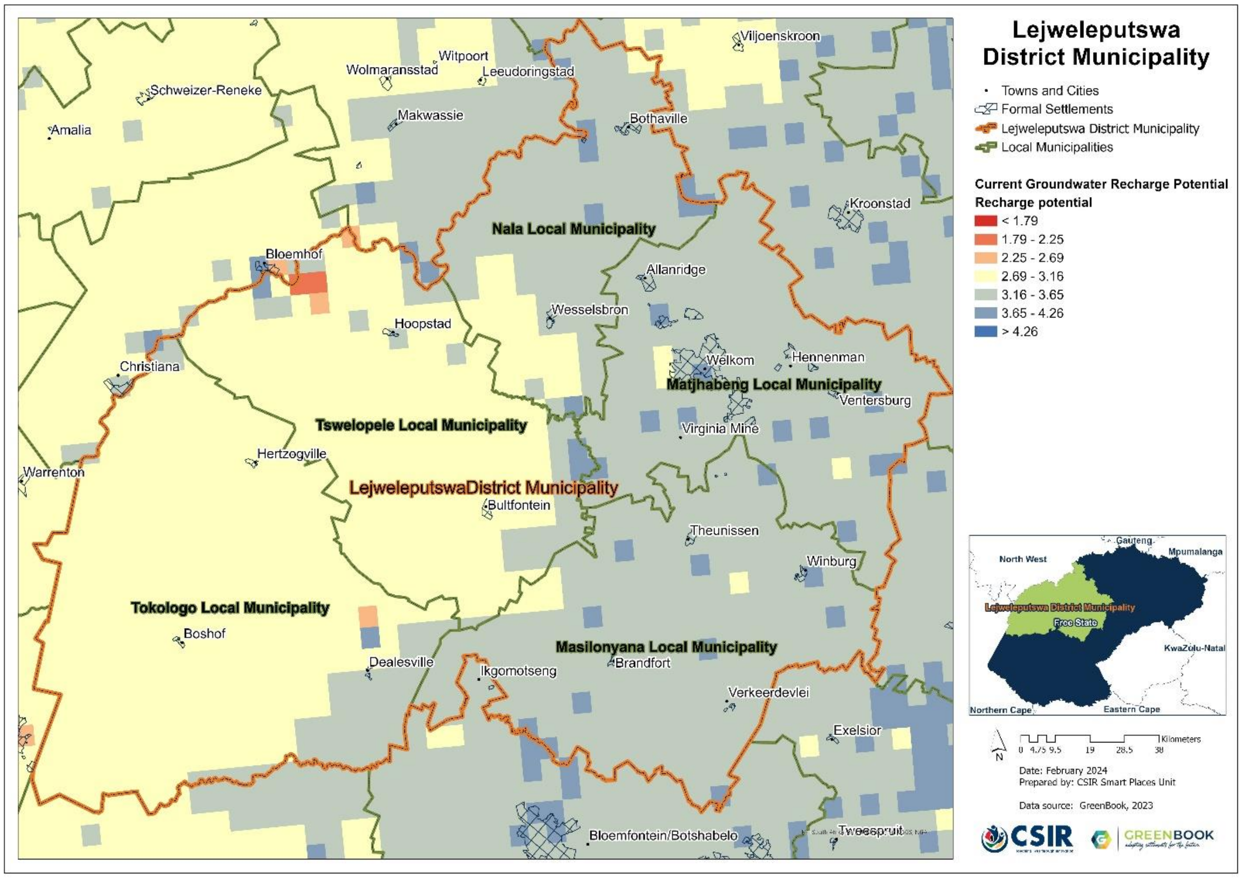

Figure 23: Groundwater recharge potential across Lejweleputswa District Municipality under current (baseline) climatic conditions

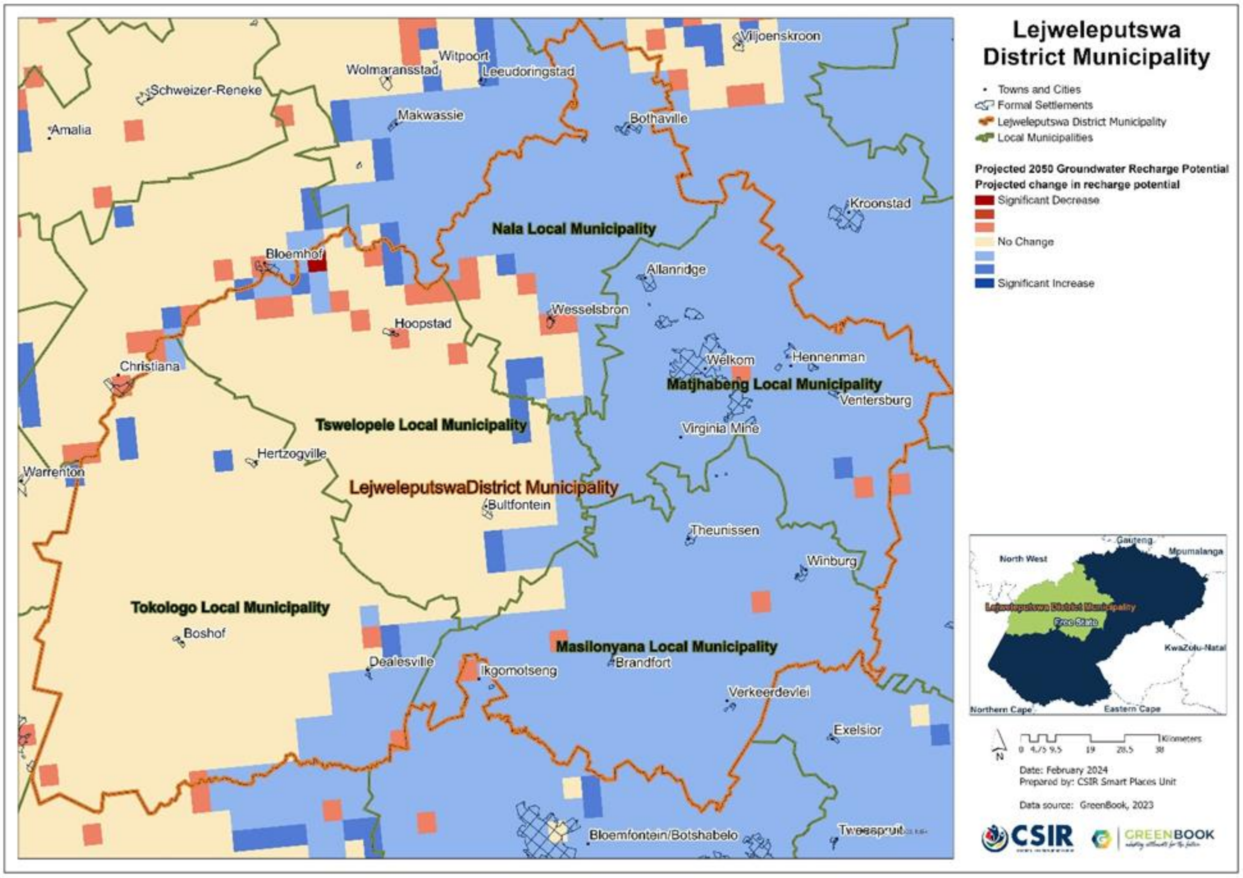

Figure 24: Projected changes in groundwater recharge potential from baseline climatic conditions to the future across Lejweleputswa District Municipality

Most groundwater dependent towns in the district have a low risk of groundwater depletion, with moderate depletion risk predicted for Verkeerdevlei in Masilonyana LM (See Figure 25).

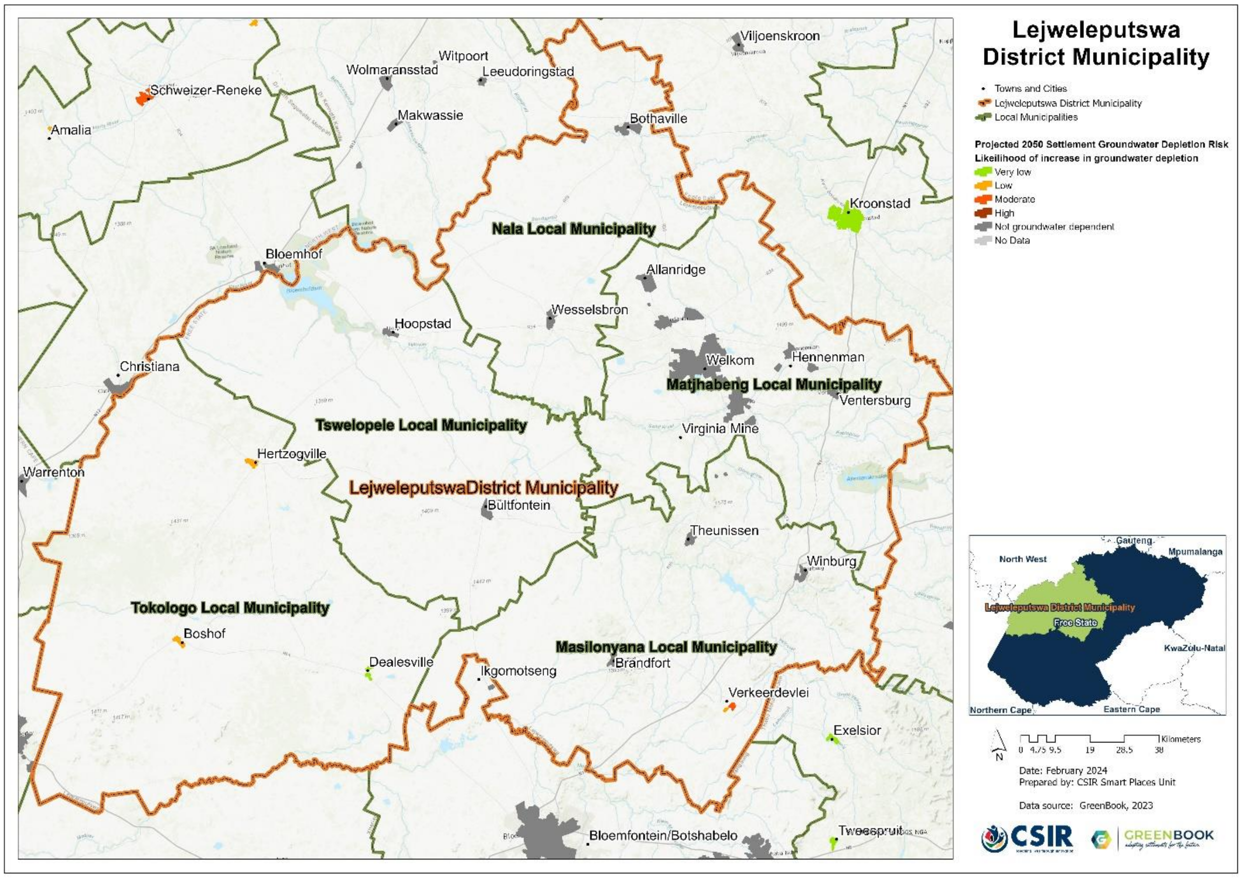

Figure 25: Groundwater depletion risk at settlement level across Lejweleputswa District Municipality

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

Local Municipality	Water Demand per Capita (l/p/d)	Water Supply per Capita (l/p/d)	Current Water Supply Vulnerability
Masilonyana	257.19	258.06	1
Tokologo	161.64	113.43	1.43
Tswelopele	234.72	152.45	1.54
Matjhabeng	207.07	144.54	1.43
Nala	113.54	113.13	1

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.

Masilonyana

Masilonyana LM water supply currently meets demand. Water supply vulnerability is however projected to decrease into the future and can be attributed to a projected increase in rainfall, an increase in regional urban water supply and a decrease in expected population growth.

Tokologo

Tokologo LM water demand currently exceeds supply. Although water supply vulnerability is projected to decrease into the future, water demand of the LM will still not be able to be met. The decrease in water supply vulnerability can be attributed to an increase in rainfall and increase in regional urban water supply and a decrease in expected population growth.

Tswelopele

Tswelopele LM water demand far exceeds supply, giving it a high-water supply vulnerability score. In future water supply vulnerability is expected to decrease, but water supply may still not be able to meet demand. The decrease in water supply vulnerability can be attributed to an increase in rainfall and increase in regional urban water supply and a decrease in expected population growth.

Matjhabeng

Matjahabeng LM current water demand far exceeds supply giving it a high water supply vulnerability. In future when considering the impacts of local runoff, water supply vulnerability is likely to decrease. For future projections based on regional and bulk water supply, the water supply vulnerability of the LM is likely to decrease but will still not be able to meet demand.

Nala

Nala LM current water demand meets supply. In future water supply vulnerability is expected to decrease, this can be attributed to an increase in both precipitation, and regional urban water supply and a projected decrease in population growth.

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.

The agriculture sector contributes 7.7% to the GVA of the District (CoGTA, 2020). The sector was flatter and weaker during the times of drought e.g. period between 2012 and 2015 but picked up in 2016/2017 after the good rains. The Free State is considered the bread-basket of South Africa supplying a significant portion of the agricultural produce. Although the District is diverse in farming activities, its main agricultural produce is maize and sunflower.

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.

Masilonyana

In the Masilonyana LM, the AFF sector contributes 6.76% to the local GVA, which is a contribution of 0.25% to the national GVA for the AFF sector. Of the total employment, 21.14 % is within the

AFF sector. The main agricultural commodities are beef cattle and maize for grain. Climate projections show generally hotter and wetter conditions with more extreme rainfall events. The warmer temperatures and increased water availability can lead to hot and moist conditions which can increase the spread of disease and parasites. Heat stress can lead to reduced growth and reproduction performance in cattle. For maize there might be a potential increase in maize yield in the near future, but heat stress can negatively impact on production towards 2050.

Tokololgo

In the Tokologo LM, the AFF sector contributes 22.4% to the local GVA, which is a contribution of 0.32 % to the national GVA for the AFF sector. Of the total employment, 39.1 % is within the AFF sector. The main agricultural commodities are maize for grain, beef cattle and sheep. Climate projections show generally hotter and wetter conditions with more extreme rainfall events. For maize there might be a potential increase in maize yield in the near future, but heat stress can negatively impact on production towards 2050. The warmer temperatures and increased water availability can lead to hot and moist conditions which can increase the spread of disease and parasites. Heat stress can lead to reduced growth and reproduction performance in cattle. Warmer temperatures and increased rainfall will lead to increased availability of forage and water resources. Warmer winters could lower cold weather associated livestock mortality but are also conducive to the survival of pests and parasites that threaten livestock such as sheep.

Tswelopele

In the Tswelopele LM, the AFF sector contributes 16.18% to the local GVA, which is a contribution of 0.33% to the national GVA for the AFF sector. Of the total employment, 36.01% is within the AFF sector. The main agricultural commodities are maize for grain, beef cattle and chickens. Climate projections show generally hotter and wetter conditions with more extreme rainfall events. For maize there might be a potential increase in maize yield in the near future, but heat stress can negatively impact on production towards 2050. The warmer temperatures and increased water availability can lead to hot and moist conditions which can increase the spread of disease and parasites. Heat stress can lead to reduced growth and reproduction performance in cattle. For broilers, higher temperatures could increase production costs (and increased investment will be required in ventilation and cooling) to maintain optimal seasonal temperatures and reduce the risk of heat stress. Heat stress will reduce body weight gain, reproduction efficiency and egg quality.

Matjhabeng

In the Matjhabeng LM, the AFF sector contributes 1.12% to the local GVA, which is a contribution of 0.51% to the national GVA for the AFF sector. Of the total employment, 4.28% is within the AFF sector. The main agricultural activities are centred around maize for grain, beef cattle and milk and cream. Climate projections show generally hotter and wetter conditions with more extreme rainfall events. For maize there might be a potential increase in maize yield in the near future, but heat stress can negatively impact on production towards 2050. The warmer temperatures and increased water availability can lead to hot and moist conditions which can increase the spread of disease and parasites. Heat stress can lead to reduced growth and reproduction performance in cattle. Hot and moist conditions caused increased spread of disease and parasites. Potential increase in heat stress could negatively affect conception rates, milk yield and milk quality.

Nala

In the Nala LM, the AFF sector contributes 11.82% to the local GVA, which is a contribution of 0.47% to the national GVA for the AFF sector. Of the total employment, 34.46% is within the AFF sector. The main agricultural activities are maize for grain, milk and cream and chickens. For maize there might be a potential increase in maize yield in the near future, but heat stress can negatively impact on production towards 2050. Hot and moist conditions caused increased spread of disease and parasites. Potential increase in heat stress could negatively affect conception rates, milk yield and milk quality. For broilers, higher temperatures could increase production costs (and increased investment will be required in ventilation and cooling) to maintain optimal seasonal temperatures and reduce the risk of heat stress. Heat stress will reduce body weight gain, reproduction efficiency and egg quality.

3. Recommendations

The greatest climate risk faced across the Lejweleputswa District are increases in temperature between 2.35 to 3.47°C, with the risk of heat extremes ranging between 24.86 to 46.90 days in some parts of the LM. The projected future change in average annual rainfall is expected to range between 88.16mm to 253.94mm. A change in annual rainfall within this wide range could have significant implications for water availability, agriculture, ecosystems, and various socio-economic activities. Increase in extreme rainfall days is predicted for parts of the district with increases of up to 4 extreme rainfall days. The increase in days with heavy precipitation can potentially cause challenges such as increased flooding, waterlogging, and damage to infrastructure. Wildfire risk is moderate to high for most of the settlements in the district. Water supply vulnerability is high for most LMs in the district, projections show even with projected increases in rainfall and decrease in population growth water supply may not meet future demand.

1. To ensure water security for human consumption and irrigation under a changing climate: Ensuring water security for human consumption and irrigation under a changing climate requires a comprehensive approach that combines sustainable water management practices, infrastructure improvements, and community engagement. The district will need to improve water infrastructure by upgrading and maintaining existing water infrastructure, including dams, pipelines, and distribution systems. The use of advanced technologies such as smart meters and leak detection systems to reduce water loss and improve efficiency should be investigated. The district should encourage the adoption of water-saving technologies and practices, such as low-flow fixtures and drip irrigations systems. Implement awareness campaigns and educational programs to teach the public about water conservation methods and the importance of using water

efficiently. Encourage water recycling and reuse in municipal and industrial settings. Use treated wastewater for irrigation and other non-potable purposes to reduce the demand of fresh water.

2. To increase the adaptive capacity of human settlements to climate change and extreme events: Responding to an increase in extreme rainfall requires actions to manage water effectively and mitigate the potential risks of flooding and waterlogging. The district should invest in and upgrade stormwater infrastructure such as drainage systems, culverts, and channels to handle increased rainfall efficiently. Implementing early warning systems by developing and deploying early warning systems for heavy rainfall and potential flooding events. Providing timely information to residents, businesses, and emergency services to prepare and respond effectively. Ensuring water treatment plants are equipped to handle large inflows of water during heavy rainfall events. Develop and practice emergency response plans for extreme rainfall events, including evacuation routes and shelter locations. Use hydrological models to predict flood risk and identify vulnerable areas. Encourage soil conservation practices, such as cover cropping and reduced tillage, to improve soil structure and water absorption.

3. To maintain and increase resilience and reduce the vulnerability of ecosystems and people to the adverse effects of climate change: To increasing resilience and reduce vulnerability to the adverse effects of extreme hot days and heat waves and wild fires will requires an approach that addresses both human health and ecosystem protection. The district should develop heat action plans that include early warning systems, emergency cooling centers, and guidance on how to stay safe during heat waves. Educate the public on heat-related health risks and preventive measures such as staying hydrated and avoiding outdoor activities during peak heat. Promote the use of energy-efficient building designs and materials that provide natural cooling, such as reflective roofing and insulation. Increase tree cover and green spaces in cities to provide shade and lower temperatures. Identify and provide support to vulnerable populations, such as the elderly, children, and low-income communities, who are at higher risk of heat-related illnesses. Provide access to cooling centers and other resources during extreme heat events. Encourage efficient water use and conservation during heat waves to ensure a reliable water supply for human consumption and irrigation. Educate communities about the risks of extreme heat and provide information on how to stay safe. Involve community members in planning and implementing heat resilience strategies. Protect and restore natural habitats such as wetlands and forests, which can provide cooling effects and help regulate temperature. Encourage the use of native plant species in landscaping and reforestation efforts to increase ecosystem resilience. Engage local communities in wildfire risk planning and adaptation efforts to tailor strategies to specific needs. Provide training on emergency response and fire preparedness and safety measures for community members, including how to secure property and navigate fires safely. Promote awareness campaigns on fire risks and preparedness actions. Develop

and deploy early warning systems to alert communities to imminent wildfires risks. Establish evacuation plans and designate safe shelters for populations affected by flood or wildfires.

4. To increase resilience of the agricultural sector to more extreme events such as heatwaves and storms as well as indirect risks such as pests and diseases: To increase resilience of the agricultural sector a combination of proactive planning, adaptation strategies and technological innovation is required. The district can encourage crop and livestock diversification to reduce dependence on a single variety or breed, which can be more susceptible to extreme events and diseases. Promote the use of polycultures and intercropping, which can enhance resilience and improve soil health. Promote the use of drought-tolerant, heat-resistant, and pest-resistant crop varieties. Incorporate trees and shrubs into agricultural landscapes to provide shade, reduce heat stress, and protect soil and water resources. Use silvopasture systems that integrate trees with livestock grazing to improve ecosystem services and reduce vulnerability. Provide farmers with access to real-time weather data and forecasts to help them plan agricultural activities and respond to extreme events. Promote integrated pest management to control pests and disease while minimising the use of chemical pesticides. Encourage collaboration among farmers, researchers and policymakers to share best practices and innovative solutions.

5. To ensure that space is set aside for recreation, ecological support and stormwater management, and to guide decision making across all sectors: The district can use zoning regulations and urban planning policies to designate areas for green spaces, parks, wetlands, and stormwater infrastructure. Protect existing natural areas such as forests, wetlands, and riparian zones, which provide habitat for wildlife and help manage stormwater. Restore degraded ecosystems to improve their capacity for stormwater management and ecological support. Design spaces that serve multiple purposes, such as parks with walking trails, native plant gardens, and stormwater management features. Encourage the creation of community gardens and urban farms that support both recreation and ecological functions. Include climate adaptation and resilience measures in planning documents to address future challenges related to extreme weather events and changing climate conditions. Prioritize nature-based solutions for stormwater management and ecological support. Explore funding opportunities such as grants, public-private partnerships, and impact investing to support the creation and maintenance of recreational and ecological spaces.

These goals should be pursued with the understanding that the 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 Lejweleputswa DM. 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.

4. Bibliography

Behsudi, A, 2021. What Is Mitigation vs Adaptation? IMF Finance Dev. Mag. 46–47.

Chen, D., M. Rojas, B.H. Samset, K. Cobb, A. Diongue Niang, P. Edwards, S. Emori, S.H. Faria, E. Hawkins, P. Hope, P. Huybrechts, M. Meinshausen, S.K. Mustafa, G.-K. Plattner, and A.-M. Tréguier, 2021: Framing, Context, and Methods. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.

Cole M.J., Bailey R.M., Cullis J.D.S., & New M.G. 2017. Spatial inequality in water access and water use in South Africa. Water Policy, 20 (1): 37-52.

Council for Scientific and Industrial Research (CSIR). 2019. GreenBook: Adapting South African settlements to climate change. Available at: www.greenbook.co.za

Council for Scientific and Industrial Research (CSIR). 2019. GreenBook Municipal Risk Profile. Available from: https://riskprofiles.greenbook.co.za/

Department of Cooperative Governance and Traditional Affairs (CoGTA). 2020. Lejweleputswa District Municipality, Municipal Profiles: District Development Model. Available from: https://www.cogta.gov.za/ddm/index.php/documents/

Department of Environmental Affairs (DEA). 2018. Lejweleputswa District Municipality Environmental Profile. Available from: https://egis.environment.gov.za/municipalenvprofiles

IPCC, 2014: Climate Change 2014: *Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

IPCC, 2021: Annex VII: Glossary [Matthews, J. B. R., J. S. Fuglestvedt, V. Masson-Delmotte, V. Möller, C., Méndez, R. van Diemen, A. Reisinger, S. Semenov (ed.)]. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E.

Lejweleputswa District Municipality (LDM). 2016. Climate Change Vulnerability Assessment and Response Plan, Developed through the Local Government Climate Change Support Programme. Available from: https://letsrespondtoolkit.org/

Lejweleputswa District Municipality (LDM). 2022. Integrated Development Plan 2022-2027.

Lejweleputswa District Municipality Annual Report 2021-2022. 2021. Available from: http://www.lejweleputswa.fs.gov.za/wp-content/uploads/2012/11/IDP-2017-2022-.pdf

Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.

McArthur, A.G. 1967. *Fire behaviour in eucalypt forests*. Leaflet 107, Forestry and Timber Bureau, Canberra, ACT

Municipal Demarcation Board. 2022. Spatial Knowledge Hub. Available from: https://spatialhub-mdb-sa.opendata.arcgis.com/

National Treasury, 2018. Supplementary Guidance Note for the Built Environment Performance Plan (BEPP) 2019/20– 2021/22: Integrating Climate Response Priorities into the BEPP.

Pieterse, A., du Toit, J., van Niekerk, W., 2021. Climate change adaptation mainstreaming in the planning instruments of two South African local municipalities. Dev. South. Afr. 38, 493–508. https://doi.org/10.1080/0376835X.2020.1760790

Pieterse, A., Ludick, C., van Niekerk, W., Arnold, K., Chilwane, L., Mateyisi, M., Nangombe, S., Steenkamp, K., John, J., Kotzee, I., Lück-Vogel, M., 2023. GreenBook MetroView: Methodology for eThekwini. Pretoria.

Republic of South Africa. (2011), *National Climate Change Response White Paper*.

Republic of South Africa. (2013), *Spatial Planning and Land Use Management Act*, *16 of 2013*.

Schulze, R. E. et al. 2008. South African Atlas of Climatology and Agrohydrology. Report No. 1489/1/08, Water Research Commission, Pretoria.

Vilholth, K.G., Tottrup, C., Stendel, M. & Maherry, A. 2013. Integrated mapping of groundwater drought risk in the Southern African Development Community (SADC) region. *Hydrogeology Journal,* 21: 863 – 885.