Nkangala District Municipality

Climate Risk Profile Report based on the GreenBook

APRIL 2024

Report compiled by the CSIR
Funded by the CDRF with Santam

Title:	Nkangala District Municipality: Climate Risk Profile Report
Authors:	Kathryn Arnold, Amy Pieterse, Chantel Ludick, Lethabo Chilwane & Willemien van Niekerk
Project lead:	Amy Pieterese (CSIR)
Date:	17 April 2024
Citation:	CSIR, 2023. Nkangala District Municipality: Climate Risk Profile Report. Climate and Disaster Resilience Fund, Santam & Nkangala District Municipality.
Version:	Draft 1

Table of Contents

Figures

Tables

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
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 Nkangala District Municipality, 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, 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.

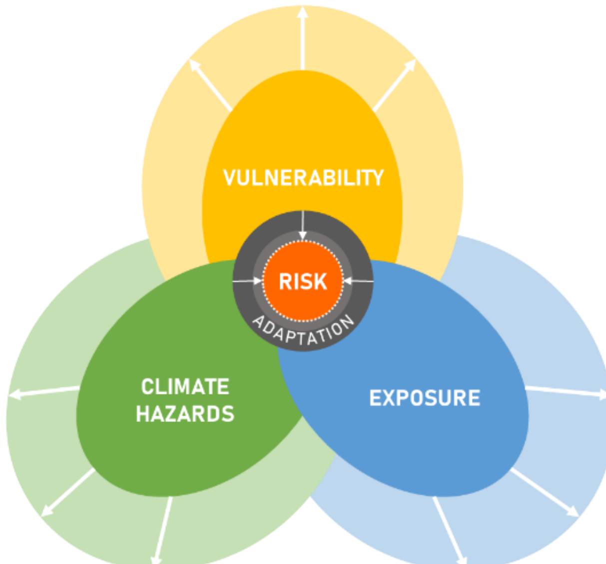

Figure 1: The interaction between the various components of risk, indicating the opportunity to reduce risk through adaptation (based on IPCC, 2014 and IPCC, 2021)

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 Nkangala District Municipality is situated in the northeastern part of the country and is the smallest of the three districts located in the Mpumalanga Province. It is bordered by the Gert Sibande District Municipality to the south, the Ehlanzeni District Municipality to the east, the Gauteng Province to the west and Limpopo Province to the north. The district itself is comprised of six local municipalities: Victor Khanye, Emalahleni, Steve Tshwete, Emakhazeni, Thembisile Hani and Dr JS Moroka. The district is home to a diverse population, including the Nguni, Sotho, and Swazi peoples, among others. The major languages spoken in the region are isiZulu, isiSwati, isiNdebele, Sesotho, and English. Nkangala District Municipality is predominantly rural, with a significant portion of the population residing in small towns and villages. The topography of the district is diverse, ranging from highveld grasslands to mountainous regions.

The district is rich in minerals and natural resources, as such, the economy of Nkangala District Municipality is primarily driven by agriculture, mining, manufacturing, and services. Agriculture plays a crucial role in the district's economy, with crops such as maize, wheat, sunflower, and vegetables being cultivated. Mining is also a significant contributor to the economy, with the district being rich in coal reserves. The coal mining industry supports employment and economic development in the region. The manufacturing sector includes industries such as food processing, textile, and chemical production. The district also benefits from its proximity to major urban centres, such as Witbank and Middelburg, which serve as hubs for commerce and trade. The proximity to Gauteng also offers opportunities to a larger market, which is of benefit to the district's agricultural and manufacturing sectors. The Maputo Corridor constitutes the district's economic strength, bringing increased potential for economic growth and tourism development.

The district is also rich in diverse ecosystems. The district is home to several protected areas and nature reserves, including the Loskop Dam Nature Reserve and the Mkhombo Nature Reserve, which are important for biodiversity conservation and tourism. However, the district also faces environmental challenges, particularly related to mining activities. Coal mining operations have raised concerns about air and water pollution, as well as habitat destruction. Efforts are being made to balance economic development with environmental conservation through initiatives such as sustainable resource management and environmental monitoring.

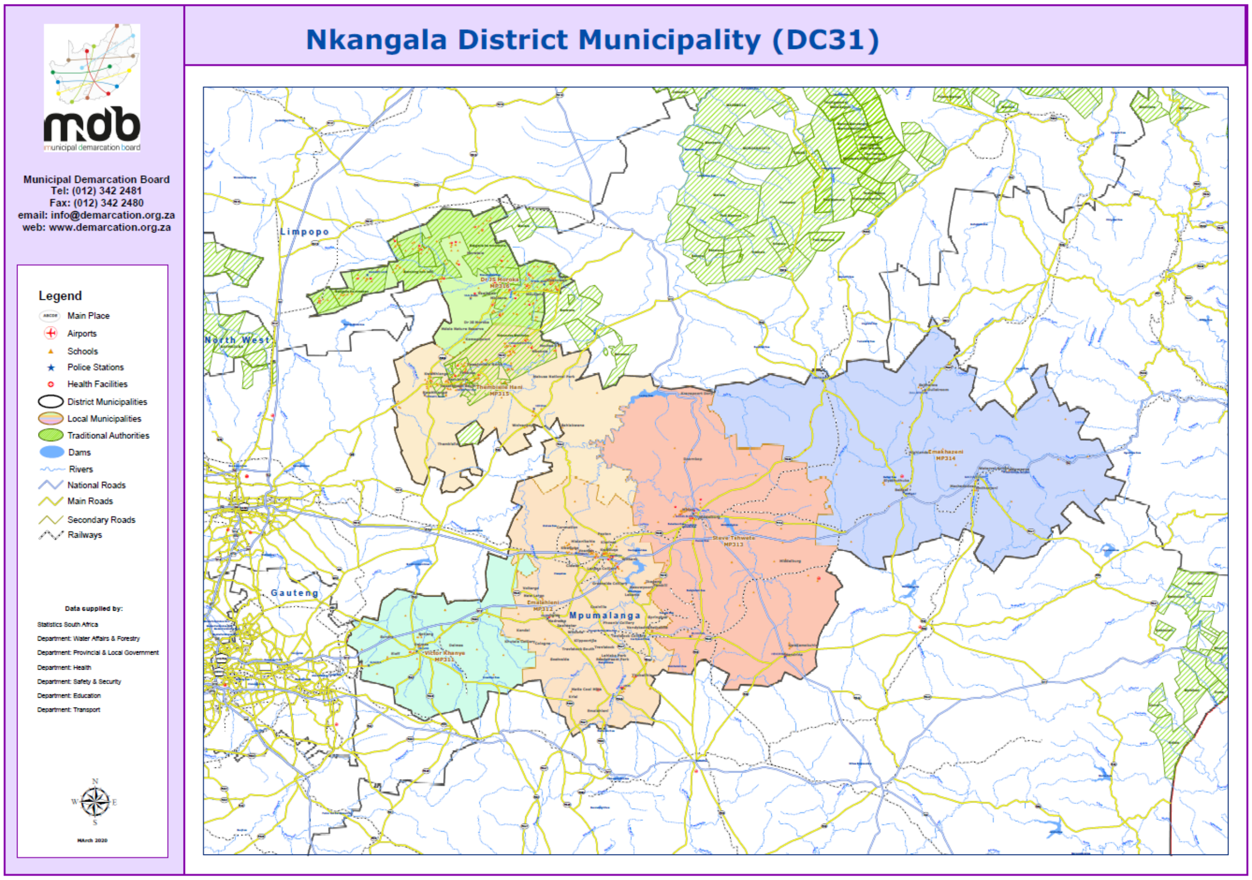

Figure 2: Nkangala District Municipality (Municipal Demarcation Board, 2022), with Local Municipalities shaded in different colours

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 Nkangala 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 Nkangala 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 Nkangala 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 Nkangala 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 Nkangala District Municipality for 1996 t0 2011

LOCAL MUNICIPALITY	SEVI 1996	SEV 2011	Trend	EcVI 1996	EcVI 2011	Trend	PVI	Trend	EnVI	Trend
Emalahleni	2.6	3.5	↘	5.34	6.09	↗	5.13	No Trend	6.36	No Trend
Thembisile Hani	5.93	5.45	↘	6.19	5.04	↘	4.55	No Trend	2.67	No Trend
Dr JS Moroka	5.40	5.78	↗	5.89	5.18	↘	4.93	No Trend	2.98	No Trend
Steve Tshwete	2.96	1.69	↘	4.87	5.21	↗	4.58	No Trend	4.96	No Trend
Victor Khanye	6.77	4.49	↘	6.87	6.91	↗	5.10	No Trend	2.58	No Trend
Emakhazeni	5.64	4.24	↘	6.80	7.05	↗	5.36	No Trend	4.44	No Trend

Between 1996 and 2011, socio-economic vulnerability decreased (improved) in most local municipalities (LMs) within the Nkangala District, except for the Dr JS Moroka LM which experienced a slight increase (worsening) in vulnerability and remains the LM with the highest socio-economic vulnerability in the province. Economic vulnerability trends in the district were mixed, with half of the LMs showing a decrease and the other half increasing. Emalahleni has a significantly high level of environmental vulnerability, second only to Thaba Chweu in the province. The other two LMs with above-average environmental vulnerability are Steve Tshwete and Emakhazeni, mainly due to their heavy dependence on mining and quarrying industries.

2.1.2. Settlement vulnerability

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

Emalahleni Local Municipality

The municipality of eMalahleni has several major settlements, including eMalahleni (formerly known as Witbank), Phola and Van Dyksdrif. Other settlements include Ogies, Kendal, Kriel and Kromdraai. Of these settlements, eMalahleni has relatively low levels of vulnerability, with environmental vulnerability being the biggest concern, followed by socio-economic vulnerability and service access demands. On the other hand, Phola is facing very high levels of socio-economic, economic and environmental vulnerability. Van Dyksdrif can be considered the most vulnerable settlement in the municipality due mainly to poor service access and regional connectivity, coupled with relatively high levels of socio-economic and economic vulnerability.

Thembisile Hani Local Municipality

The major formal settlements in this municipality are Verena and Kwaggafontein. Verena faces challenges of relatively high socio-economic vulnerability, as well as economic, environmental and regional connectivity challenges. Economic vulnerability is the most pressing concern for

Kwaggafontein. Both settlements also face challenges of socio-economic vulnerability and environmental concerns.

Dr JS Moroka Local Municipality

The major settlements in this municipality are Siyabuswa, Allemansdrift, Vaalbank and Leeufontein. Siyabuswa has relatively low vulnerability across the six metrics compared to the other settlements in the LM. Socio-economic vulnerability is the greatest challenge for Siyabuswa but is considerably lower than other settlements in the municipality. Thabana faces the highest relative environmental vulnerability of all settlements, and socio-economic vulnerability is also very high, although Ramokgeletsane has the highest socio-economic vulnerability of all settlements in the area. Allemansdrift has the second-highest economic vulnerability as well as relatively high service access vulnerability. Vaalbank has the second highest environmental vulnerability of all settlements in LM. It also has relatively high economic vulnerability when compared with other settlements in the municipality. Leeufontein has the highest economic vulnerability of all settlements in the LM. It also has notably high socio-economic vulnerability. 52.6% of the population living in Dr JS Moroka Local Municipality live in traditional areas. Population growth pressure, service access and regional connectivity are the biggest developmental concerns in these traditional areas.

Steve Tshwete Local Municipality

The main towns in this municipality include Middelburg, Piet Tlou, Rietkuil, and Hendrina. Of these, Middelburg, Piet Tlou, and Hendrina have relatively high levels of growth pressure and together with high levels of environmental vulnerability. Piet Tlou is economically and socio-economically vulnerable, and face service access issues. Rietkuil is the most regionally isolated settlement in the municipality, contribution to its inherent vulnerability.

Victor Khanye Local Municipality

The major settlements in this municipality are Delmas and Eloff. Both settlements experience high levels of growth pressure. Delmas also faces relatively high levels of socio-economic vulnerability and poor service access. Eloff faces challenges around regional connectivity and environmental vulnerability.

Emakhazeni Local Municipality

The major settlements in this municipality are Dullstroom, eMakhazeni (formerly known as Belfast), and eNtokozweni (formerly known as Machadodorp). Relative to other settlement in the municipality, Dullstroom faces some of the highest levels of vulnerability, especially around economic, socio-economic, service access and growth pressure challenges. eNtokozweni also faces similar challenges but to a lesser degree. eMakhazeni faces challenges around economic vulnerability and pressure from population growth.

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 Nkangala District Municipality

Population per municipality	2011	Medium Growth Scenario	
		2030	2050
Emalahleni	395 467	648 163	877 815
Thembisile Hani	877 815	394 697	409 526
Dr JS Moroka	409 526	227 585	161 166
Steve Tshwete	229 813	434 967	696 724
Victor Khanye	310 429	394 697	409 526
Emakhazeni	47 217	52 178	46 125
Nkangala DM Total	2 270 267	2 152 287	2 600 882

Based on the 2022 Census (StatsSA, 2022) Nkangala in Mpumalanga has a total population of 1 588 684. Within this population, young children (0-14 years) make up 26.7% of the total population. The working-age population (15-64 years) accounts for 67.3%, while the elderly (65+ years) constitute 6.0%. The district's dependency ratio is reported at 48.5 with a sex ratio of 96.2 Education indicators reveal that 9,4% of individuals aged 20 and above have no formal schooling, while 7.6% have attained higher education qualifications. With regards to housing, the district hosts 483 169 households, with an average household size of 3.3. Formal dwellings dominate the housing landscape, representing 91.3% of the housing stock. Sanitation and waste management services are accessible, with 62.0% of formal dwellings equipped with flushing toilets connected to sewerage, and 58.5% receiving weekly refuse disposal services. Moreover, 53.3% of households enjoy access to piped water within their dwellings, while 91.7% have electricity for lighting.

The district's population is projected to increase by 14.6 % between 2011 and 2050, under a medium growth scenario (see Table 2). Most of this growth will take place in the Emalahleni and Steve Tshwete municipal areas. The municipalities of Thembisile Hani and Dr JS Moroka are predicted to see stagnation and declines in their population numbers by 2025. Figure 3 depicts the growth pressures that the settlements across the district are likely to experience. The settlements that are likely to experience extreme growth pressures up to 2050, include Delmas, Emalahleni, Middelburg, and Piet Tlou.

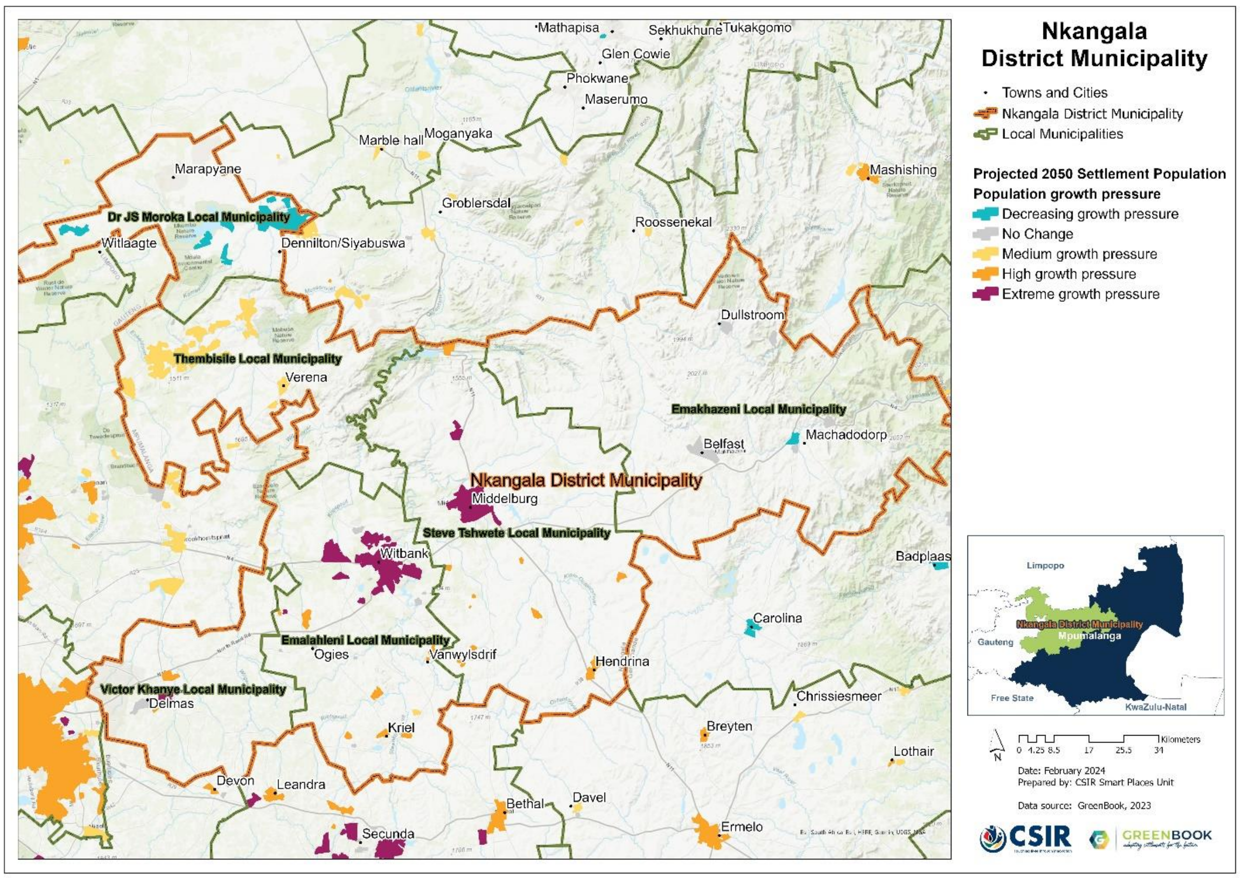

Figure 3: Settlement-level population growth pressure across Nkangala District Municipality

2.2. Climate

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

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

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

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

For each of the climate variables discussed below:

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

2.2.1.Temperature

The model was used to simulate average annual 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.

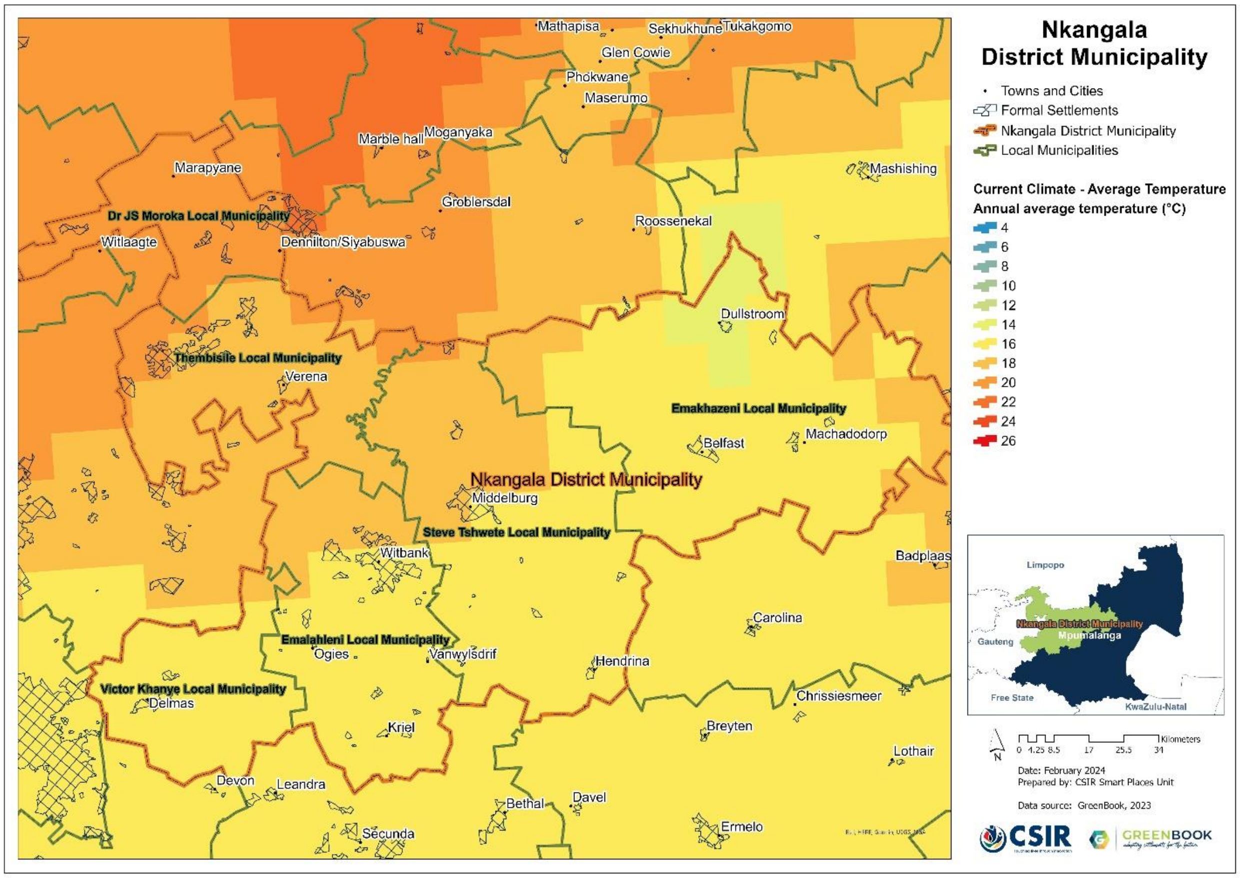

Figure 4: Average annual temperature (°C) for the baseline period 1961-1990 for Nkangala District Municipality

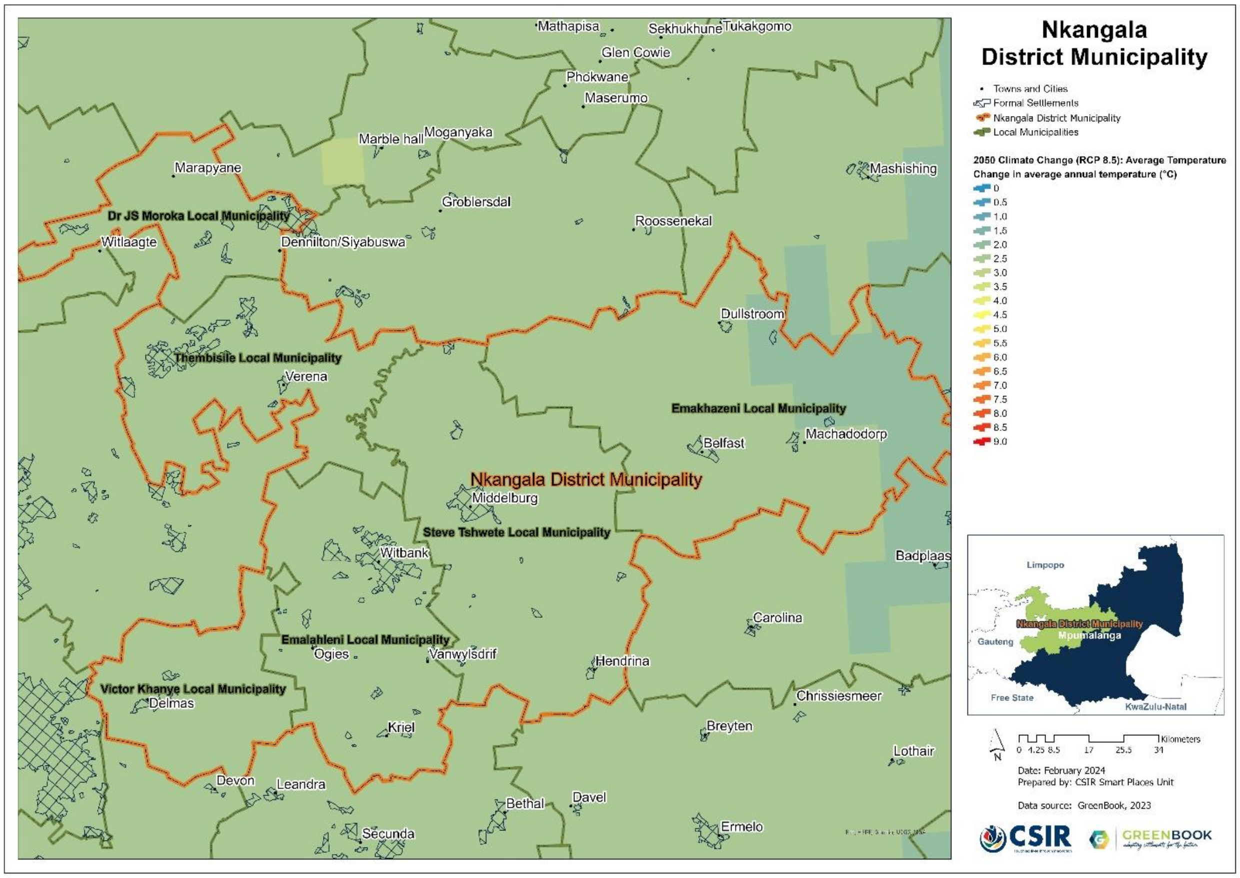

Figure 5: Projected changes in average annual temperature (°C) from the baseline period 1961-1990 to the future period 2021-2050 for Nkangala District Municipality, assuming an RCP 8.5 emissions pathway

The Nkangala District Municipality experiences an average annual temperature of 16-22°C. The southern parts of the district have a lower average temperature, while the temperature increases progressively towards the northwest parts of the region, particularly over Thembisile Hani Local Municipality and Dr JS Moroka Local Municipality (as shown in Figure 4). According to projections, the average annual temperature will increase by 2.5-3.0 °C under the RCP 8.5 (low mitigation, high emissions) scenario (as shown in Figure 5).

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.

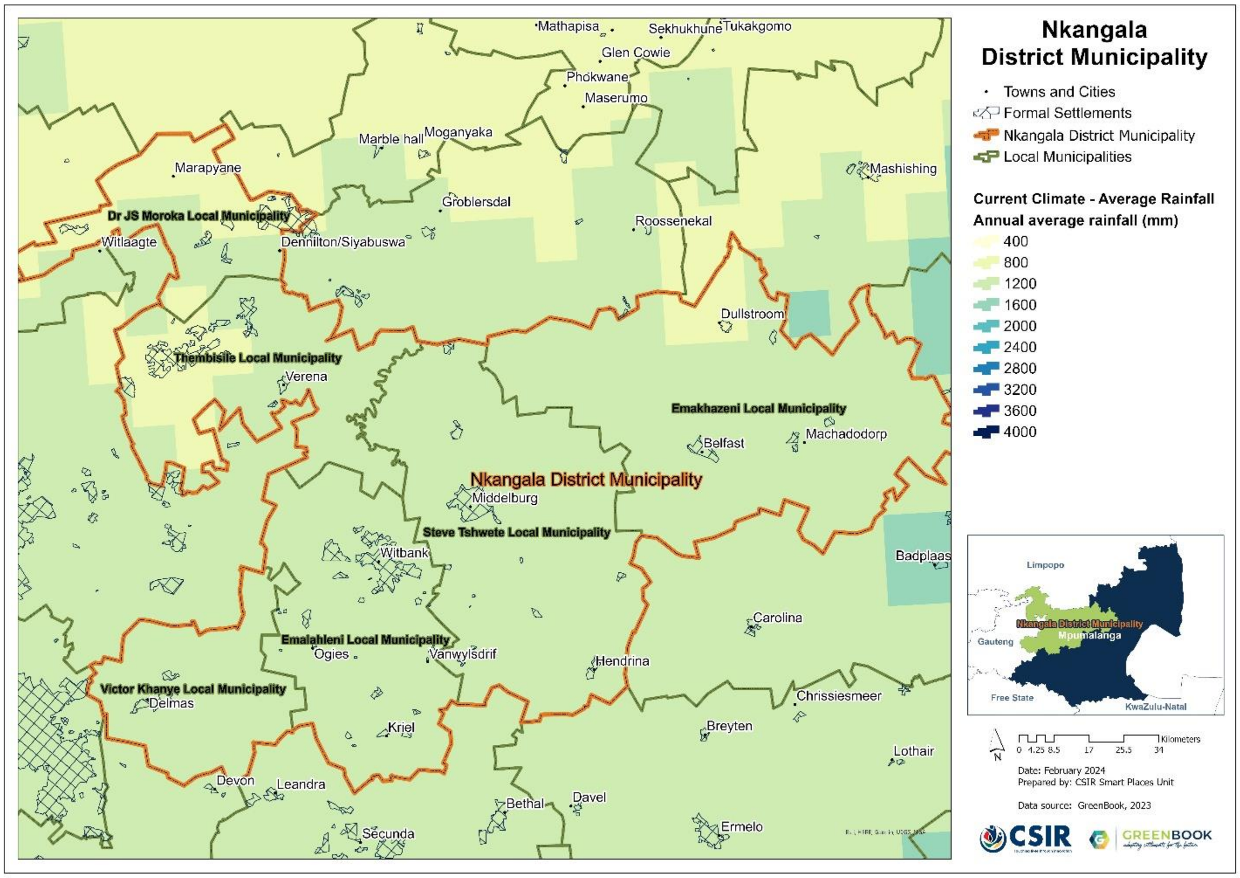

Figure 6: Average annual rainfall (mm) for the baseline period 1961-1990 for Nkangala District Municipality

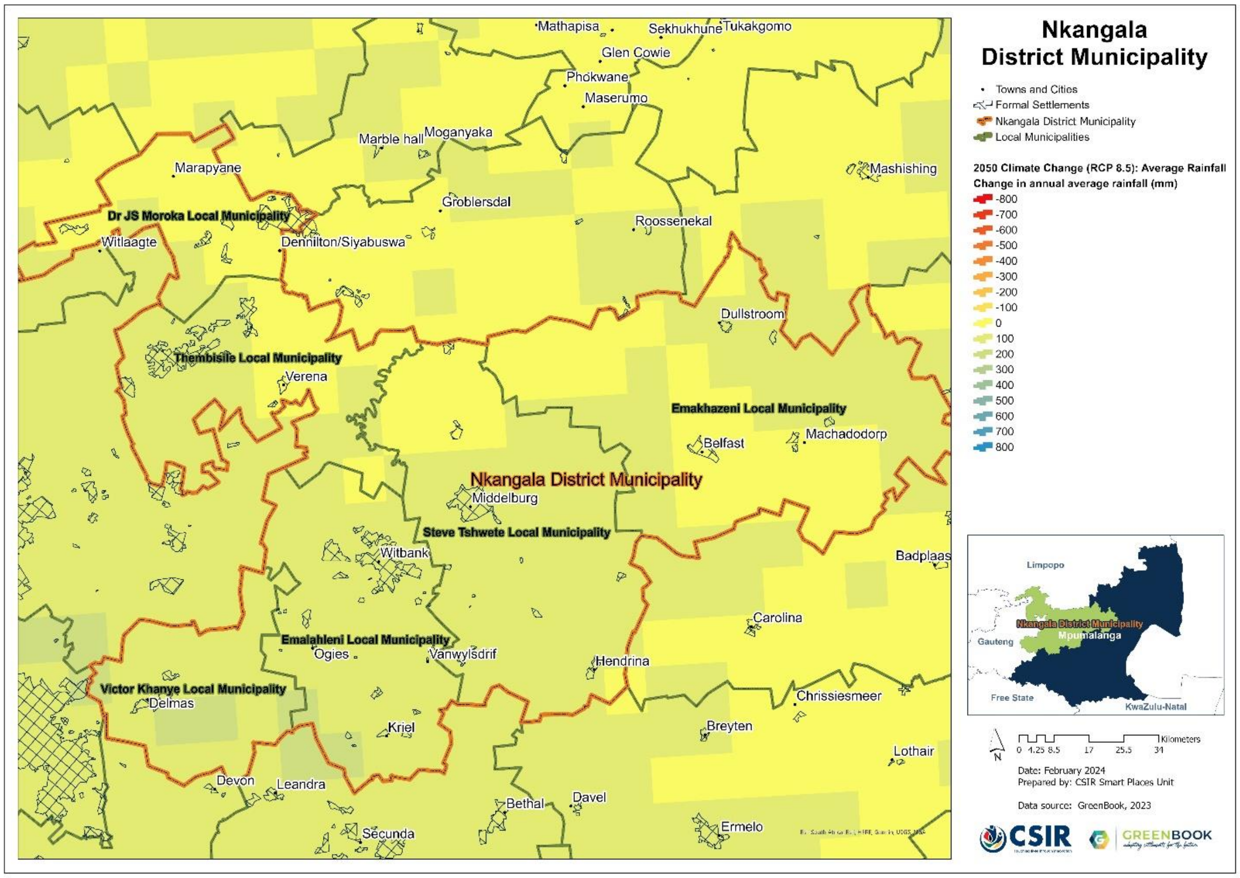

Figure 7: Projected change in average annual rainfall (mm) from the baseline period to the period 2021-2050 for Nkangala District Municipality, assuming an RCP8.5 emission pathway

The Nkangala District Municipality experiences an average annual rainfall ranging between 730 mm and 1075 mm. The southeastern part of the district, particularly Emakhazeni Local Municipality, receives higher averages of rainfall, while the northwest parts of the region, specifically Thembisile Hani Local Municipality and Dr JS Moroka Local Municipality, receive lower averages of annual rainfall (as shown in Figure 6). According to future projections, there are mixed signals regarding changes in rainfall, indicating some degree of uncertainty about future rainfall patterns in 2050. The northern and eastern parts of the district are expected to experience a decline in average annual rainfall of up to 50 mm, while the southern and western parts may see a slight increase of up to 100 mm annually. This increase is particularly projected over Victor Khanye Local Municipality (see Figure 7).

2.3. Climate Hazards

This section showcases information with regards to Nkangala 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).

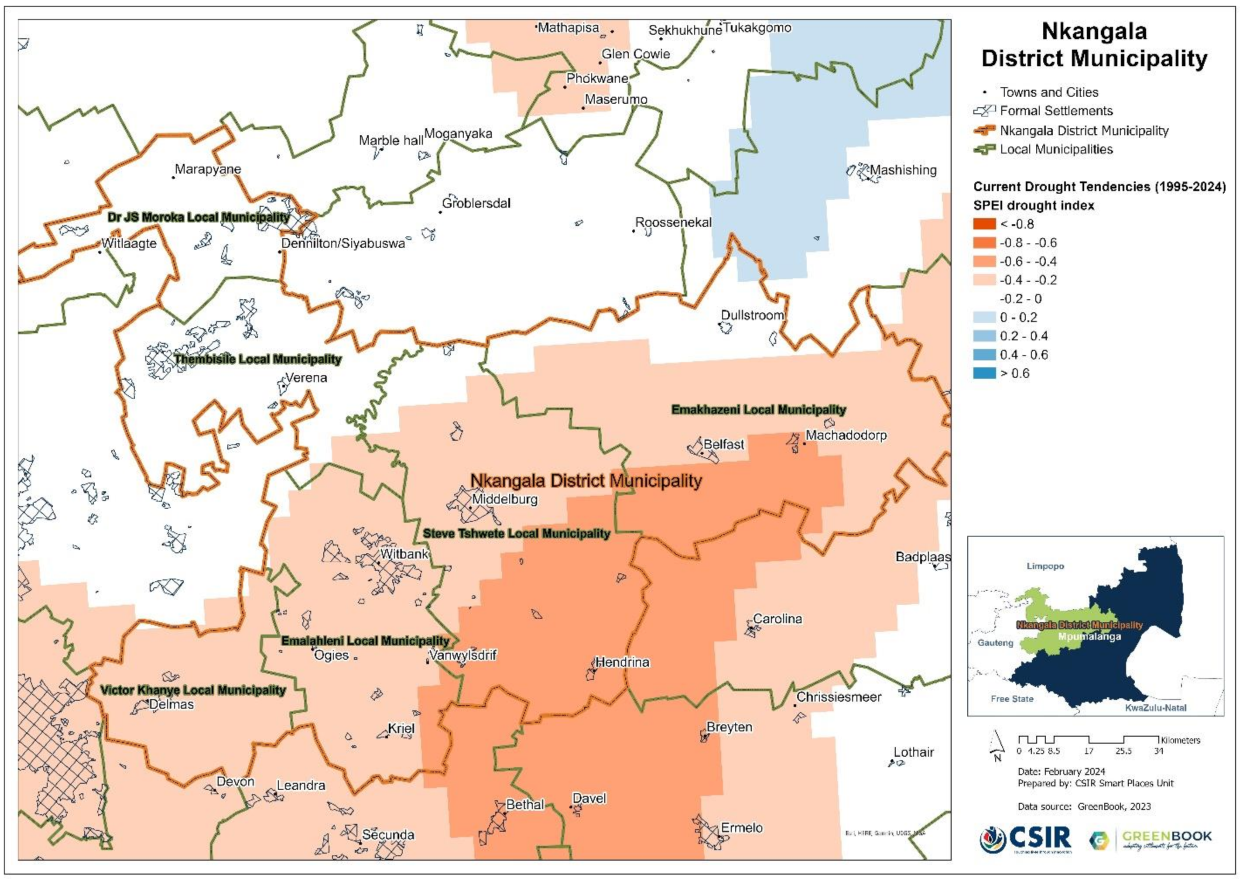

Figure 8: Current drought tendencies from the baseline period (1986-2005) to the current period (1995-2024) across Nkangala District Municipality

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.

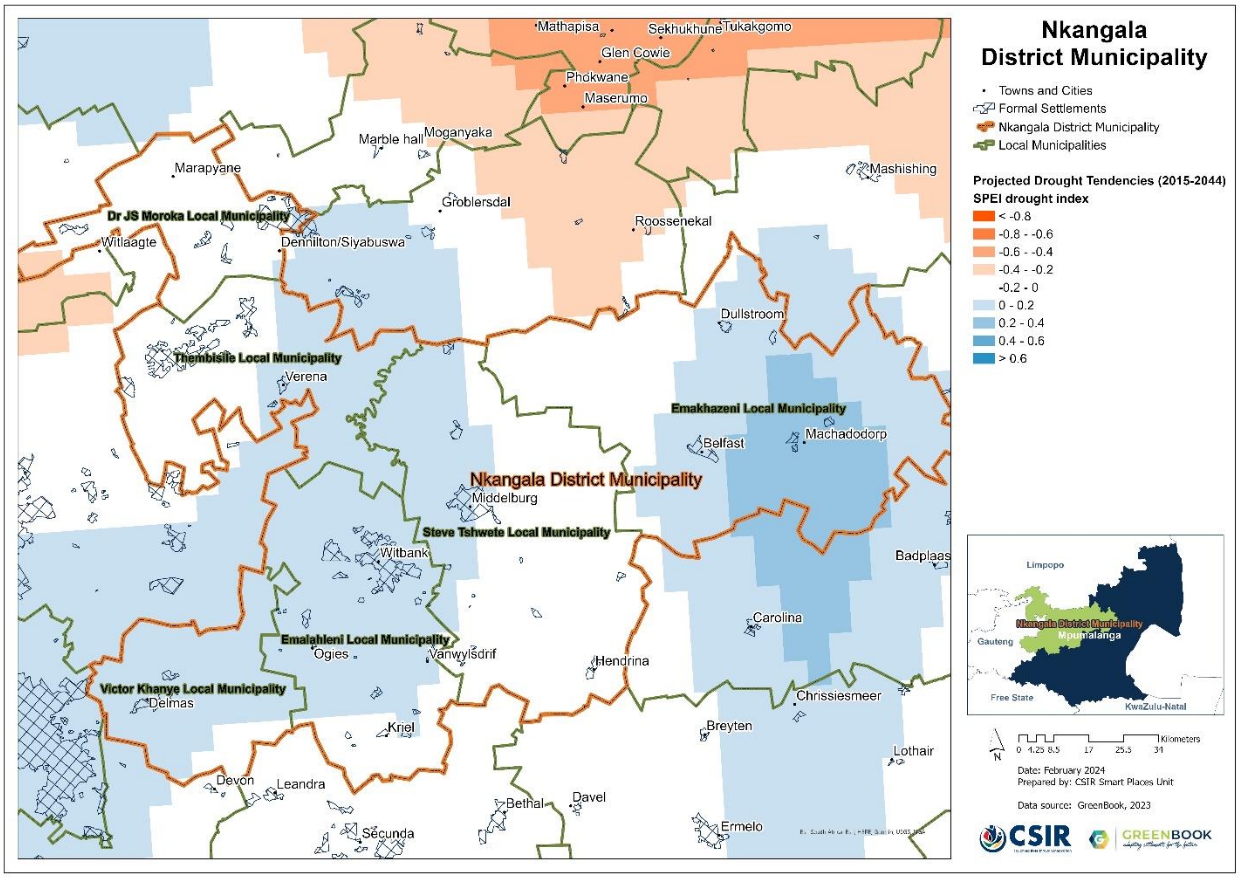

Figure 9: Projected changes in drought tendencies from the baseline period (1986-2005) to the future period 2015-2044 for Nkangala District Municipality

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.

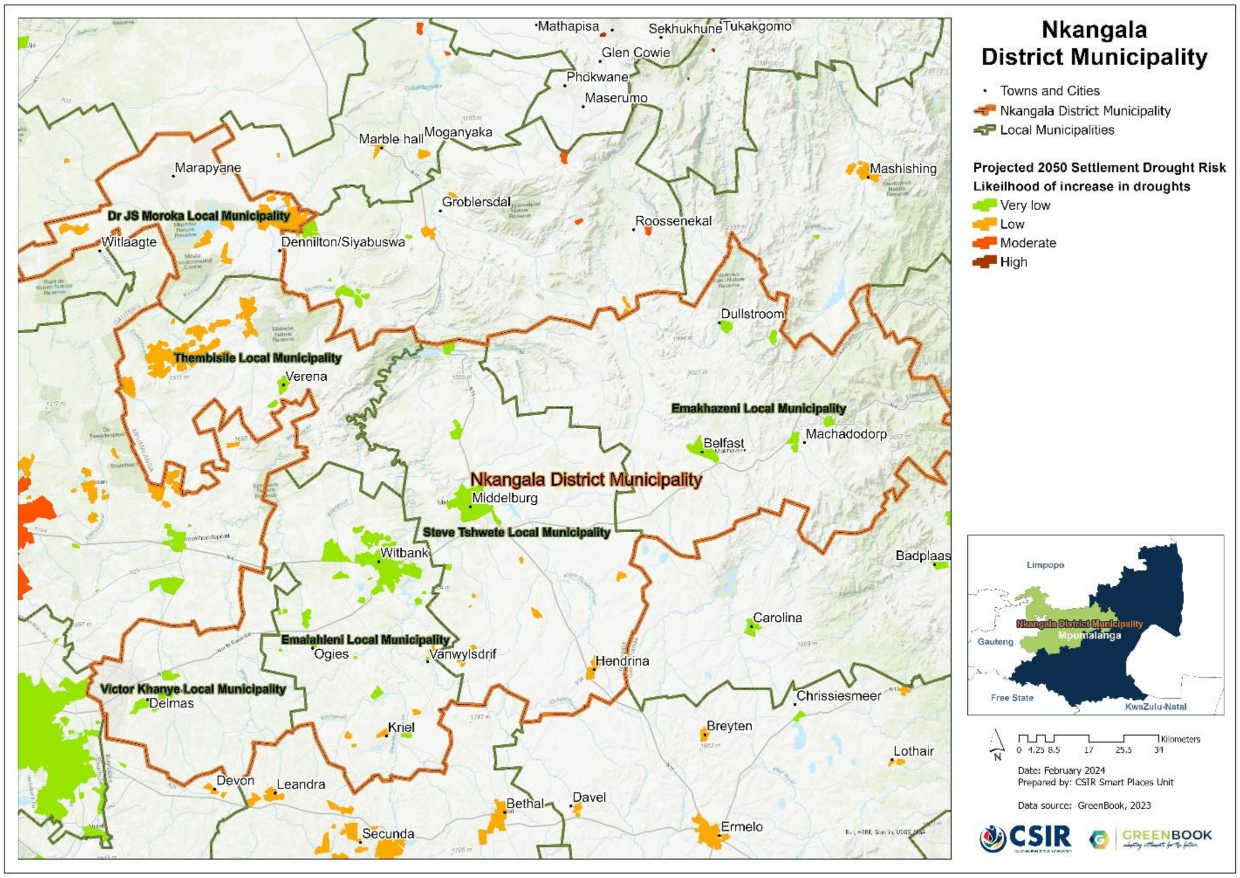

Figure 10: Settlement-level drought risk for Nkangala District Municipality

Figure 10 depicts the settlements that are at risk of increases in drought tendencies. Based on the projections (Figure 9) for drought tendencies, drought is not a pertinent risk for Nkangala District, with all settlements across the district having low to very low degrees of drought risk (as shown in Figure 10).

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.

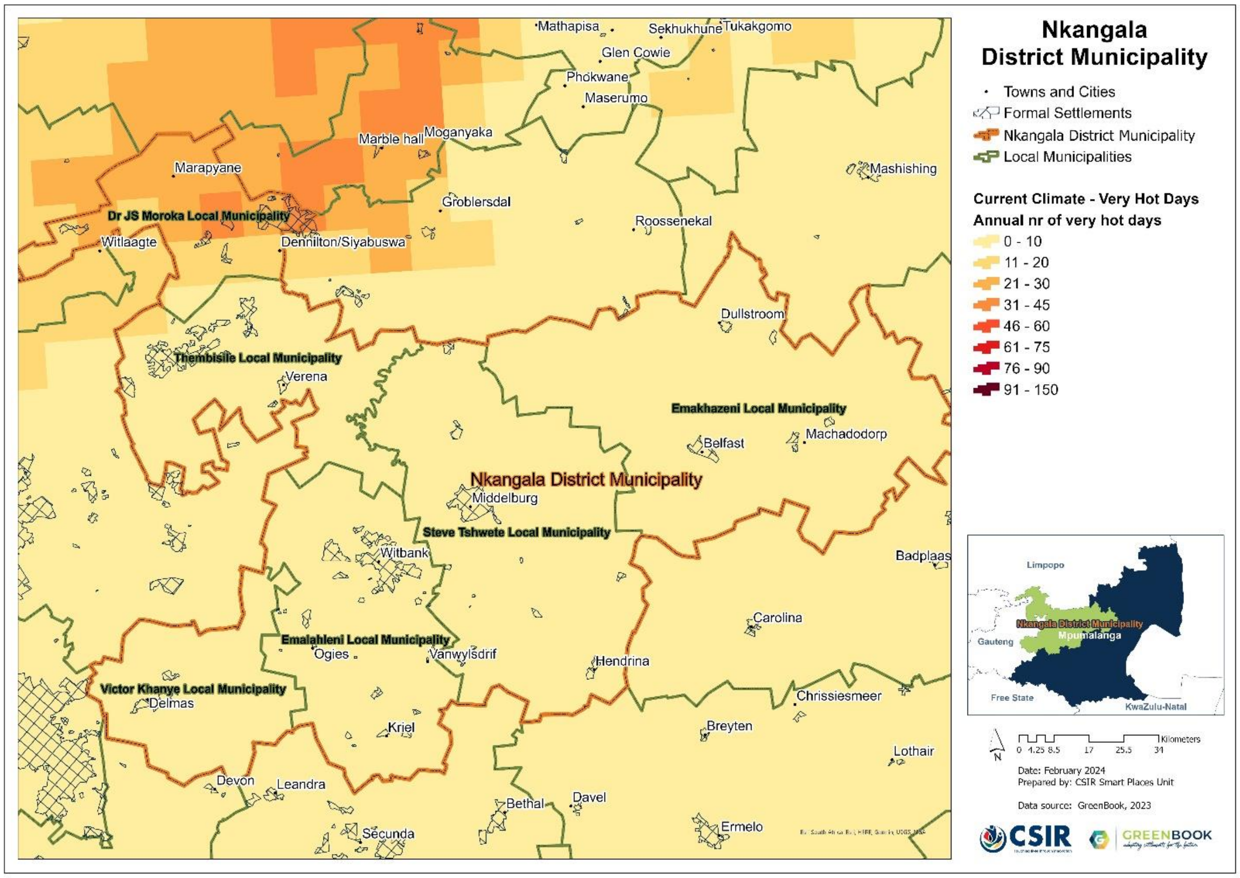

Figure 11: Annual number of very hot days under baseline climatic conditions across Nkangala District Municipality with daily temperature maxima exceeding 35°C

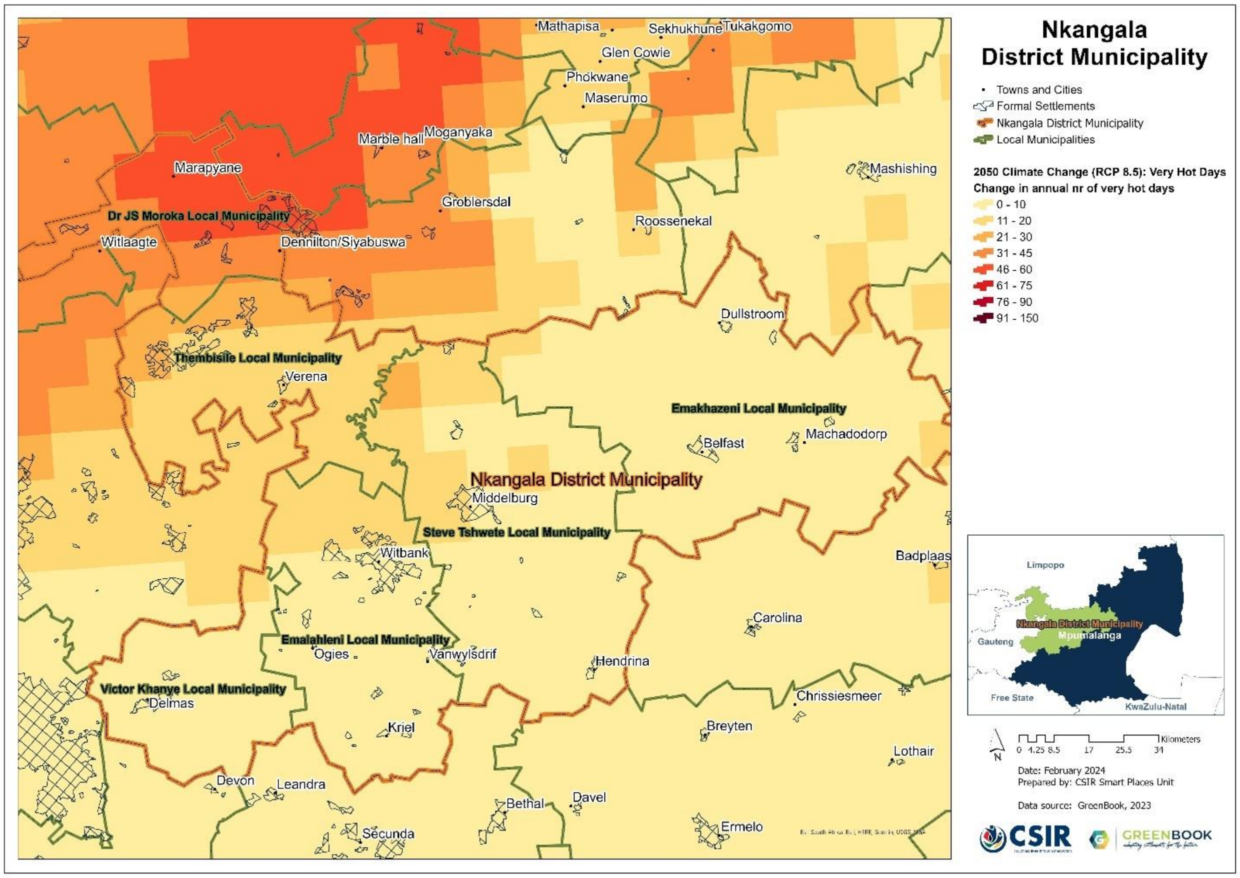

Figure 12: Projected change in annual number of very hot days across Nkangala District Municipality with daily temperature maxima exceeding 35°C , assuming and RCP 8.5 emissions pathway

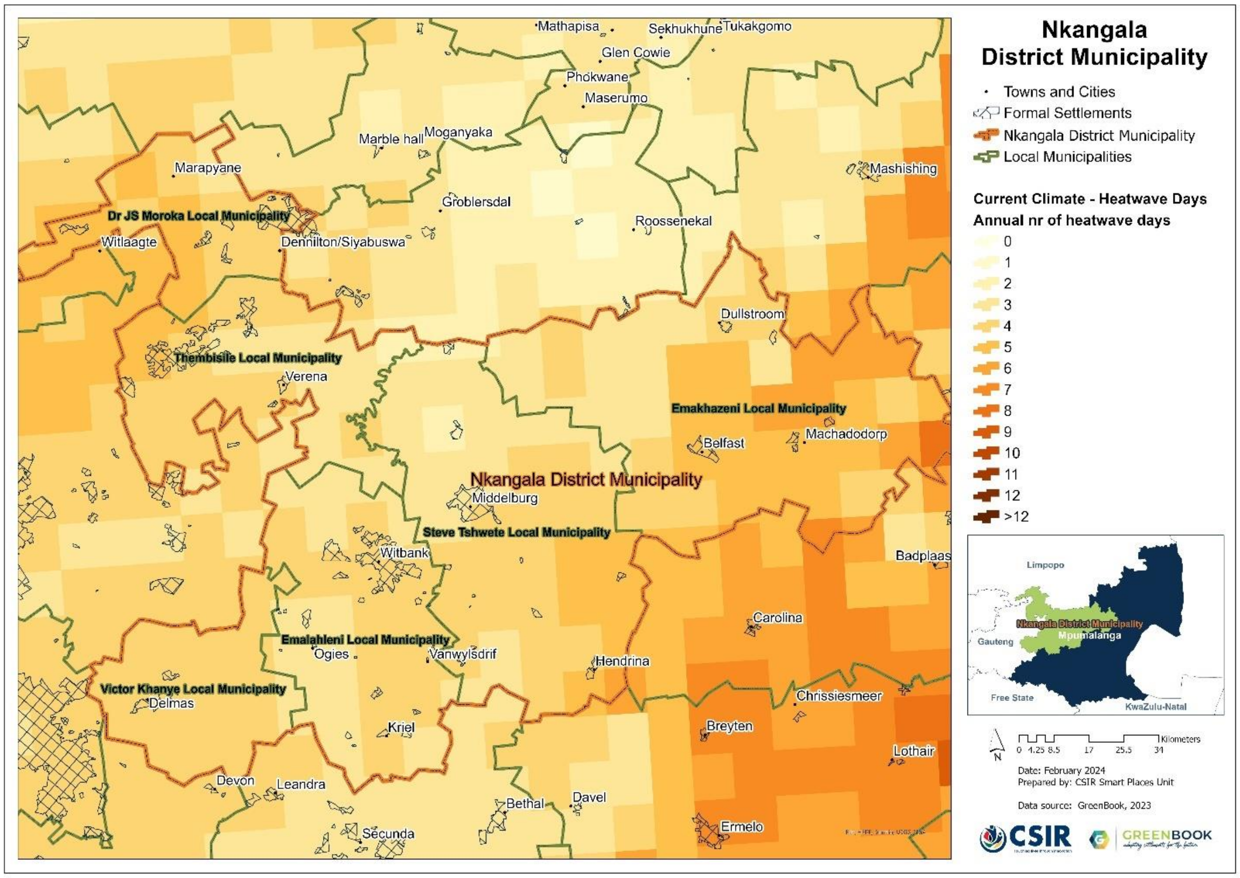

Figure 13: Number of heatwave days under baseline climatic conditions across Nkangala District Municipality

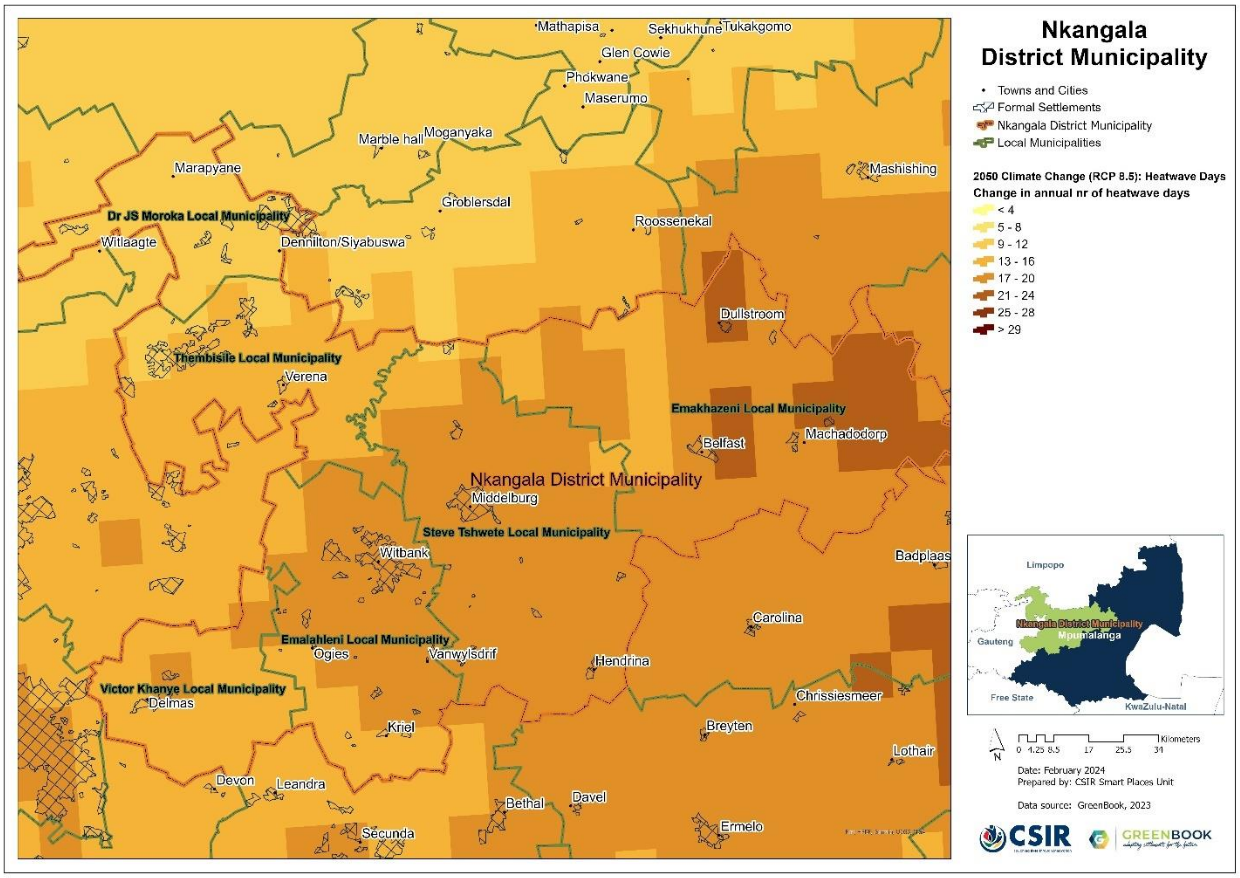

Figure 14: Projected change in annual number of heatwave days across Nkangala District Municipality, assuming an (RCP 8.5) emissions pathway

There is a significant difference in the number of very hot days per year across the Nkangala District Municipality. The range is from 1 to 42 days annually, with fewer very hot days occurring in the southern areas. The far northern parts of the district, particularly Dr JS Moroka municipality, experience more very hot days each year, as shown in Figure 11. The same trend is observed for projected changes in very hot days by 2050 (figure 12), with an expected increase in the number of very hot days in the areas that already experience extreme heat. That means up to 60 more very hot days annually for settlements in Dr JS Moroka municipality, and up to 40 more very hot days across Thembisile Hani Local Municipality. Heatwave events are more likely to take place towards the southeast of the district, affecting areas south and to the east of Verena (see Figures 13 and 14).

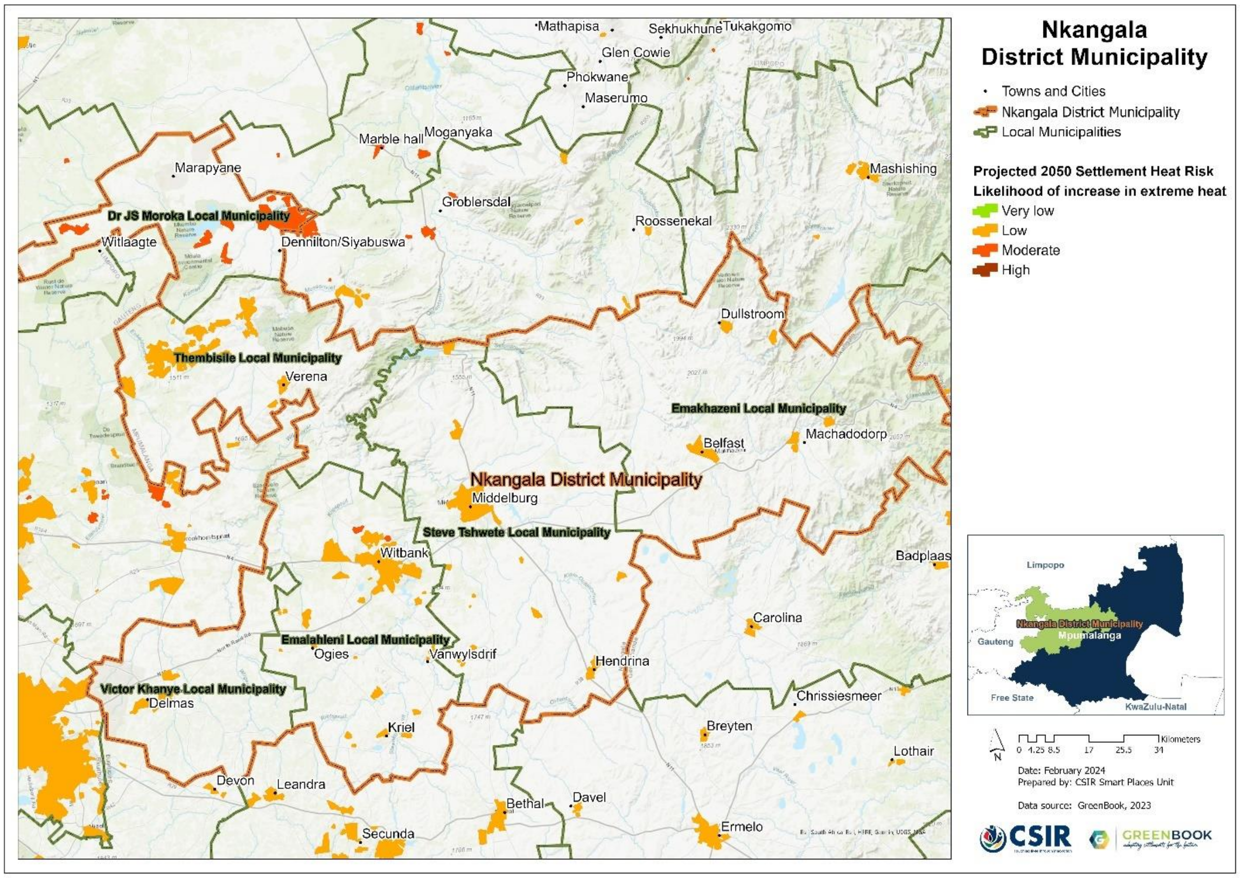

Figure 15: Settlement-level heat risk across Nkangala District Municipality

Figure 15 shows settlements at risk of increased heat stress. The Dr JS Moroka municipality and settlements like Siyabuswa, Allemansdrift, Vaalbank, and Leeufontein will be most exposed to heat stress in the future.

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.

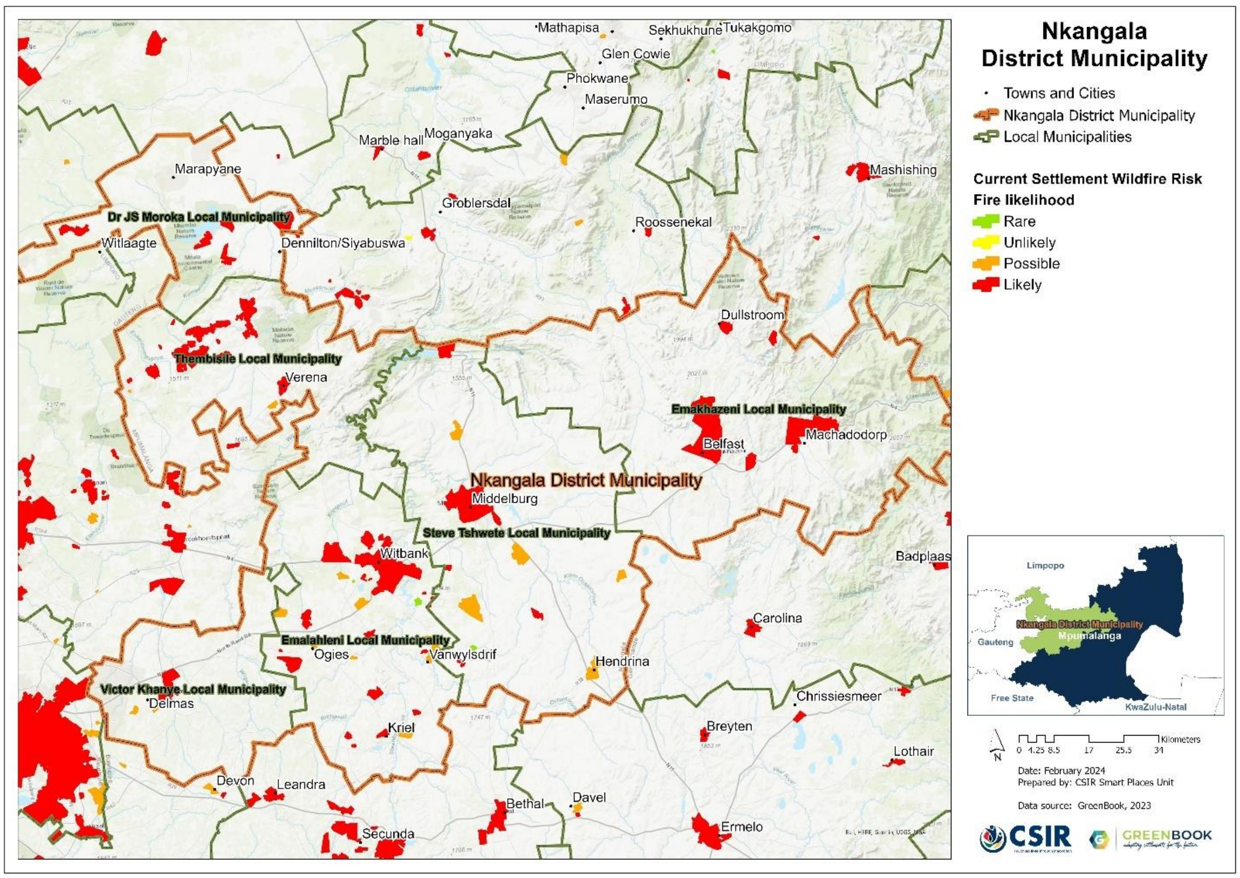

Figure 16: The likelihood of wildfires under current climatic conditions across settlements in Nkangala District Municipality

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.

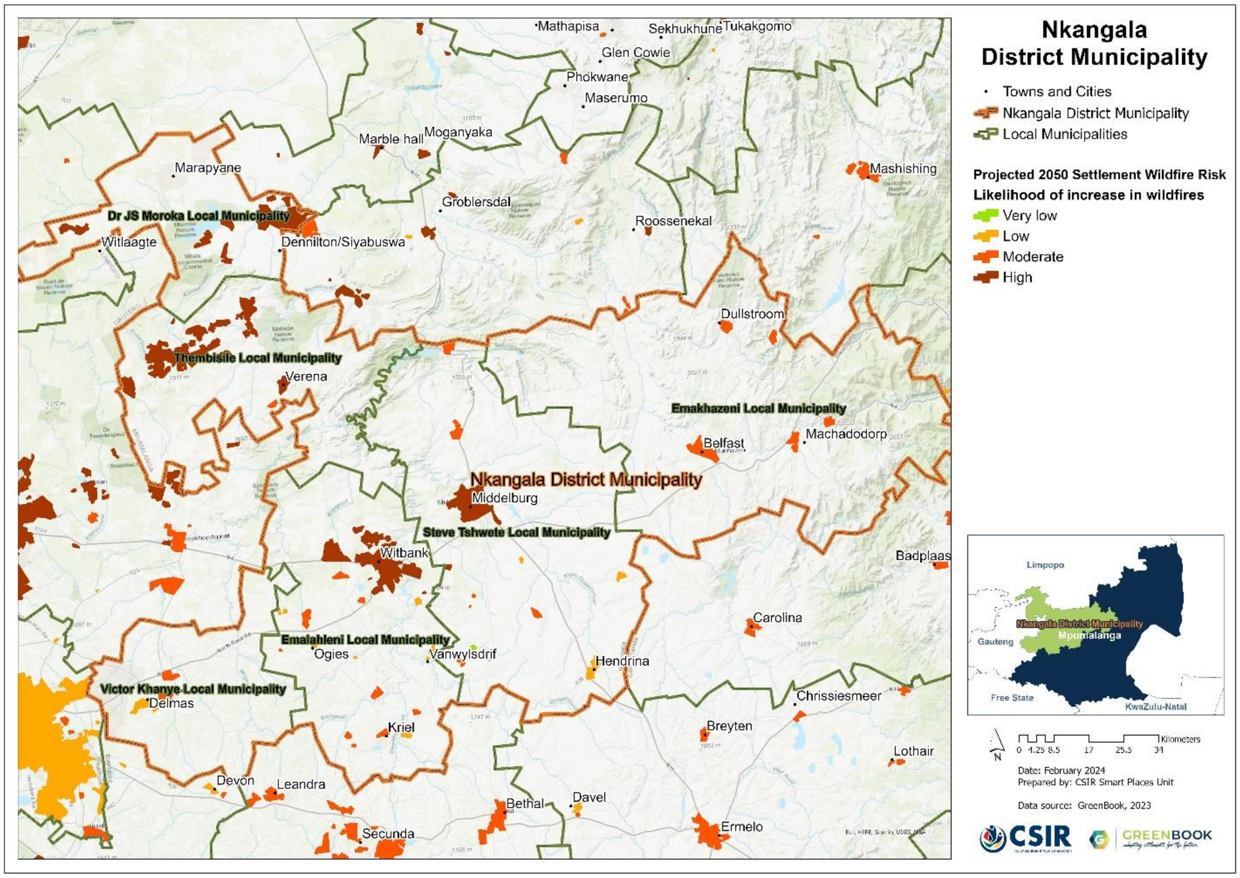

Figure 17: The likelihood of wildfires under projected future climatic conditions across settlements in Nkangala District Municipality

The likelihood of wildfires under current climatic conditions across the settlements within the Nkangala District Municipality is high (likely) (see Figure 16). The likelihood of increases in wildfires under 2050 projected change is high (see Figure 17). The settlements within the Nkangala District Municipality are thus at high risk of wildfires, both currently and into the future.

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.

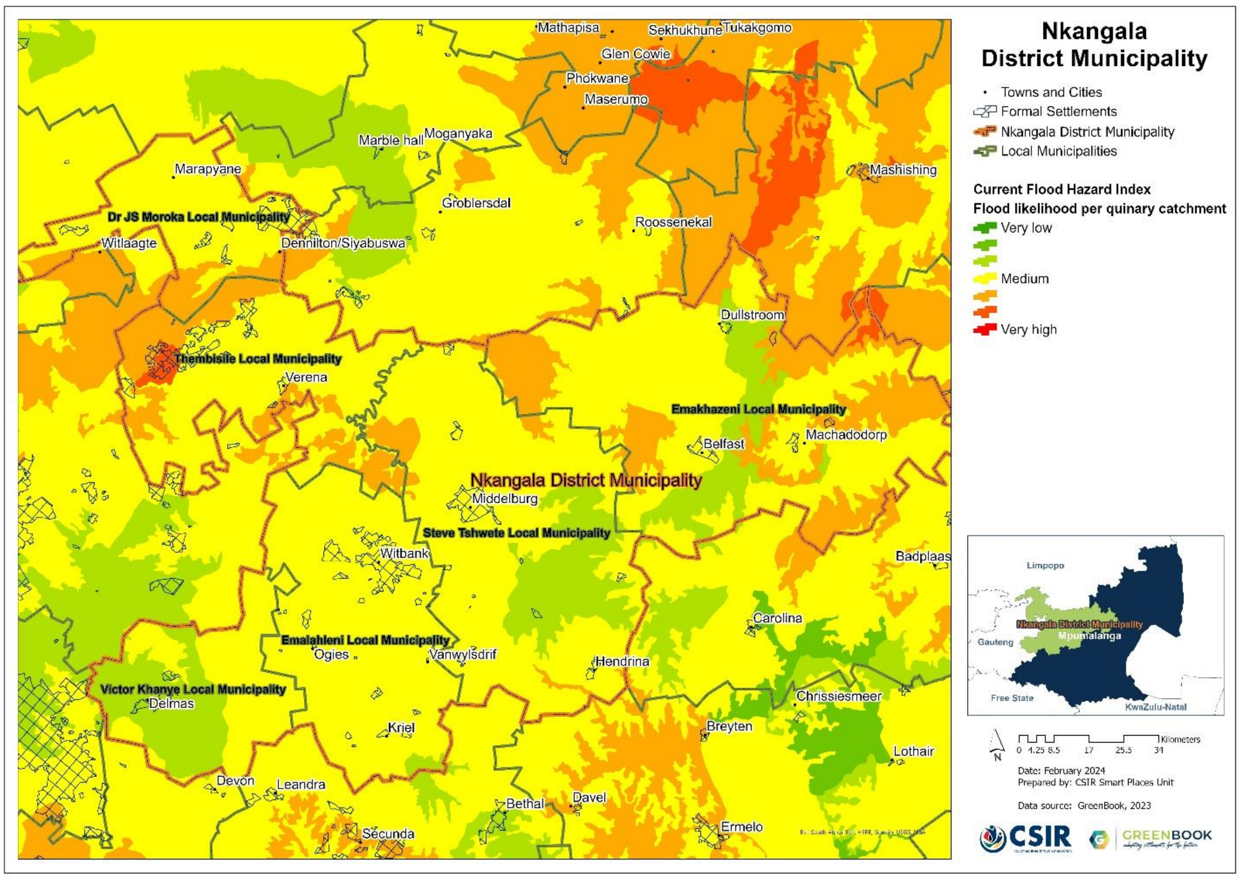

Figure 18: The current flood hazard index across Nkangala District Municipality under current (baseline) climatic conditions

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. There is a notable difference in the flood hazard index throughout the district. While much of the district has a moderate (medium) flood hazard, there are certain areas that have a very high flood hazard, specifically in Thembisile Hani municipality, Dr JS Moroka municipality, and Emakhazeni municipality.

Figure 19 depicts the projected change into the future in extreme rainfall days for an 8x8 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.

As with changes in average annual rainfall (see Figure 7) there are mixed signals regarding changes in extreme rainfall days (Figure 19), indicating uncertainty about future rainfall patterns into the future.

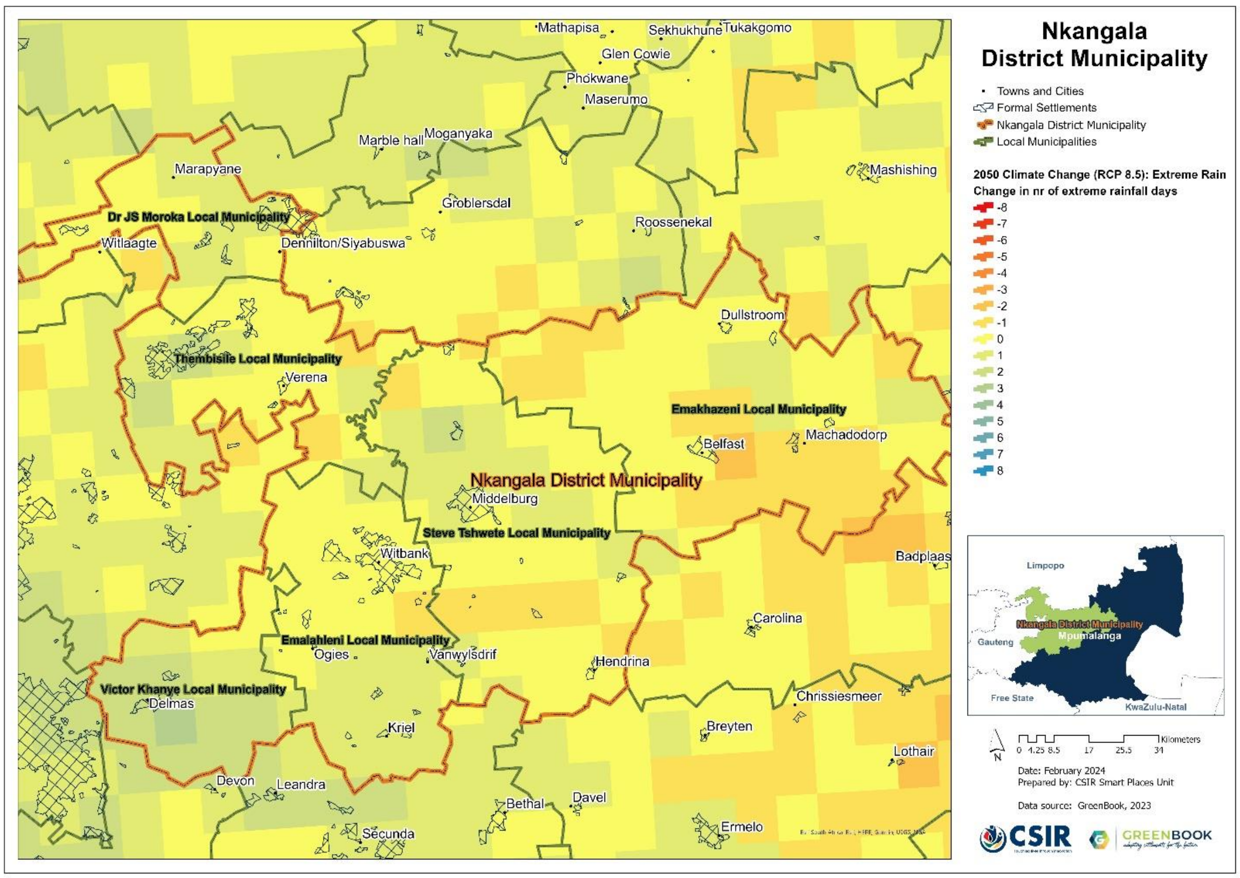

Figure 19: Projected changes into the future in extreme rainfall days across Nkangala District Municipality

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 illustrates the settlements that are expected to face an escalated risk of flooding under an RCP 8.5 low mitigation (worst case of greenhouse gas emissions) scenario. The settlements that are likely to face moderate increases in flooding risks include Phola, Middleburg, eNtokozweni, Dullstroom, Kameelpoortnek, and Kwaggafontein.

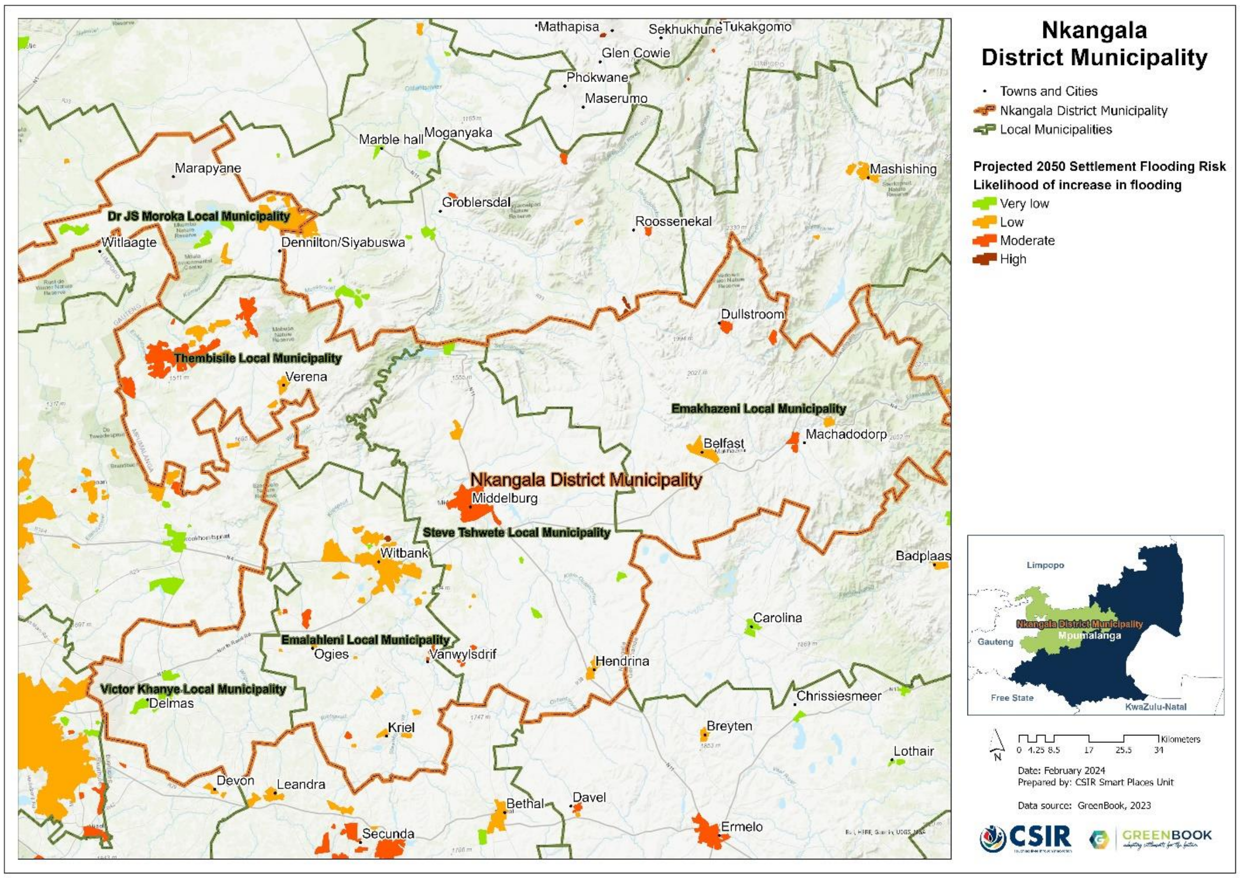

Figure 20: Flood risk into a climate change future at settlement level across Nkangala District Municipality.

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 Nkangala 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 Olifants and Inkomati-Usuthu quaternary catchments.

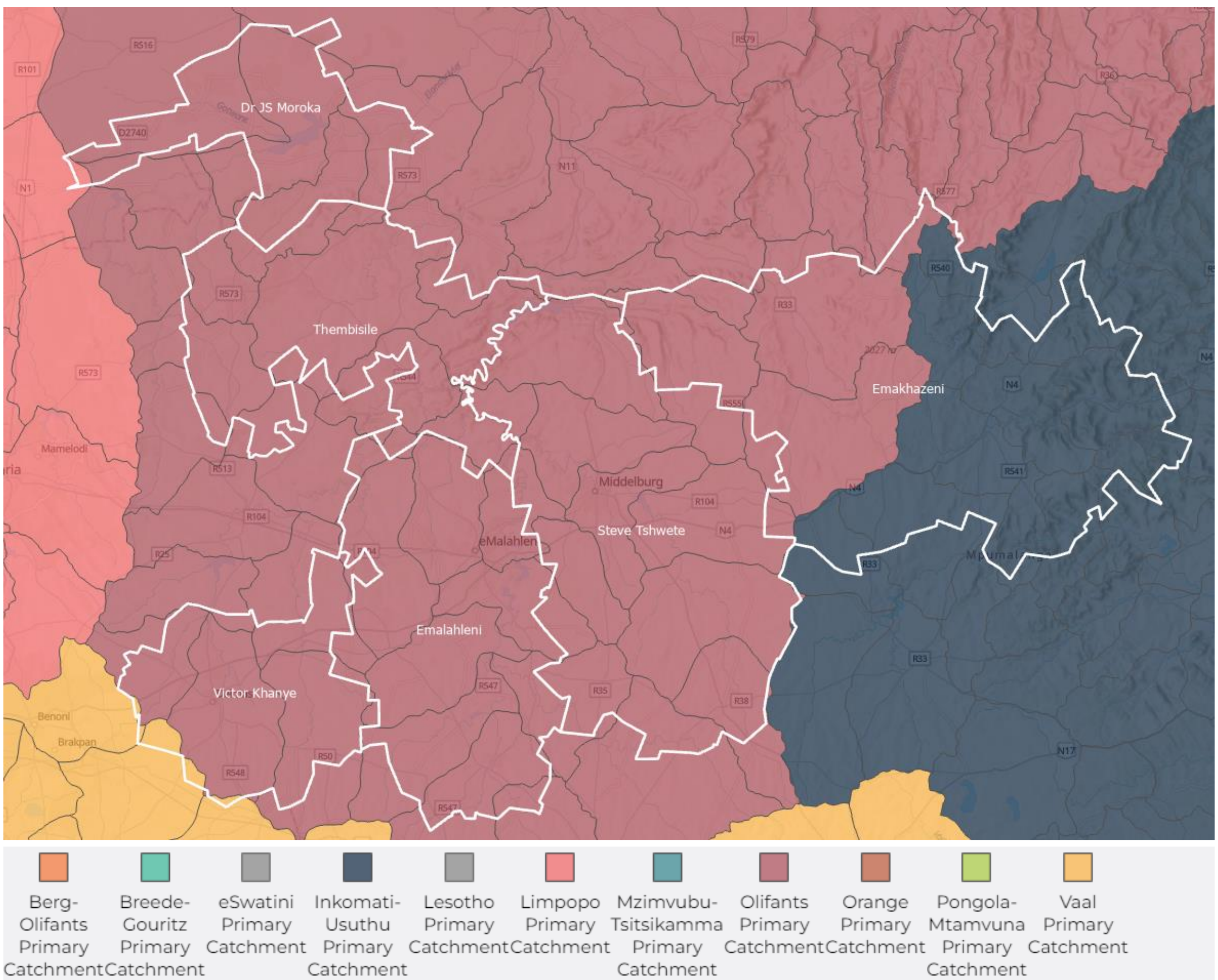

Figure 21: Quaternary catchments found in Nkangala District Municipality

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 Nkangala District, most towns are surface water dependent with a few that use a combination of surface water and groundwater sources.

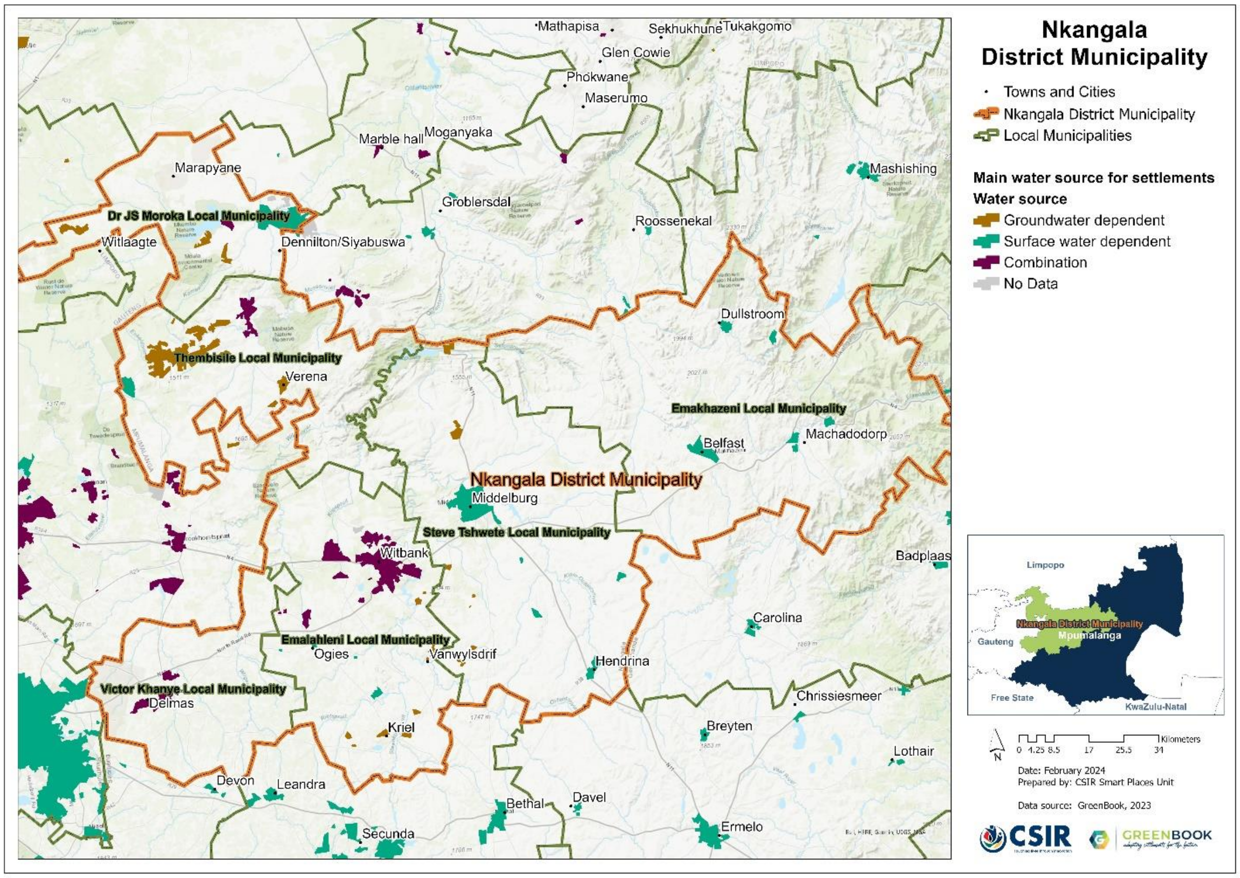

Figure 22: Main water source for settlements in the Nkangala District Municipality

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 across the Nkangala District Municipality (see Figure 23).

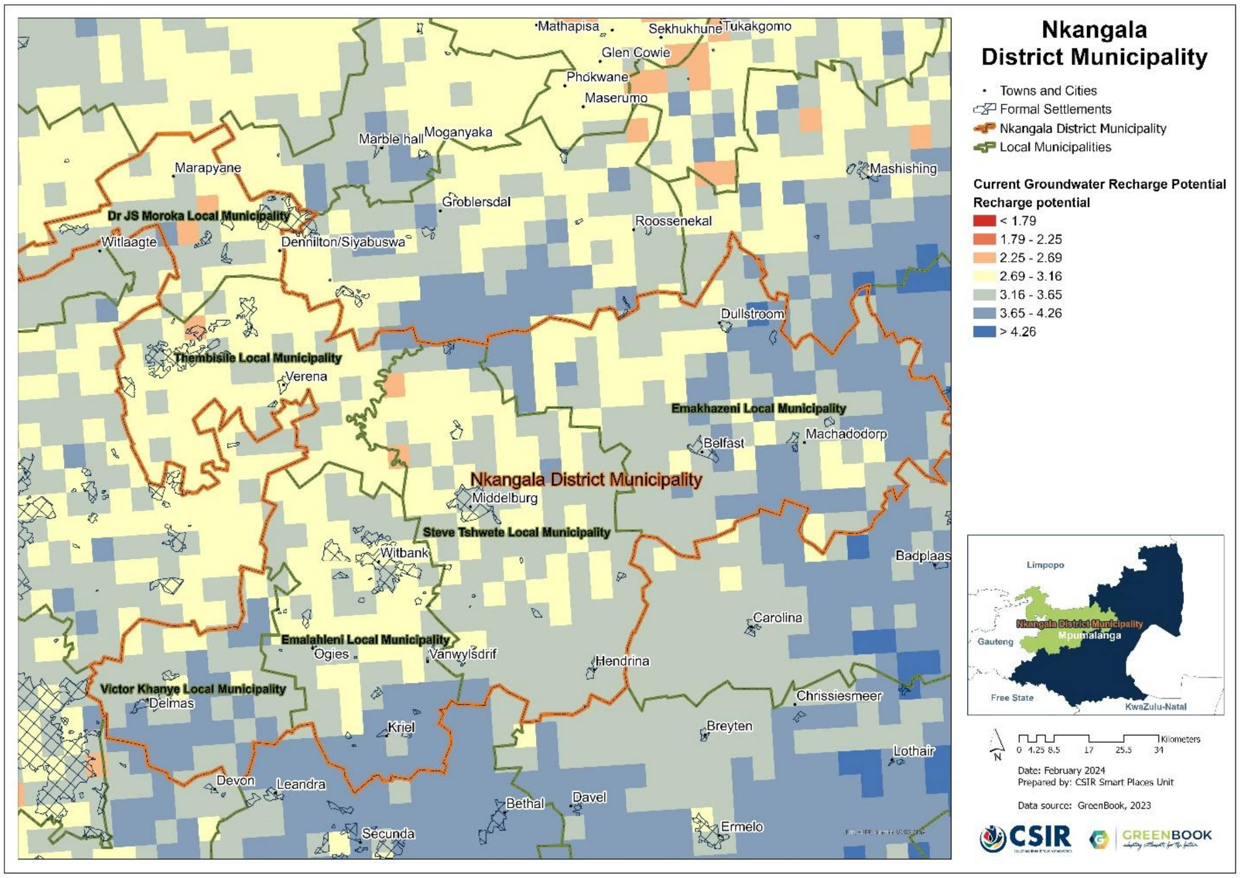

Figure 23: Groundwater recharge potential across Nkangala District Municipality under current (baseline) climatic conditions

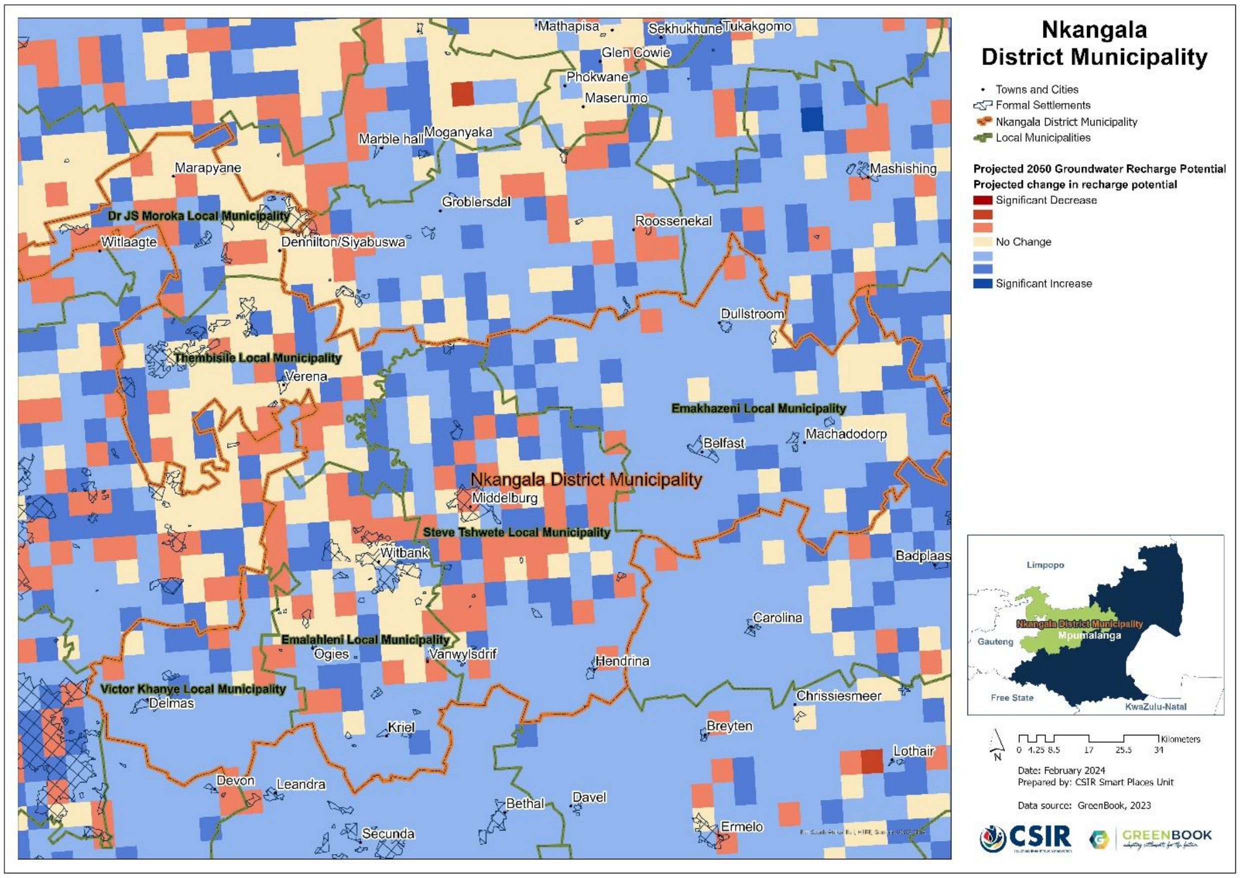

Figure 24: Projected changes in groundwater recharge potential from baseline climatic conditions to the future across Nkangala District Municipality

Emalahleni and Thembisile Hani municipalities are expected to have moderate to low risk of groundwater depletion (see Figure 25) based on the anticipated pressure from population growth.

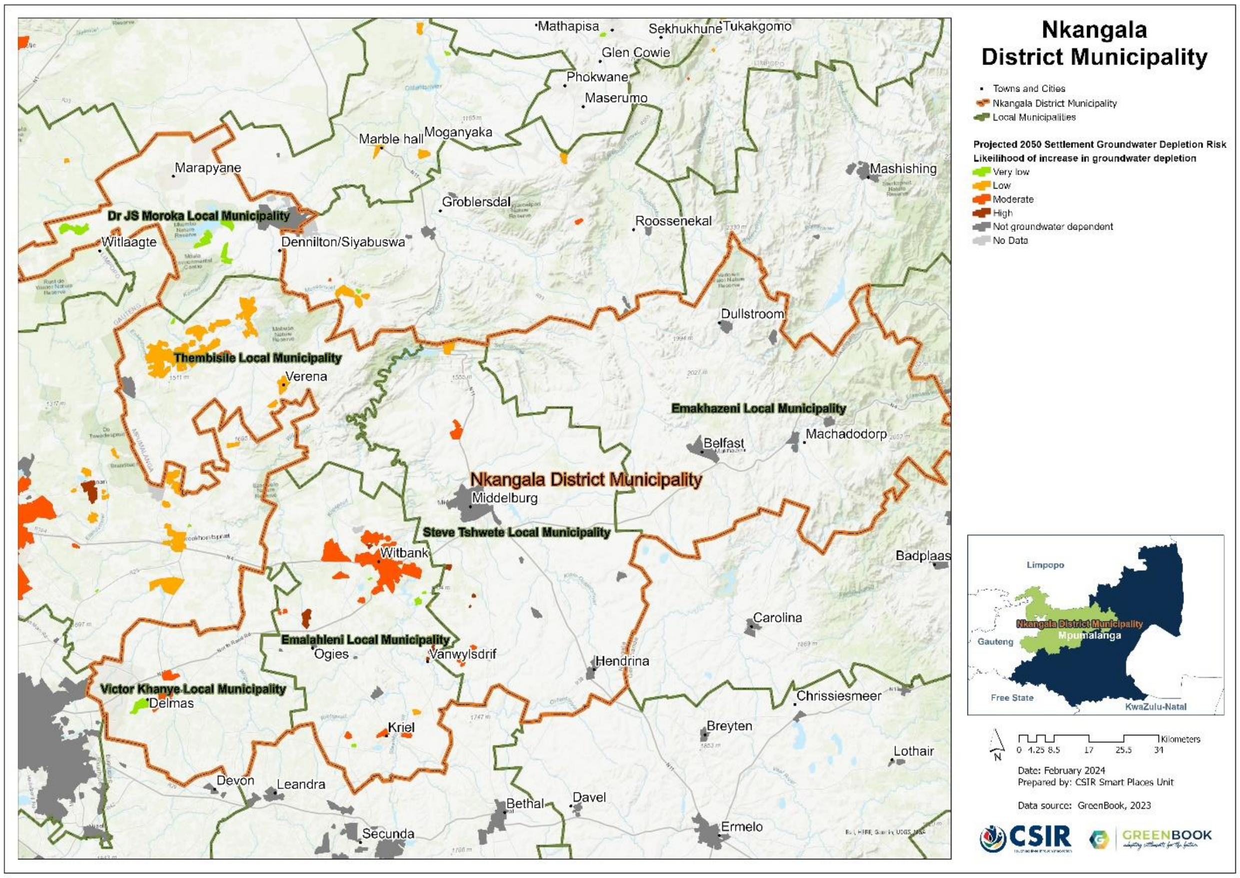

Figure 25: Groundwater depletion risk at settlement level across Nkangala District Municipality

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

Local Municipality	Water Demand per Capita (l/p/d)	Water Supply per Capita (l/p/d)	Current Water Supply Vulnerability
Emalahleni	549.06	614.68	0.89
Thembisile Hani	168.93	184.25	0.92
Dr JS Moroka	129.08	145.12	0.89
Steve Tshwete	147.7	161.87	0.91
Victor Khanye	103.56	193.35	0.54
Emakhazeni	297.66	195.54	1.52

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.

Emalahleni

The current water supply in Emalahleni LM exceeds the demand, as presented in Table 4. Additionally, the future water supply situation in the municipality looks promising, as the supply is expected to remain consistently higher than the demand even under a medium population growth scenario. However, high population growth remains an important factor that could potentially affect water supply vulnerability in the municipality.

Thembisile Hani

The current water supply in Thembisile Hani LM is greater than the demand, according to Table 4. However, the water demand in the municipality is very close to exceeding the water supply. Additionally, due to predicted changes in annual precipitation and increases in mean annual evaporation, coupled with population growth forecasts, the future water supply situation in the municipality is vulnerable to meeting demand.

Dr JS Moroka

Dr JS Moroka Local Municipality's water demand is currently lower than its supply (Table 4). The future water supply situation in the municipality is favourable, with supply projected to be consistently higher than demand The future water supply situation in the municipality looks promising, as the supply is expected to remain consistently higher than the demand under all scenarios. Contributing factors are the large population declines projected into the future that will lower water demand, although a projected decline in mean annual precipitation and an increase in mean annual evaporation may also have a bearing on water supply.

Steve Tshwete

According to Table 4, the current water supply in Thembisile Hani LM is greater than the demand. However, the municipality is at a serious risk of water supply vulnerability as the demand for water is very close to exceeding the supply. This vulnerability is driven by projected extreme population growth pressure, a decrease in average annual rainfall, and increased evaporation.

Victor Khanye

Of all local municipalities in the Nkangala District, Victor Khanye LM has the lowest current water supply vulnerability.

Emakhazeni

Emakhazeni LM currently has the highest current water supply vulnerability among all local municipalities in the Nkangala District, with demand significantly exceeding supply.

2.4.2. Agriculture, forestry, and fisheries

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

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

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

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.

Emalahleni

In Emalahleni LM, the AFF sector contributes 0.35% to the local GVA, which is a contribution of 0.24 % to the national GVA for the AFF sector. Of the total employment, 1.94 % is within the AFF sector. The main agricultural products in the area are beef cattle, maize for grain, and cultivated and wild flowers. Climate projections predict a generally hotter and drier climate in the region, which could lead to potential yield reductions for beef cattle due to a decline in rainfall and increasing temperatures. While there may be a potential increase in maize yield in the near future, towards 2050, heat stress can negatively impact production. For cultivated and wild flowers, increased production costs may become associated with irrigation and maintaining optimal seasonal temperatures.

Thembisile Hani

In Thembisile Hani LM, the AFF sector contributes 0.98 % to the local GVA, which is a contribution of 0.09 % to the national GVA for the AFF sector. Of the total employment, 1.92 % is within the AFF sector. The primary agricultural commodities in this region are beef cattle and maize for grain. Climate projections indicate that the climate will become hotter and wetter in the future, potentially leading to increased water availability for beef cattle. However, elevated temperatures and humidity could also promote the spread of diseases and parasites, and reduce growth and reproduction performance due to heat stress. Additionally, there may be an increase in maize yield in the near future, but towards 2050, heat stress could negatively impact production.

Dr JS Moroka

In Dr JS Moroka LM, the AFF sector contributes 0.95% to the local GVA, which is a contribution of 0.06% to the national GVA for the AFF sector. Of the total employment, 2.28 % is within the AFF sector. The main agricultural commodities are beef cattle and maize for grain. Climate projections show a generally hotter and drier climate, becoming wetter into the future (at least up to 2050). This shift in climate may lead to a decline in the quality and quantity of veld/forage associated with reduced rainfall, affecting the growth and reproduction performance of beef cattle due to heat stress. Additionally, maize may experience potential yield reductions due to declining rainfall and increasing temperatures.

Steve Tshwete

In Steve Tshwete LM, the AFF sector contributes 1.05 % to the local GVA, which is a contribution of 0.36 % to the national GVA for the AFF sector. Of the total employment, 4.87 % is within the AFF sector. The main agricultural activities in the region revolve around the production of maize for grain, tobacco, and beef cattle. Climate projections indicate a generally hotter and wetter climate, but it is expected to become drier towards the end of the century. There is a potential increase in maize yield in the near future, but towards 2050, heat stress can negatively impact production. For tobacco, production remains viable as long as heat stress is managed. In the case of beef cattle, increased water availability is necessary. Hot and moist conditions can cause an increased spread of disease and parasites, which can lead to reduced growth and reproduction performance due to heat stress.

Victor Khanye

In Victor Khanye LM, the AFF sector contributes 5.03 % to the local GVA, which is a contribution of 0.3 % to the national GVA for the AFF sector. Of the total employment, 15.91 % is within the AFF sector. The main agricultural commodities in the area are chickens, maize for grain and cultivated as well as wild flowers. Climate projections indicate that there will be a generally hotter and wetter climate with more extreme rainfall events. For chicken farming, increased production costs are expected as there will be a need for increased investment in ventilation and cooling systems to maintain optimal seasonal temperatures and reduce the risk of heat stress on the birds. Heat stress can reduce body weight gain, reproduction efficiency, and egg quality. On the other hand, there is a potential increase in maize yield in the near future. However, towards 2050, heat stress can negatively impact maize production. For cultivated and wild flowers, there will be increased production costs associated with temperature regulation.

Emakhazeni

In Emakhazeni LM, the AFF sector contributes 7.17 % to the local GVA, which is a contribution of 0.27 % to the national GVA for the AFF sector. Of the total employment, 23.96 % is within the AFF sector. The main agricultural commodities in the area are maize for grain, beef cattle and aquaculture, particularly in the Dullstroom area. Climate projections show a generally hotter and drier climate, becoming wetter into the future (at least up to 2050). For maize for grain, there may be a reduction in potential yield due to a decline in rainfall and increasing temperatures. For beef cattle, there may be a deterioration of veld/forage quality and quantity associated with declining rainfall, along with reduced growth and reproduction performance due to heat stress. As for aquaculture, it is important to note that water temperature plays a crucial role in regulating fish species metabolism, reproduction success, and disease resistance. Increased water temperatures may impact the distribution or productivity of freshwater fish stocks.

3. Recommendations

The Nkangala District comprises six local municipalities and is primarily rural, comprising extensive farming, nature reserve and mining areas. While rich in natural resources, especially coal, the district faces environmental challenges such as unsustainable mining practices, pollution and habitat destruction from mining. Other key challenges in the district include limited infrastructure, underdeveloped rural areas, and an economy heavily reliant on natural resources. Extreme population growth pressure is also a concern, particularly in Emalahleni LM and Steve Tshwete LM, while stagnation and declining populations are projected for other municipalities in the district.

Climate projections indicate increasing temperatures and heightened risks of heat stress (particularly in the far north of the district, namely Dr JS Moroka LM), high likelihood for wildfires, and moderate flood risk which may impact agriculture, water supply, and population exposure and vulnerability to natural hazards. There are mixed signals regarding projections for rainfall over the region, indicating uncertainty around changes in future rainfall patterns.

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

1. To ensure water security and good water quality for human consumption and irrigation under a changing climate
2. To protect biodiversity and improve sustainable use of natural resources
3. To reduce the vulnerability and exposure and increase the adaptive capacity of human settlements to wildfires
4. To protect and increase the resilience of critical municipal infrastructure
5. To increase the resilience of the agricultural sector, including commercial, small-scale and subsistence farming systems.

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 the district. 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. Nkangala District Municipality, Municipal Profiles: District Development Model. Available from: https://www.cogta.gov.za/ddm/index.php/documents/

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

Department of Environmental Affairs (DEA). 2018. Nkangala 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. 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

Mpumalanga Province. 2016. Mpumalanga Climate Change Adaptation Strategy. Prepared by PEGASYS. Available from: https://letsrespondtoolkit.org/

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.

Nkangala District Municipality. 2018. Climate Change Vulnerability Assessment and Response Plan, Developed through the Local Government Climate Change Support Programme. Available from: https://letsrespondtoolkit.org/

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.