uMgungundlovu District Municipality

Risk Profile Report based on the GreenBook

31 July 2023

Report compiled by the CSIR
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List of Acronyms and Abbreviations

°C	Degree Celsius
AFF	Agriculture, Forestry, and Fisheries
AR5	Fifth Assessment Report
CABLE	CSIRO Atmosphere Biosphere Land Exchange model
CCAM	Conformal-cubic atmospheric model
CDM	Capricorn District Municipality
CDRF	Climate and Disaster Resilience Fund
CMIP5	Coupled Model Intercomparison Project 5
CoGTA	Department of Cooperative Governance and Traditional Affairs
CRVA	Climate Risk and Vulnerability Assessment
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEA	Department of Environmental Affairs
DM	District Municipality
DRR	Disaster Risk Reduction
DWS	Department of Water and Sanitation
EcVI	Economic Vulnerability Index
EnVI	Environmental Vulnerability Index
GCM	General circulation model
GRiMMS	Groundwater Drought Risk Mapping and Management System
GVA	Gross Value Added
GDP	Gross Domestic Product
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
KZN	KwaZulu-Natal
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
UMDM	uMgungundlovu District Municipality
WMAs	Water Management Areas

WMO	World Meteorological Organisation
WRYM	Water Resources Yield Model
WUI	Wildland-Urban Interface

Glossary of Terms

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

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

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

1. Introduction

This Climate Risk Profile report, as well as the accompanying draft Climate Change Adaptation Plan, were developed specifically for uMgungundlovu District Municipality (UMDM), to support its strategic climate change response agenda. Both documents are primarily informed by the GreenBook, which is an open-access online planning support system that provides quantitative scientific evidence in support of local government's pursuit in the planning and design of climate-resilient, hazard-resistant settlements. The GreenBook is an information-dense resource and planning support system offered to South African local governments to better understand their risks and vulnerabilities in relation to population growth, climate change, exposure to hazards, and vulnerability of critical resources. In addition to this, the GreenBook also provides appropriate adaptation measures that can be implemented in cities and towns, so that South African settlements are able to minimise the impact of climate hazards on communities and infrastructure, while also contributing to developmental goals (See Green Book l Adapting settlements for the future).

The GreenBook was initially co-funded by the International Development Research Centre (IDRC) and the Council for Scientific and Industrial Research (CSIR), i.e., from 2016-2019, and in partnership with the National Disaster Management Centre (NDMC). With more partners coming on board since 2019 to support further research and development, and the roll-out and uptake of the GreenBook. More recently, Santam, the Climate and Disaster Resilience Fund (CDRF), and the CSIR established the GreenBook Roll-out Initiative to facilitate the uptake of the GreenBook and support resilience-building within local government. The initiative aims to roll out the GreenBook to 32 District Municipalities (DMs) by 2025 by supporting each District's climate change response and adaptation planning and implementation efforts through the GreenBook. Each of the Districts targeted for support are guided along a value-chain towards the implementation of climate change response and adaptation plans in municipalities (See Figure 1 below). Thus, in fulfilment of steps four and five, each target DM is provided with a draft GreenBook Climate Risk Profile report, as well as a draft Climate Change Adaptation Plan.

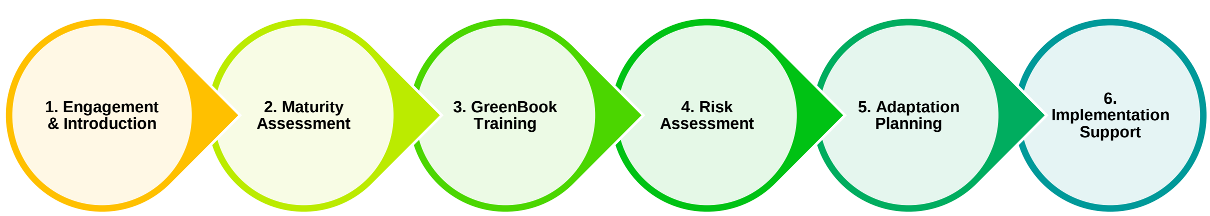


Figure 1: The Value-chain towards the implementation of climate change response and adaptation in municipalities

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

- Build and further the climate change response agenda,

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

1.1. Approach followed

The approach used in the GreenBook, and the Climate Risk Profile is centred around understanding climate-related risk. Climate-related risk implies the potential for adverse consequences resulting from the interaction of vulnerability, exposure, and the occurrence of a climate hazard (see Figure 2). "Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, and services (including ecosystem services, ecosystems and species)" (Chen, et al., 2021, p. 64). The components of risk are dynamic. Climate hazards are driven by natural climate variability and anthropogenic climate change. Human activity contributes to Greenhouse Gas emissions that increase temperatures and which in turn affects changes in the occurrence of climate hazards such as drought, flooding, coastal flooding, and heat extremes. Planned as well as unplanned development and growth of our settlements drive the exposure of people, as well as the built- and natural environment to climate hazards. Vulnerability includes the inherent characteristics that make systems sensitive to the effects and impacts of climate hazards. Municipal risk is driven by vulnerability and exposure to certain climate-related hazards.

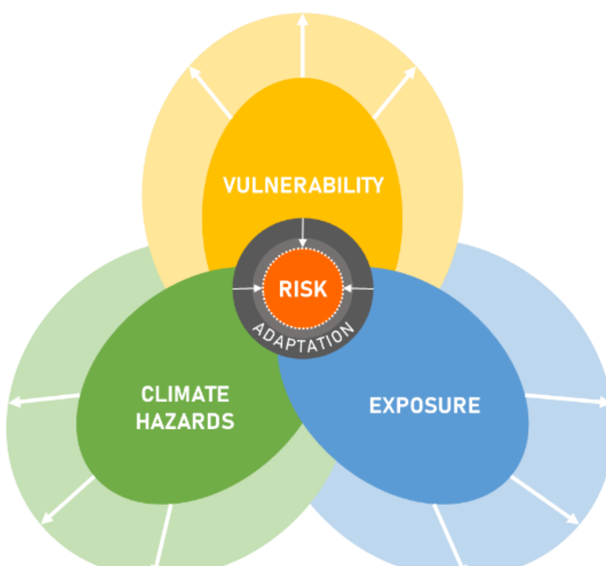


Figure 2: The interaction between the various components of risk, indicating the opportunity to reduce risk through adaptation (based on IPCC, 2014 and IPCC, 2021)

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

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

1.2. Policy framework

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

Furthermore, the National Climate Change Response White Paper – which outlines the country’s comprehensive plan to transition to a climate resilient, globally competitive, equitable and low-carbon economy and society through climate change adaptation- and mitigation, while simultaneously addressing the country’s key priorities, including job creation, poverty reduction, social equality and sustainable development, amongst others – identifies local governments as critical role players that can contribute towards effective climate change adaptation through their various functions, including “[the] planning [of] human settlements and urban development; the provision of municipal infrastructure and services; water and energy demand management; and local disaster response, amongst others.” (Republic of South Africa, 2011, p. 38). The Climate Change Bill takes it further by setting out reporting requirements on climate change response needs and interventions for every municipality in the country. The Bill also sets out requirements for every district intergovernmental forum to serve as a Municipal Forum on climate change that coordinates climate response actions and activities in its respective municipality.

The National Climate Change Adaptation Strategy outlines several actions in support of climate change adaptation, that are applicable at municipal level, including the development and implementation of adaptation strategies and vulnerability reduction programmes targeting communities and individuals that are most at risk to the impacts of climate change; the development of municipal early warning systems; as well as the integration of climate change adaptation measures into municipal development plans and relevant sector plans. The National Climate Risk and Vulnerability Assessment Framework – which is aimed at all actors, including local governments – guides the development and review of climate risk and vulnerability assessments (CRVAs) to enable alignment, aggregation and comparison across all CRVAs, in an effort to inform an integrated and effective climate change adaptation response across all scales and sectors.

1.3. District Municipal context

uMgungundlovu District Municipality (UMDM) (DC22) is one of 10 Districts Municipalities (DMs) within in the KwaZulu-Natal (KZN) Province, located approximately 80 km west of the eThekwini Metropolitan Municipality, and central to the KZN Midlands. The District covers approximately 9 603 km^2 and comprises of the following seven Local Municipalities (LMs): Msunduzi LM, uMshwathi LM, uMngeni LM, Richmond LM, Mkhambathini LM, Mpofana LM and Impendle LM (Figure 3). Along its western boundary, the District also adjoins the Kingdom of Lesotho and includes a portion of the uKhahlamba Drakensberg Park World Heritage Site (Ezemvelo KZN Wildlife, 2014).

With a mix of both rural and urban areas, the District is home to 10 % of the province's total population and has a population density of around 110 people per km^2 (UMDM, 2021; UMDM, 2022a). The Msunduzi LM is home to the majority of the District's population (UMDM, 2022a). Notable settlements located in the District are Pietermaritzburg, the seat of the District and the capital of the province, as well as smaller towns such as Howick, Nottingham Road, Mooi River, Wartburg, Impendle and Richmond. The N3, a major national transport/mobility corridor, traverses the District from the north-west to the south-east and serves to link KZN, and Durban Harbour, with the Free State as well as the country's industrial hub, Gauteng. The District is also very rich in terms of tourism and is hailed for having some of the best schools in the province (CoGTA, 2020).

UMDM contributes 10 % to KZN's Gross Value Added (GVA) and 12 % to its employment (CoGTA, 2020). The Gross Domestic Product (GDP) of the District is not equally distributed amongst the various economic sectors. The tertiary sector is the main driver of the UMDM economy, contributing 69 % to the District's economy, with the main industries being community and personal services, followed by trade, accommodation, finance and business services, with lesser contributions from the transport, storage, communications and government services sectors. The secondary sector, which makes up 23 %, consists predominantly of manufacturing activities, but also some utilities and construction activity. Manufacturing activities in the District are varied depending on the Local Municipality.

The primary sector contributes 7 % of the economy and comprises predominantly of agriculture and forestry (CoGTA, 2020; UMDM, 2022b). Approximately 33 % of land in the UMDM area is occupied by agriculture. Most of the commercial forestry takes place in the Richmond and uMshwathi LMs and to a lesser degree in the uMngeni LM (UMDM, 2017; UMDM, 2022a). The abundance of water resources in the form of six significant rivers and five major dams makes the area strategically important (DEA, 2018) in terms of supplying water to the industrial and logistics hub of eThekwini. These water resources, coupled with the high agricultural production potential of the land within District, puts UMDM into the country's top bracket for agriculture yield potential (CoGTA, 2020).

Some of the main development challenges facing the District, according to the UMDM Spatial Development Framework (SDF), include urbanisation and the associated informal settlements, poverty, service backlogs, environmental degradation, economic stagnation, general lack of investment in the rural areas, particularly traditional council areas, land issues, and deteriorating infrastructure (bulk infrastructure), mainly in the urban centres (UMDM, 2022a).

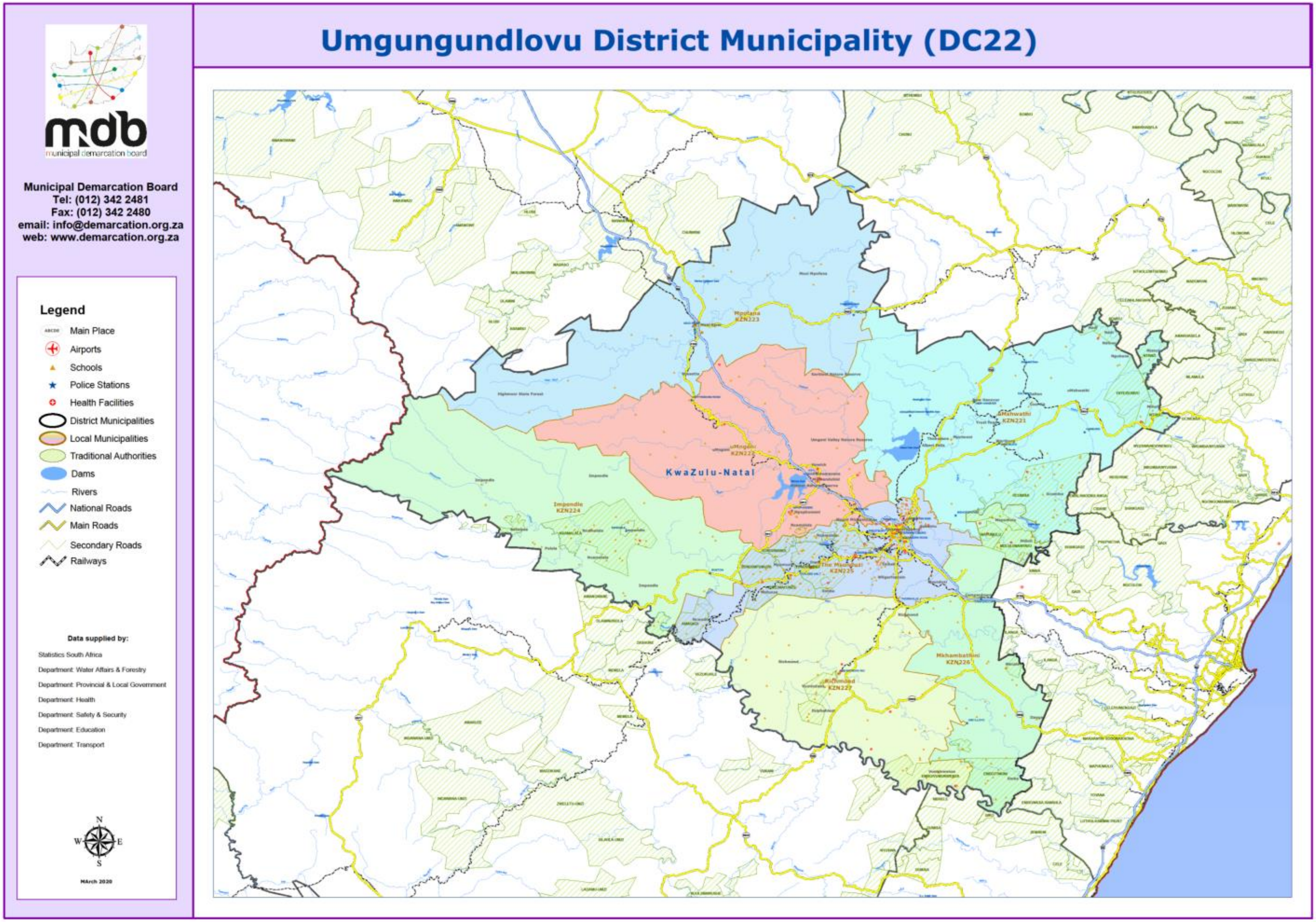


Figure 3: uMgungundlovu District Municipality (Municipal Demarcation Board, 2022), with Local Municipalities shaded in different colours

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 uMgungundlovu 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 uMgungundlovu 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 drives 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 uMgungundlovu District.

The Socio-Economic Vulnerability Index (SEVI) shows the vulnerability of households living in the municipality with regards to household composition, income composition, education, mobility, health, access to basic services, access to social government services, political instability, and safety and security of households. A high vulnerability score indicates municipalities that house a high number of vulnerable households with regards to their ability to withstand adverse shocks from the external environment.

The Economic Vulnerability Index (EcVI) speaks toward the economic resilience of the municipality, and considers economic sector diversification, the size of economy, labour force, the GDP growth/decline pressure experienced in the municipality, as well as the inequality present in the municipality. The higher the economic vulnerability the more susceptible these municipalities are to being adversely affected by external shocks.

The Physical Vulnerability Index (PVI) relates to the built environment and the connectedness of the settlements in the local municipality. It is a composite indicator that considers road infrastructure, housing types, the maintenance of the infrastructure, densities, and general accessibility. A high physical vulnerability score highlights areas of remoteness and or areas with structural vulnerabilities.

The Environmental Vulnerability Index (EnVI) highlights municipalities where there is a high conflict between preserving the natural environment and accommodating the growth pressures associated with population growth, urbanisation, and economic development. The index considers the human influence on the environment, the amount of ecological infrastructure present that needs protection, the presence of critical water resources, environmental health, and environmental governance. A high vulnerability score highlights municipalities that experience increasing pressure relating to protecting the environment and allowing land use change due to growth pressures.

Each municipality in the uMgungundlovu 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 uMgungundlovu District Municipality

LOCAL MUNICIPALITY	SEVI 1996	SEVI 2011	Trend	EcVI 1996	EcVI 2011	Trend	PVI	Trend	EnVI	Trend
Mpofana	5.8	5.7	↘	3.9	4.5	↗	4.2	N/A	6.8	N/A
Impendle	6.8	7.6	↗	5.5	4.4	↘	4.8	N/A	9.4	N/A
uMngeni	4.0	3.6	↘	4.9	6.2	↗	5.0	N/A	7.1	N/A
uMshwathi	7.4	6.9	↘	7.2	4.8	↘	5.3	N/A	4.8	N/A
The Msunduzi	3.9	3.9	↘	5.4	6.3	↗	4.9	N/A	7.0	N/A
Richmond	6.9	6.8	↘	7.1	4.5	↘	5.2	N/A	3.7	N/A
Mkhambathini	10.0	9.4	↘	6.9	4.7	↘	4.3	N/A	3.2	N/A

A major challenge in the District is the overwhelming prevalence of poverty (COGTA, 2020), and this is evident in the District's high average socio-economic vulnerability. Socio-economic vulnerability (SEVI) has remained high and fairly constant across all seven of the Local Municipalities within uMgungundlovu District (Table 1), from an average of 6.4 in 1996 to 6.3 in 2011. The only Municipality to have shown a significant increase (worsening) in socio-economic vulnerability over these years was Impendle, the Municipality with the largest population located in traditional authority areas. The Local Municipality the with highest socio-economic vulnerability in the District was Mkhambathini LM. In both 1996 and 2011, Mkhambathini LM had amongst the highest socio-economic vulnerability of all Municipalities in the country due to its high rates of child-headed households, unemployment, poor healthcare and child mortality, low levels of literacy and education, as well as high incidence of violent crimes. Impendle LM, uMshwathi LM and Richmond LM also have notably high socio-economic vulnerability.

On average, economic vulnerability (EcVI) within uMgungundlovu District saw a decrease (improvement) between 1996 and 2011, from 5.8 to 5.1, although the trend signal for individual Local Municipalities was highly varied, with three Municipalises seeing an increase (worsening), namely Mpofana LM, Msunduzi LM and uMngeni LM, while four Municipalities saw a decrease (improvement), namely Impendle LM, uMshwathi LM, Richmond LM and Mkhambathini LM (Table 1). In 2011, Msunduzi LM and uMngeni LM had the highest economic vulnerability in the District, and amongst the highest in the province. Both Local Municipalities saw a considerable increase in economic vulnerability from 1996 to 2011 due the relatively small size of their economies in combination with low GDP growth, high labour force unemployment and high levels of income inequality.

uMgungundlovu District has an average physical vulnerability (PVI) of 4.8, and an average environmental vulnerability (EnVI) of 6.0 across all seven Local Municipalities. Notably, Impendle LM has amongst the highest environmental vulnerabilities of all Municipalities in the country (Table 1). Located at the foot of the Drakensberg mountains, bordering Lesotho to the north-west, the area has a rich and complex ecological infrastructure and is extremely diverse in its topography, climate and soil. Its location as a highland makes the area an important water source area within the KZN province and the country as a whole. The Municipality falls within the catchment areas of the Umkhomazi River in the south and the Umgeni River in the north-east, both of which have been flagged as critically stressed, contributing to the municipality's environmental vulnerability.

2.1.2. Settlement vulnerability

The unique set of indicators outlined below highlight the multi-dimensional vulnerabilities of the settlements within the uMgungundlovu District and its Local Municipalities, with regards to six composite indicators. This enables the investigation of the relative vulnerabilities of settlements within the District.

A high vulnerability score (closer to 10) indicates a scenario where an undesirable state is present, e.g., low access to services, high socio-economic vulnerabilities, poor regional connectivity, environmental pressure or high economic pressures. An indicator of growth pressure, providing a temporal dimension (15-year trend), was added to show which settlements were experiencing growth pressures on top of the other dimensional vulnerabilities up to 2011.

The Socio-Economic Vulnerability Index comprises of three indicators (and eight variables) that show the vulnerability of households occupying a specific settlement with regards to their (1) household composition (household size, age dependency, female/child headed household), (2) income composition (poverty level, unemployment status, and grant dependency of the households), as well as (3) their education (literacy and level of education).

The Economic Vulnerability Index comprises of five variables grouped into three indicators that highlight the economic vulnerability of each settlement with regards to (1) its size (GDP per capita and GDP production rates), (2) the active labour force (taking note of unemployed and discouraged work seekers), and (3) the GDP growth rate for the past 15 years.

The Environmental Vulnerability Index considers the footprint composition of the settlement taking the ratio of built-up versus open spaces into account.

The Growth-Pressure Vulnerability Index shows the relative (1996-2011 growth rates) and anticipated pressure on settlements.

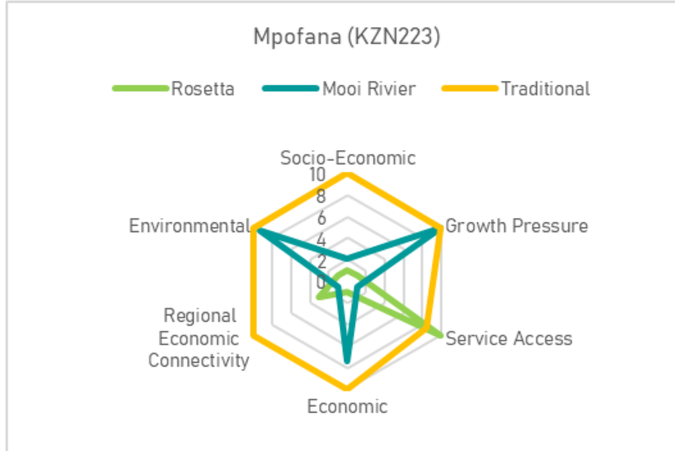
The Regional Economic Connectivity Vulnerability Index looks at the regional infrastructure of each settlement (measured through a remoteness/accessibility index), as well as the role of the town in terms of its regional economy.

The Service Access Vulnerability Index comprises of 10 variables grouped into four indictors, that show the level of services offered and rendered within a settlement and it includes the settlement's (1) access to basic services (electricity, water, sanitation, and refuse removal), (2) the settlement's access to social and government services (health access, emergency service access, access to schools, and early childhood development), (3) access to higher order education facilities, and (4) access to adequate housing.

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

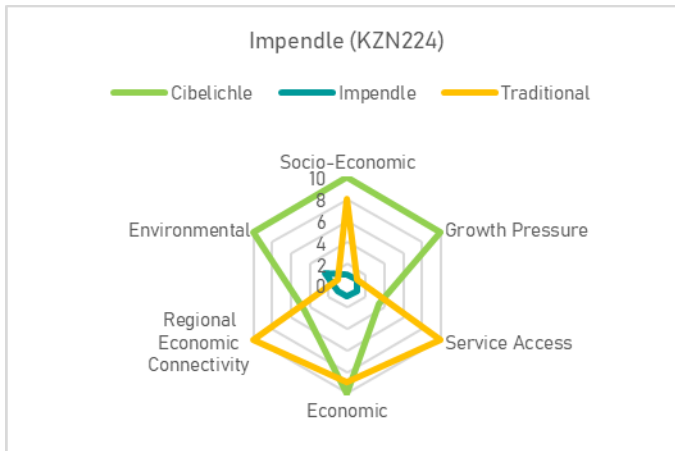
Mpofana

The major settlements in this Local Municipality are Rosetta and Mooi River. Mooi River is the larger settlement in size and faces the greatest growth pressure combined with high economic and environmental vulnerability. Rosetta faces the greatest vulnerability to low service access.



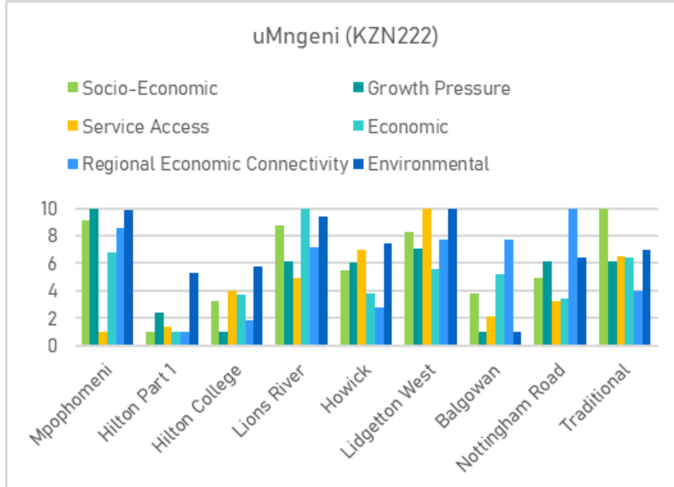
Impendle

Impendle LM is made up largely of traditional settlements (home to 81.9 % of the population). Other settlements include Impendle settlement and Cibelichle. Cibelichle is faced with high growth pressure, together with high socio-economic and economic vulnerability. It also faces high environmental vulnerability. The traditional areas are also faced with high socio-economic and economic vulnerability, together with low levels of service access and poor regional economic activity.



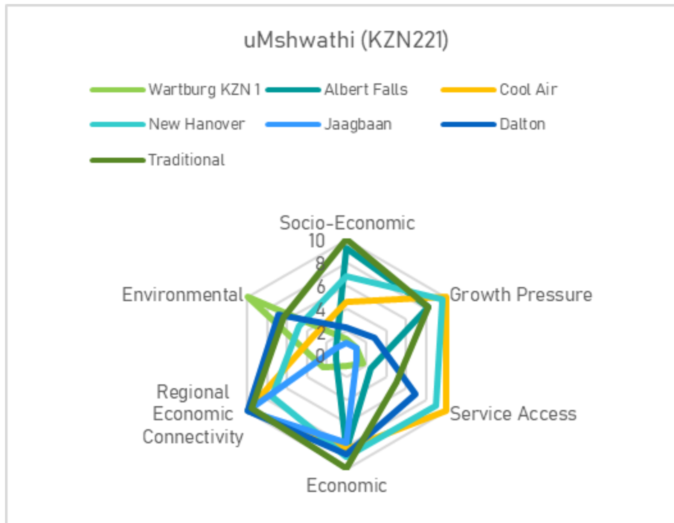
uMngeni

The major settlements in this Local Municipality are Howick and Nottingham Road. Nottingham Road has the poorest regional economic connectivity of all settlements in the Municipality. Howick has moderate service access vulnerability. Both settlements face low to moderate growth pressure, socio-economic vulnerability and economic vulnerability.



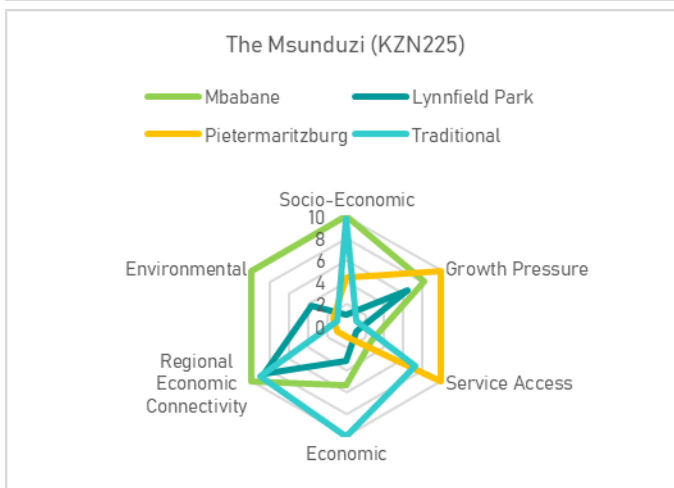
uMshwathi

The major settlements in this Local Municipality include Albert Falls, New Hanover and Dalton. New Hanover faces large service access vulnerability combined with high growth pressure, socio-economic vulnerability, although Albert Falls has one of the largest socio-economic vulnerabilities of settlements in the LM. Dalton faces poor regional connectivity. All three settlements face high economic vulnerability.



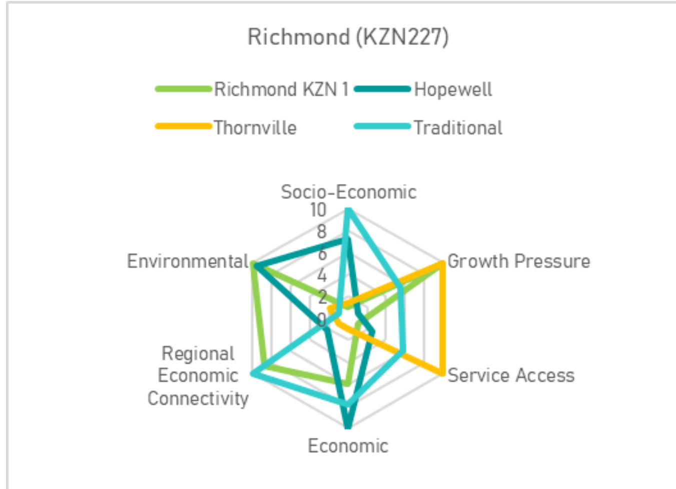
The Msunduzi

The main settlement in the Msunduzi LM is Pietermaritzburg, which faces the greatest growth pressure, combined with high service access vulnerability.



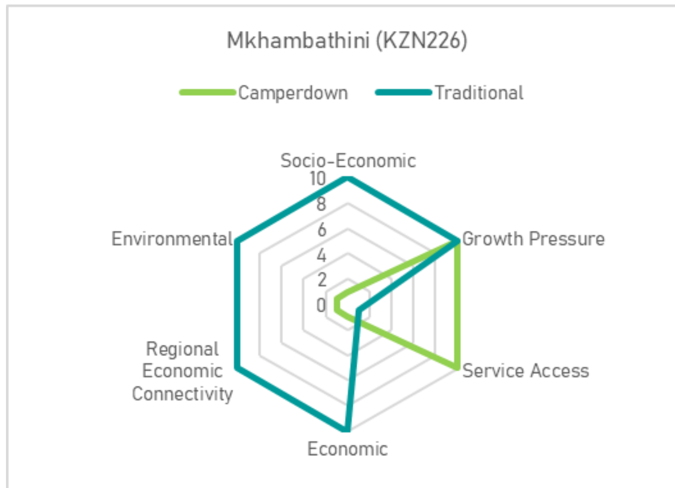
Richmond

Settlements in Richmond include Richmond town, Hopewell and Thornville. Hopewell faces the greatest economic vulnerability combined with high environmental pressure and high socio-economic vulnerability. Richmond and Thornville are faced with high growth pressure, while the traditional areas (55.36% of the population) have the highest socio-economic vulnerability and poor regional connectivity.



Mkhambathini

The major settlement in this Local Municipality is Camperdown, while 66.65 % of the population live in traditional areas. Camperdown notably faces high growth pressure coupled with high service access vulnerability.



2.1.3. Population growth pressure

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

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

Table 2: Population growth pressure across uMgungundlovu District Municipality

Population per municipality	2011	Medium Growth Scenario	
		2030	2050
Mpofana	34 515	48 926	60 328
Impendle	30 517	26 702	19 276
uMngeni	92 878	159 195	236 088
uMshwathi	107 212	120 742	115 403
The Msunduzi	621 205	874 329	1 065 670
Richmond	65 631	83 762	90 587
Mkhambathini	54 540	74 035	88 935
uMgungundlovu DM Total	1 006 498	1 387 691	1 676 287

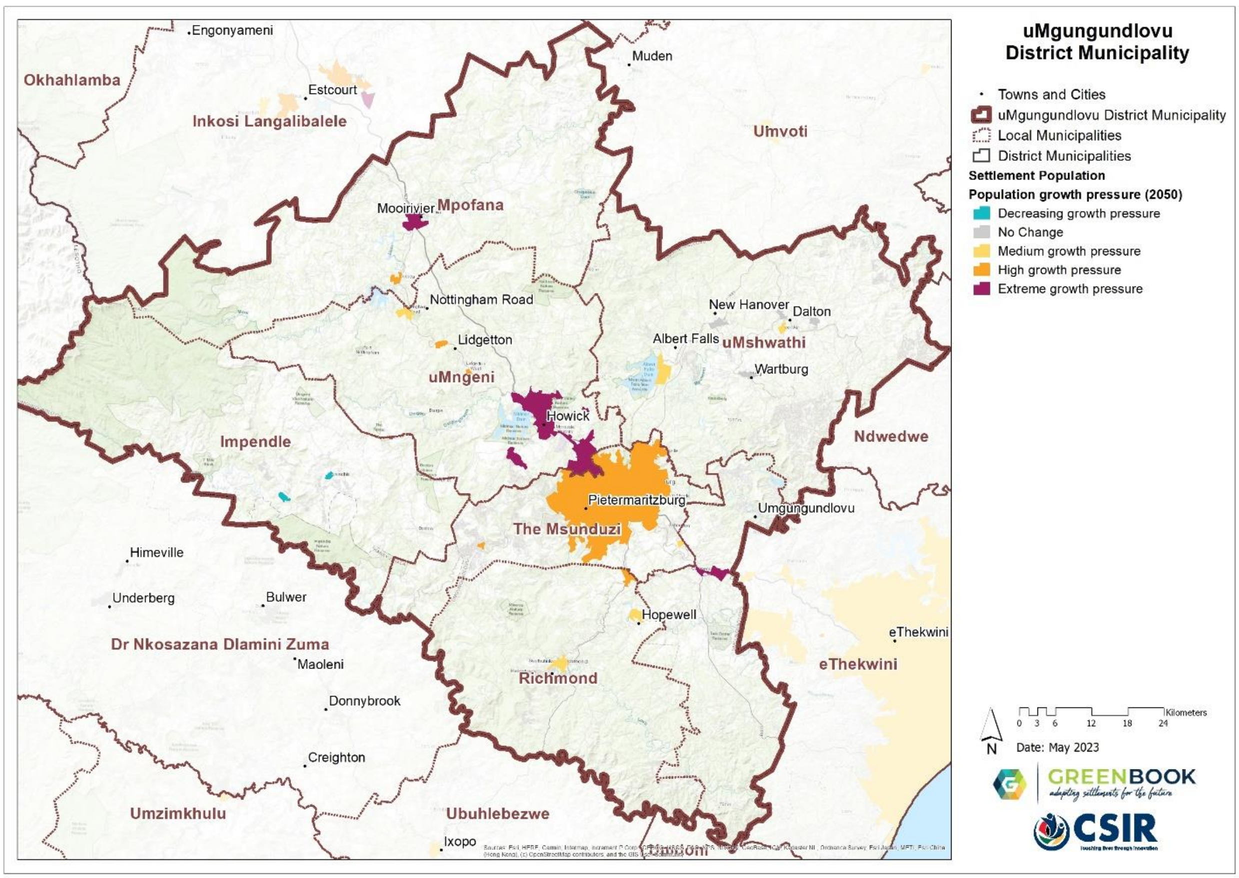


Figure 4: Settlement-level population growth pressure across uMgungundlovu District Municipality

Under the GreenBook's medium growth scenario, the total population of UMDM is projected to reach just over 1.38 million people by 2030, and 1.67 million people by 2050 (Table 2), a projected increase of 67 % from 2011 to 2050. In absolute terms, most of this growth will take place in two

Local Municipalities, namely Msunduzi LM and uMngeni LM. The Msunduzi LM (in which Pietermaritzburg, the capital and second-largest city in the province of KwaZulu-Natal falls) could see population growth of almost half a million people by 2050, an increase of 72 % from its population recorded in 2011. This will put the large regional centre of Pietermaritzburg under high growth pressure (Figure 4) as it tries to keep up with housing and service delivery needs of the growing population. In the centre of the District, the population of uMngeni LM is one of five Municipalities in the province projected to increase by over 100 % (154 % in the case of uMngeni LM). Most of the growth is projected to occur in Howick and Hilton, and will put the area under extreme growth pressure. Other settlements in the District that may see extreme growth pressures up to 2050, include Mooi River, Mpophomeni, and Camperdown. Impendle is the only Local Municipality projected to possibly see a decline in population between 2011 and 2050 for all settlements. Figure 4 depicts the growth pressures that the settlements across the Municipalities will likely experience.

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

2.2.1.Temperature

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

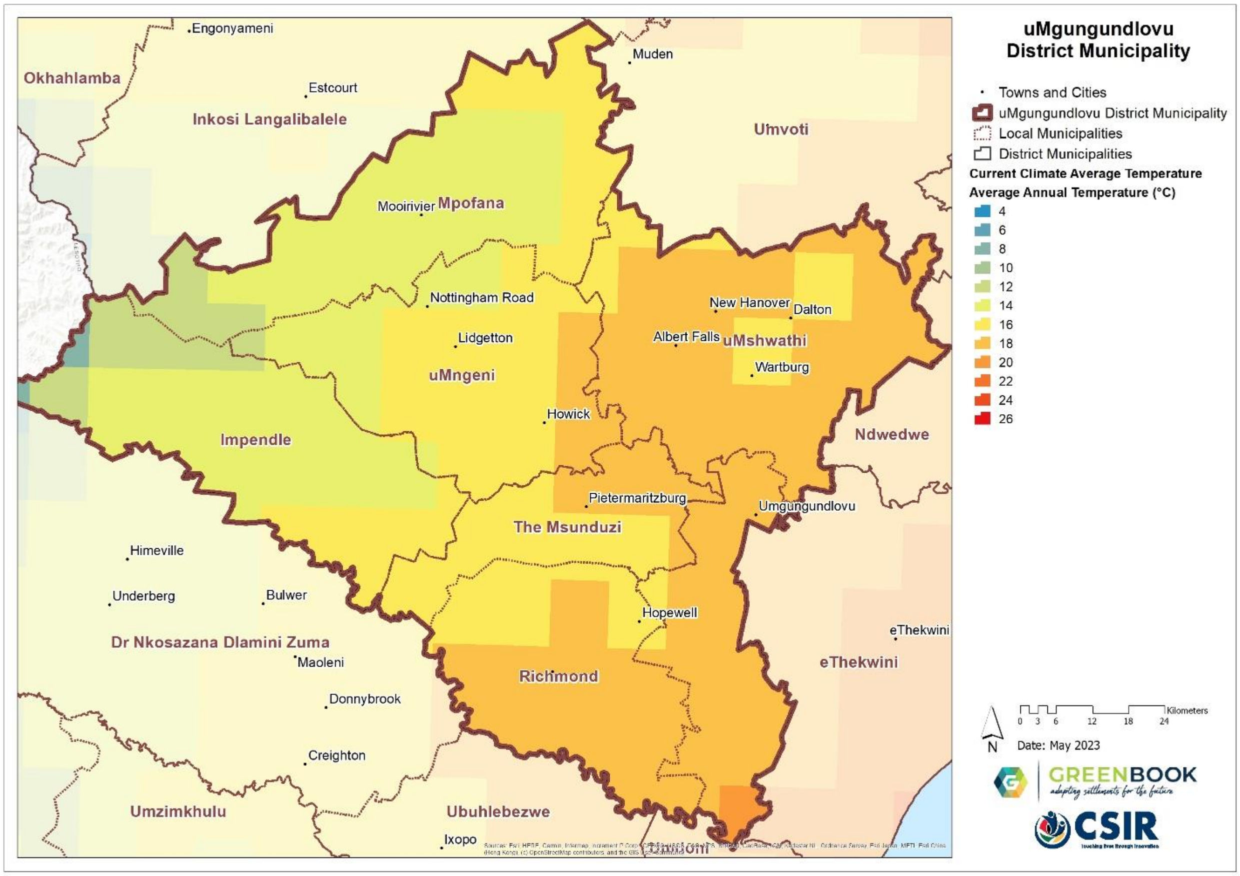


Figure 5: Average annual temperature (°C) for the baseline period 1961-1990 for uMgungundlovu District Municipality

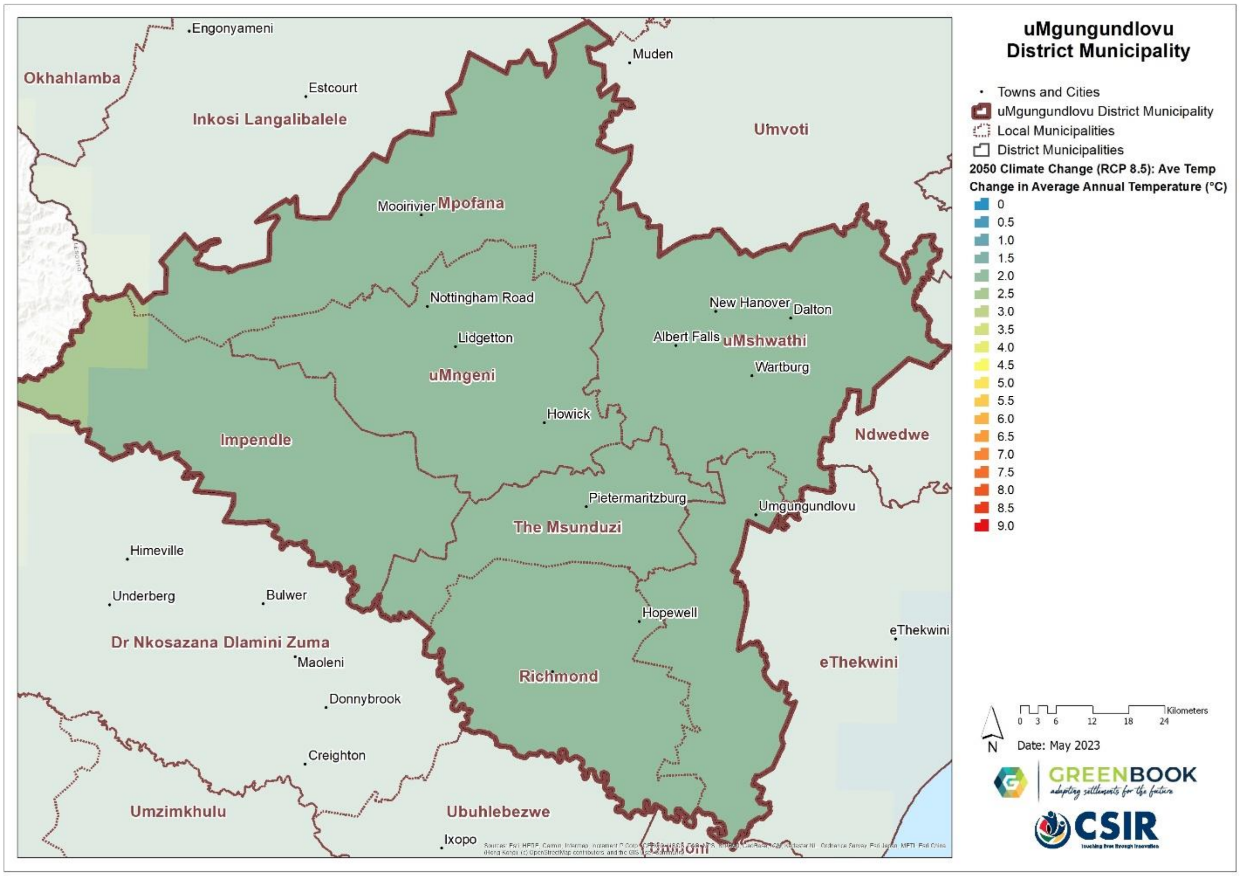


Figure 6: Projected change in average annual temperature (°C) from the baseline period 1961-1990 to the future period 2021-2050 for uMgungundlovu District Municipality, assuming an RCP 8.5 emissions pathway

The District experiences current average annual temperatures of between 7 °C and 18 °C along an east-west temperature gradient, with higher annual averages to the east of the District, and cooler temperature towards the more mountainous west (Figure 5). The projections show average annual temperature increases of between 2.36 °C and 3.08 °C across the District by 2050 under a low mitigation scenario (RCP 8.5; Figure 6).

2.2.2. Rainfall

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

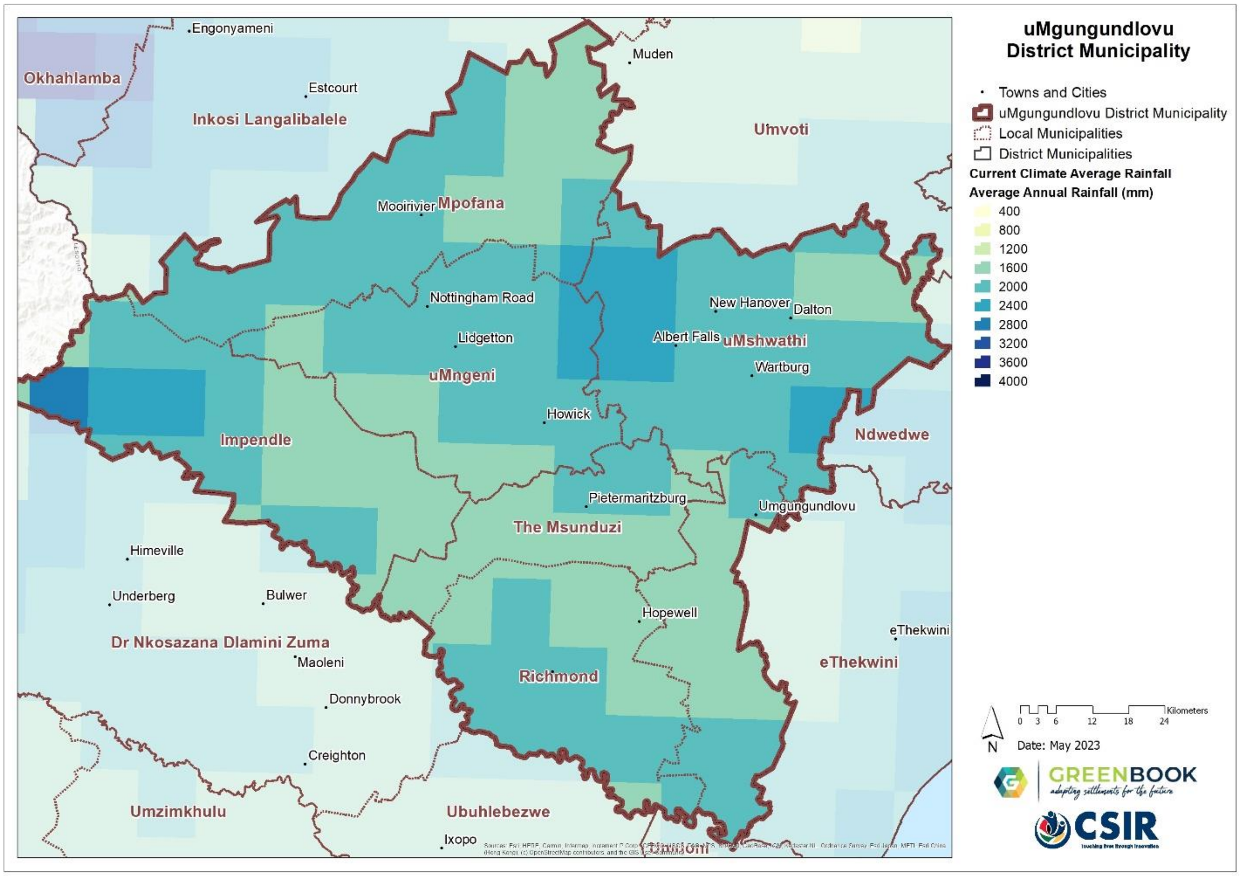


Figure 7: Average annual rainfall (mm) for the baseline period 1961-1990 for uMgungundlovu District Municipality

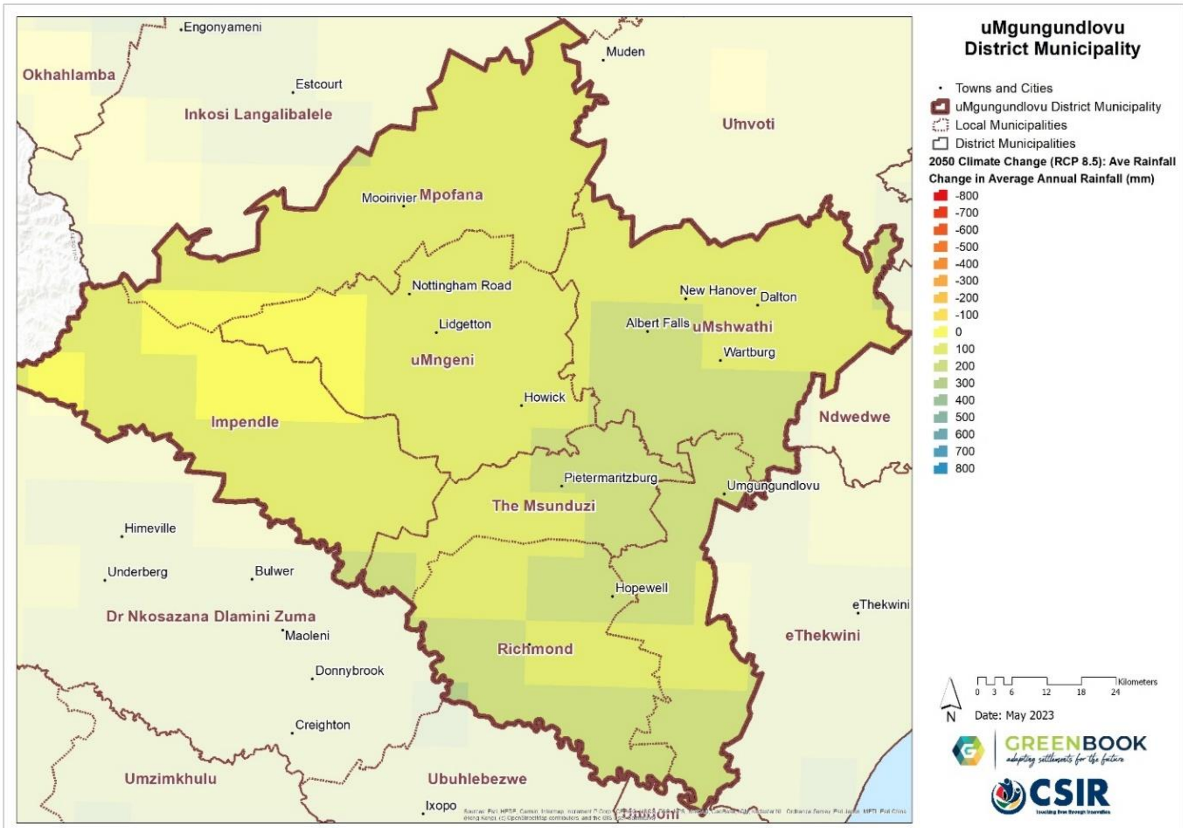


Figure 8: Projected change in average annual rainfall (mm) from the baseline period to the period 2021-2050 for uMgungundlovu District Municipality, assuming an RCP8.5 emissions pathway

The District experiences high current average annual rainfall of between 1 308 mm and 2 550 mm (Figure 7). Climate change projections show a mixed rainfall signal over the region, with average annual rainfall changes of between a decrease of -104 mm to an increase of 165 mm, possible by 2050 under a low mitigation (i.e., a "business as usual" greenhouse gas emissions) scenario (Figure 8).

2.3. Climate Hazards

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

2.3.1. Drought

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

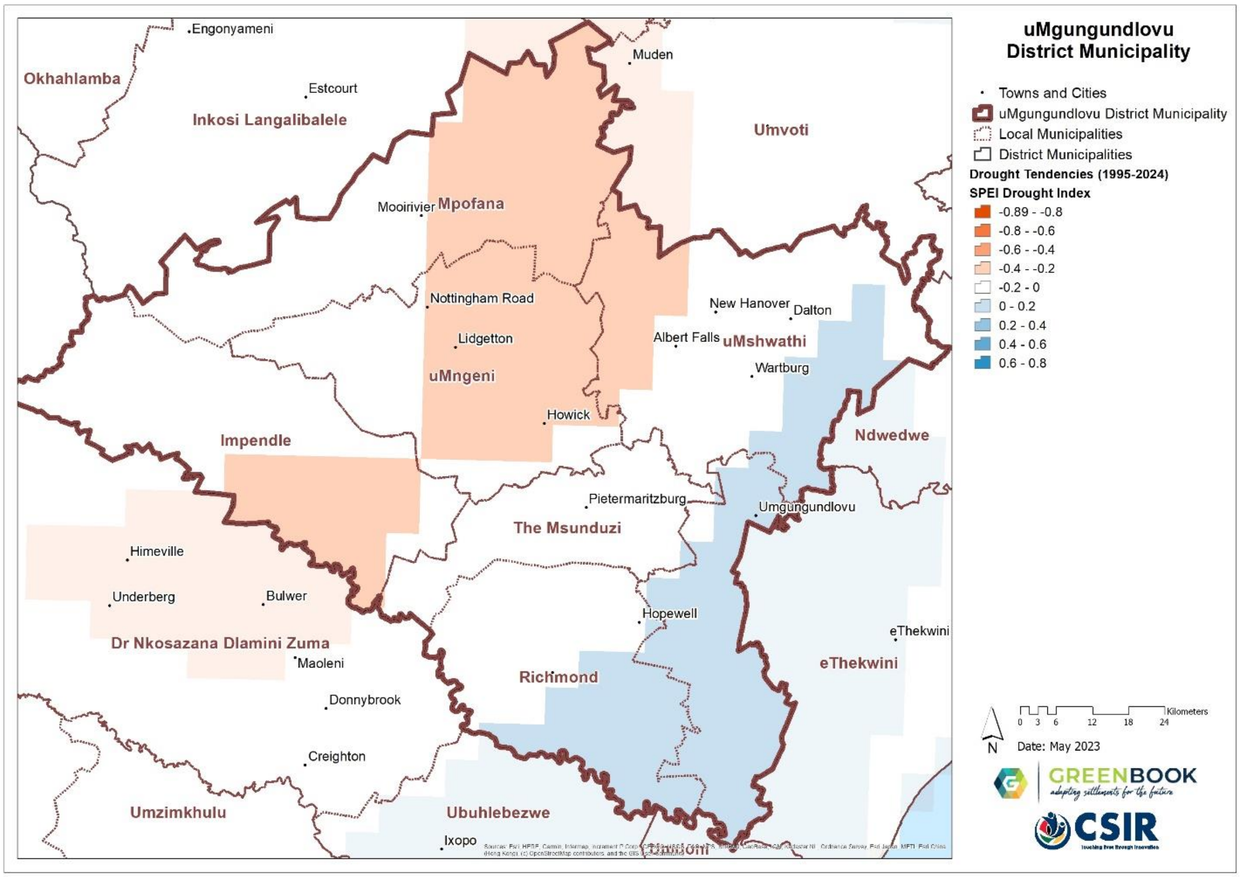


Figure 9: Drought tendencies for the period 1995-2024 relative to the baseline period 1986-2005 across the uMgungundlovu District Municipality

Figure 9 depicts the projected change in drought tendencies (i.e., the number of cases exceeding near-normal per decade) for the period 1995-2024, relative to the 1986-2005 baseline period, under a low mitigation 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.

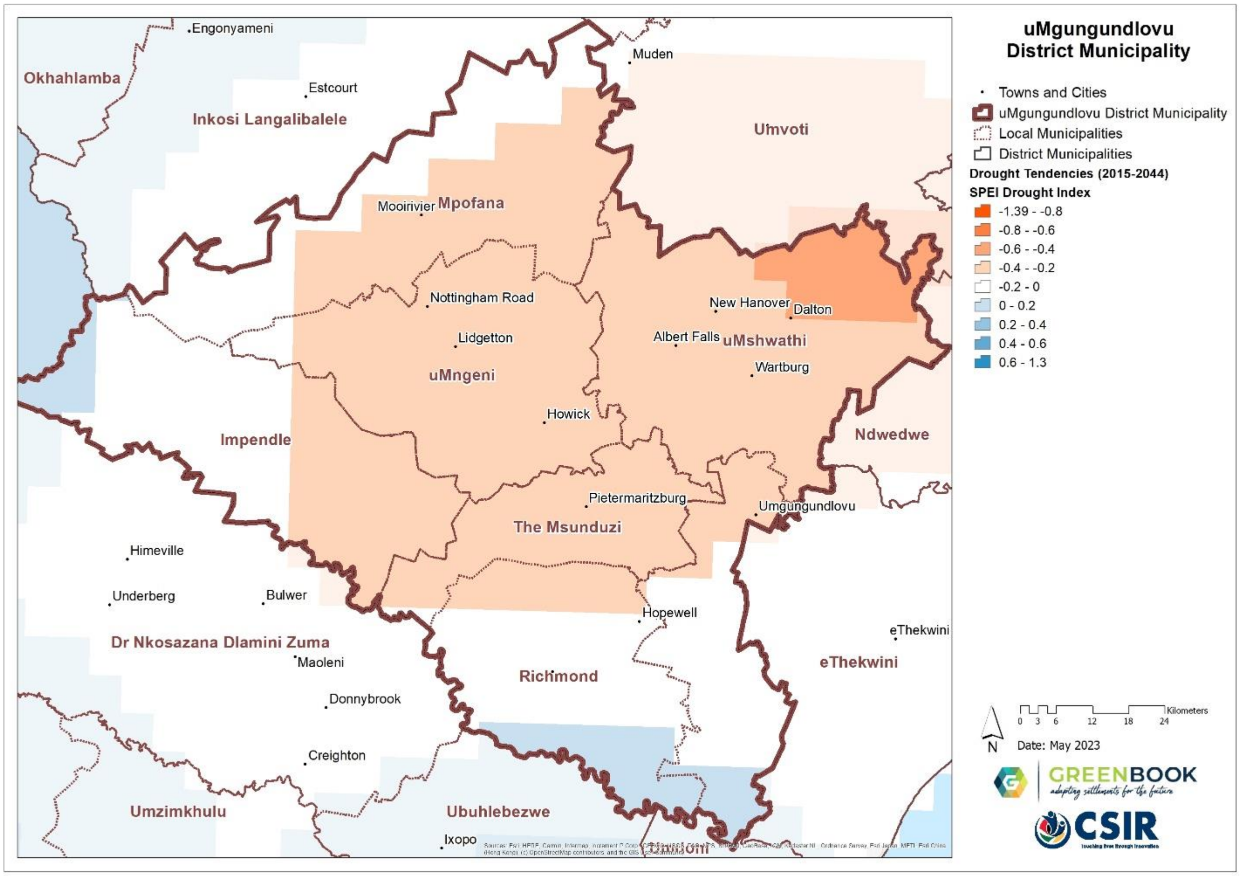


Figure 10: Projected drought tendencies for the period 2015-2044 relative to the baseline period for uMgungundlovu District Municipality

Figure 10 depicts the projected change in drought tendencies (i.e., the number of cases exceeding near-normal per decade) for the period 2015–20444 relative to the 1986–2005 baseline period, under the low mitigation "business as usual" emissions scenario (RCP 8.5). A negative value is indicative of an increase in drought tendencies per 10 years (more frequent than baseline) with a positive value indicative of a decrease in drought tendencies.

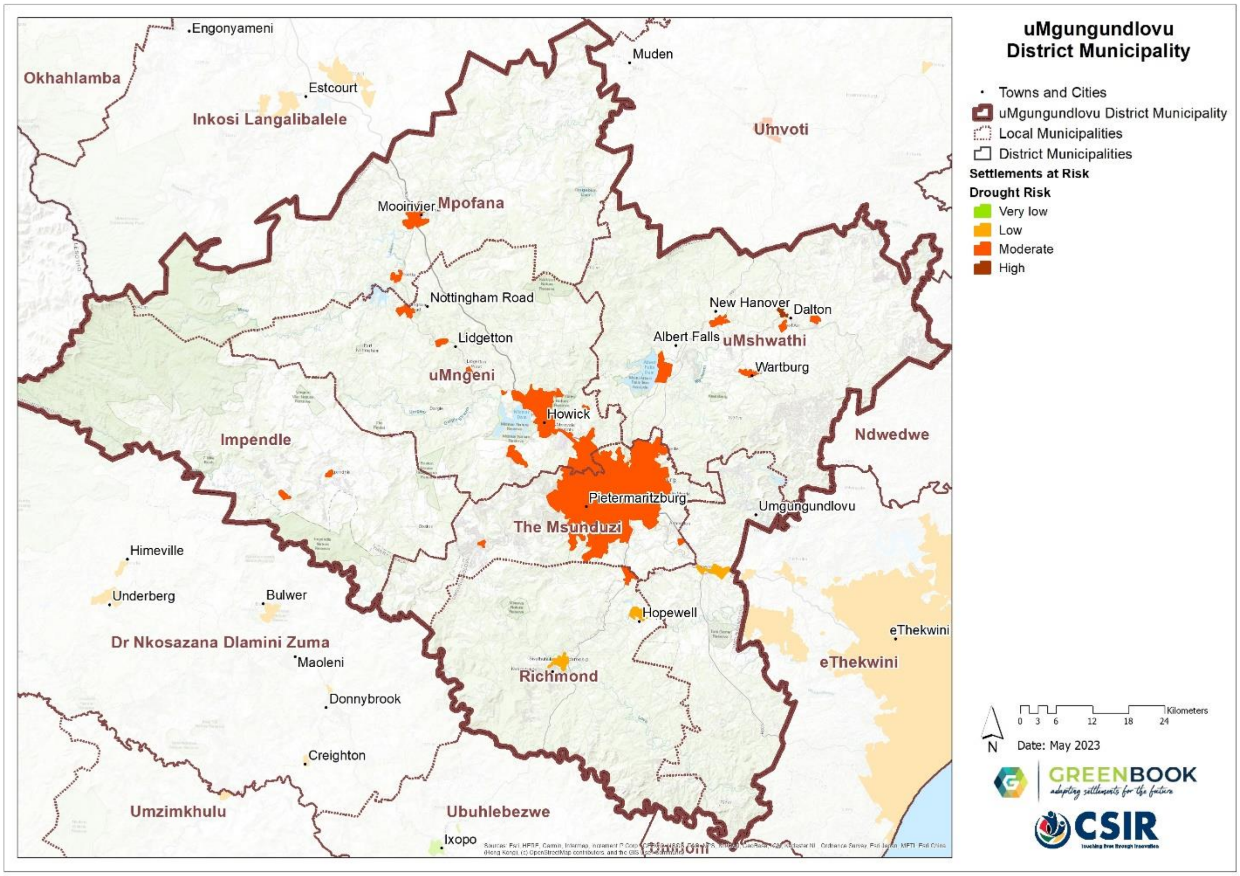


Figure 11: Settlement-level drought risk for uMgungundlovu District Municipality

All the settlements across the District are at risk of drought (Figure 11). At the baseline, large parts of the District are exposed to higher drought tendencies (Figure 9), which are projected to increase towards 2050. A tendency for more intense droughts is predicted into the future (Figure 10).

2.3.2. Heat

The GCMs were used to simulate bias-corrected, annual average number of very hot days, defined as days when the maximum temperature exceeds 35°C per GCM grid point for the baseline (current) period of 1961–1990 (Figure 12), and for the projected change for the period 2021–2050.

The annual heatwave days map under baseline climatic 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, and that for a period of at least three consecutive days.

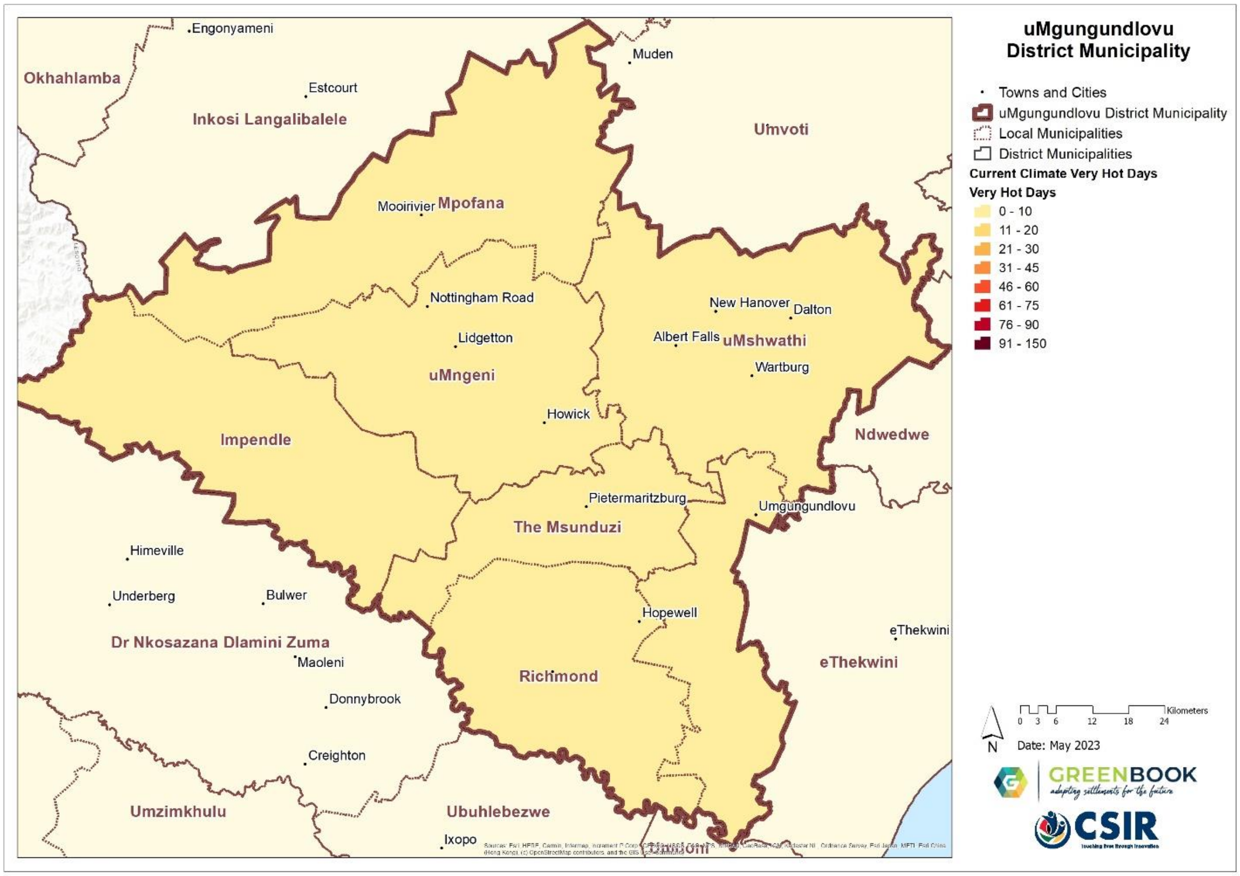


Figure 12: Annual number of very hot days across uMgungundlovu District Municipality under current climatic conditions when daily temperature maxima exceed 35°C

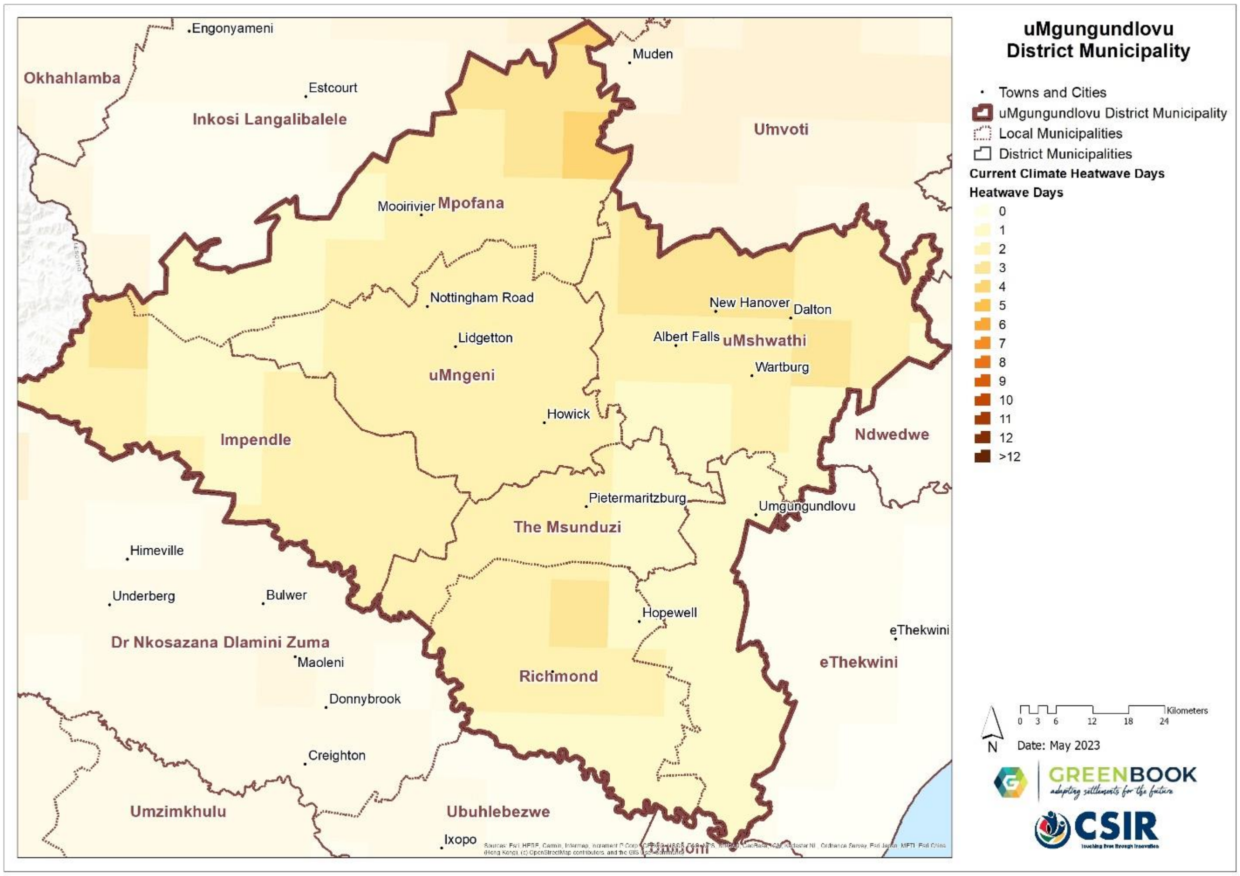


Figure 13: Annual number of very hot days across the uMgungundlovu District Municipality under current climatic conditions showing daily temperature maxima exceeding 35°C

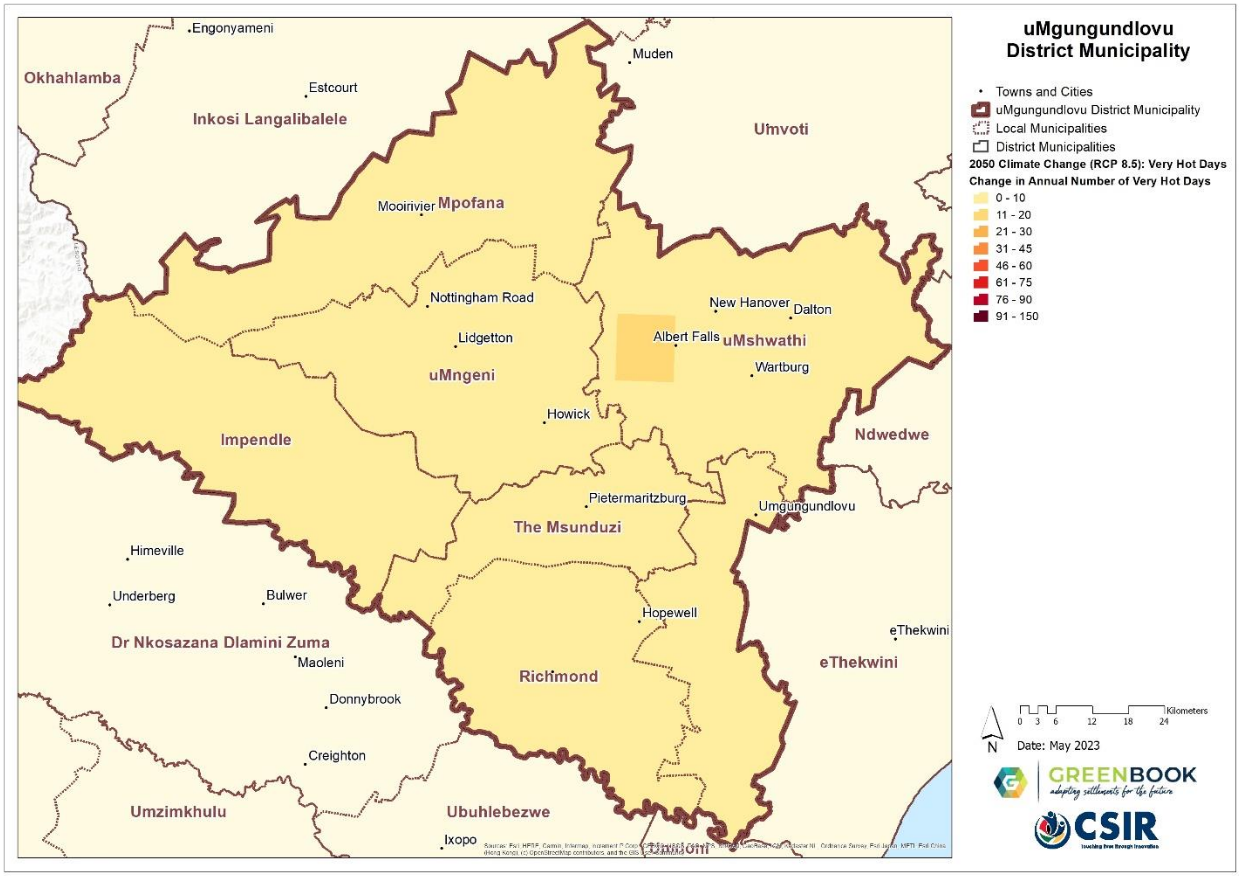


Figure 14: Annual number of heatwave days under GCM derived baseline climatic conditions across uMgungundlovu District Municipality

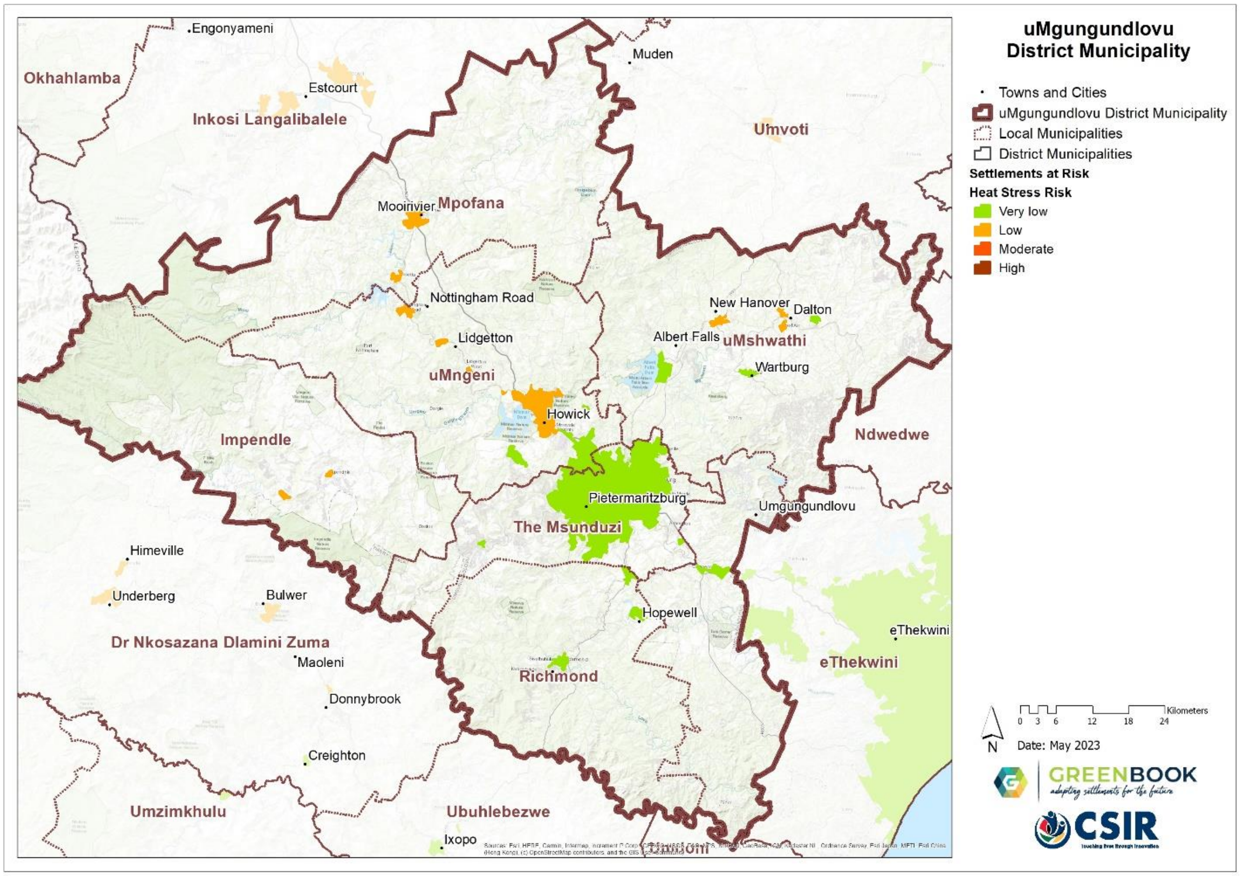


Figure 15: Heat risk across uMgungundlovu District Municipality at settlement level in the 2050s

The area has a cool to moderate climate. At the baseline, the region seldom experiences any very hot days (Figure 12). Under a "business as usual" (low mitigation) climate change scenario, however, the number of very hot days could likely increase by between 1 and 7 days annually by 2050 (Figure 14). While heatwave events are equally rare with no more than 2 heat wave days (if any) occurring in a typical year, the north-eastern part of the District bordering Umvoti Local Municipality is most likely to experience some heatwaves (Figure 13).

Figure 15 depicts the levels of heat risk of settlements under projected future climates. With the changing climate, it is expected that the impacts of heat will only increase in the future. The heat-absorbing qualities of built-up urban areas make them, and the people living inside them, especially vulnerable to increasingly high temperatures. The combination of the increasing number of very hot days and heatwave days over certain parts of South Africa is likely to significantly increase the risk of extreme heat in several settlements. All the settlements in UMDM have a low to very low risk of experiencing heat stress.

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. We used a scale where the likelihood was rated from 'rare' to 'almost certain' and the consequences were rated from 'insignificant' to 'catastrophic' to determine a level of fire risk which ranged from 'low' to 'extreme'. The risks were then summarised for all the settlements within a local authority. Changes in the fire risk in future were accommodated by adjusting either the fire scenarios or the likelihood, or both.

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

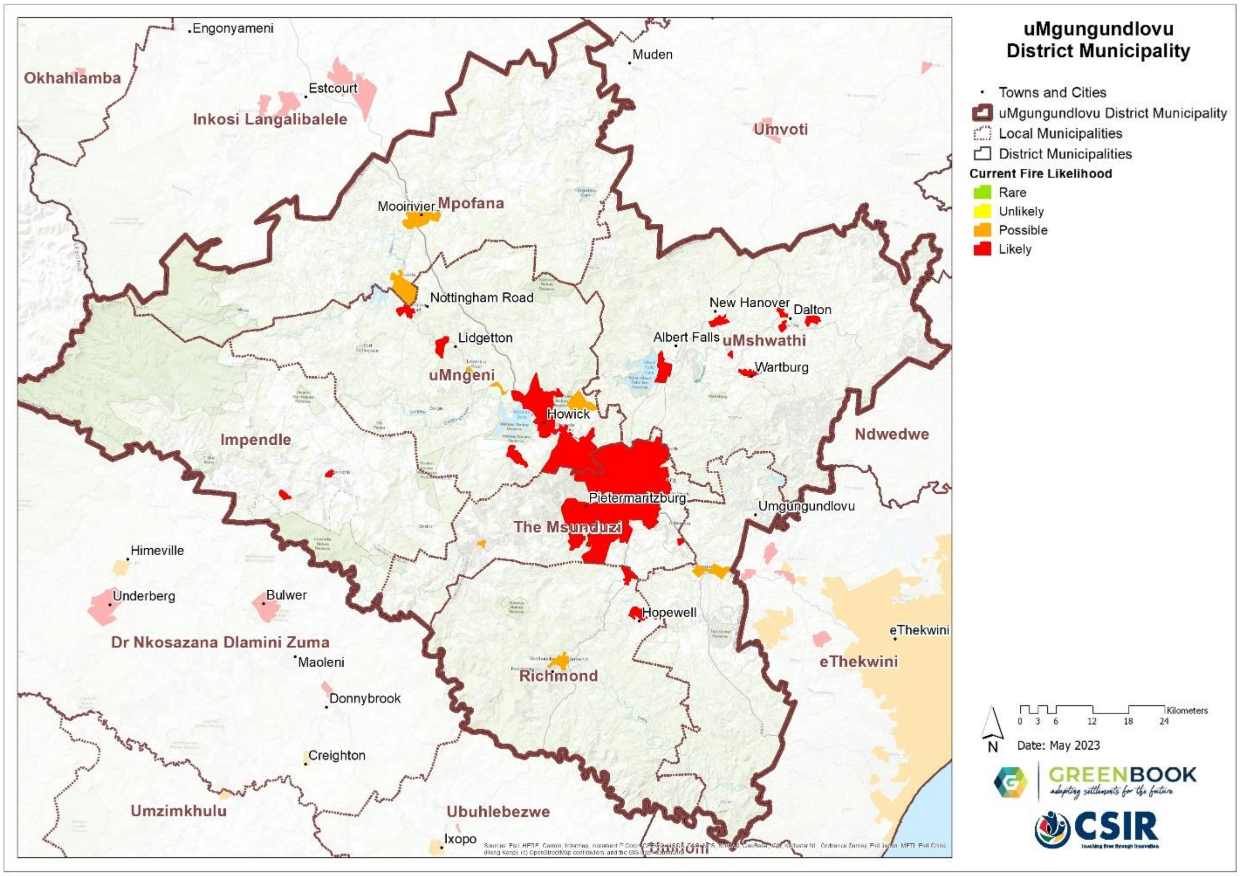


Figure 16: The likelihood of wildfires under current climatic conditions across settlements in uMgungundlovu District Municipality

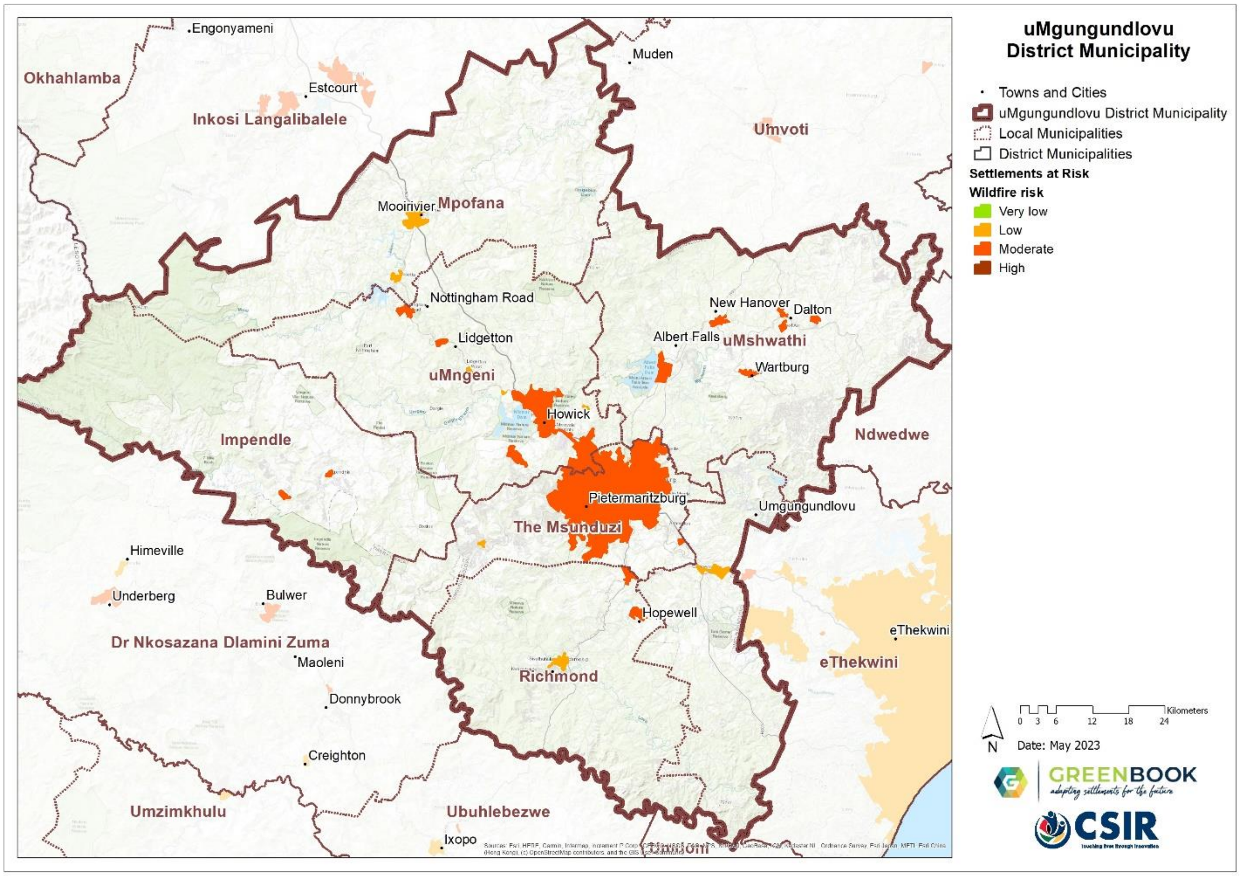


Figure 17: The likelihood of wildfires under projected future climatic conditions across settlements in the uMgungundlovu District Municipality

Figure 16 depicts the likelihood and the risk of wildfires occurring in the wildland-urban interface (the boundary or interface between developed land and fire-prone vegetation) of the settlement under current climatic conditions, while Figure 17 depicts the settlements that could be at risk of increases in wildfires by the year 2050. Settlements which are likely to experience wildfires in and around their wildland-urban interface include Pietermaritzburg, Hilton, Howick, Nottingham Road, Dalton, New Hanover and Mpolwemi (Figure 16). It is projected that these settlements will see moderate increases in their wildfire risk due to climate change by 2050 (Figure 17).

2.3.4. Flooding

The flood hazard assessment combines information on the climate, observed floods, and the characteristics of water catchments that make them more or less likely to produce a flood. The climate statistics were sourced from the South African Atlas of Climatology and Agrohydrology, and a study of river flows during floods in South Africa (Schulze et al. 2008). The catchment characteristics that are important are those that regulate the volume and rate of the water flowing down and out of the catchment. The SCIMAP model was used to analyse the hydrological responsiveness and connectivity of the catchments and to calculate a Flood Hazard Index.

Changes in the land cover, such as urbanisation, vegetation and land degradation, or poorly managed cultivation, reduce the catchment's capacity to store or retain water. More dynamic changes in land cover could not be considered in this analysis, such as for example, recent informal settlement that may increase exposure and risk. Additional local and contextual information should be considered to further enrich the information provided here.

Since the magnitude and intensity of rainfall are the main drivers of floods and rainfall intensity is likely to increase into the future, estimates of the extreme daily rainfall into the future were obtained from high-resolution regional projections of future climate change over South Africa. The settlements that are at risk of an increase in floods were identified using a risk matrix, that considered the flood hazard index and the projected change in extreme rainfall days from 1961-1990 to the 2050s.

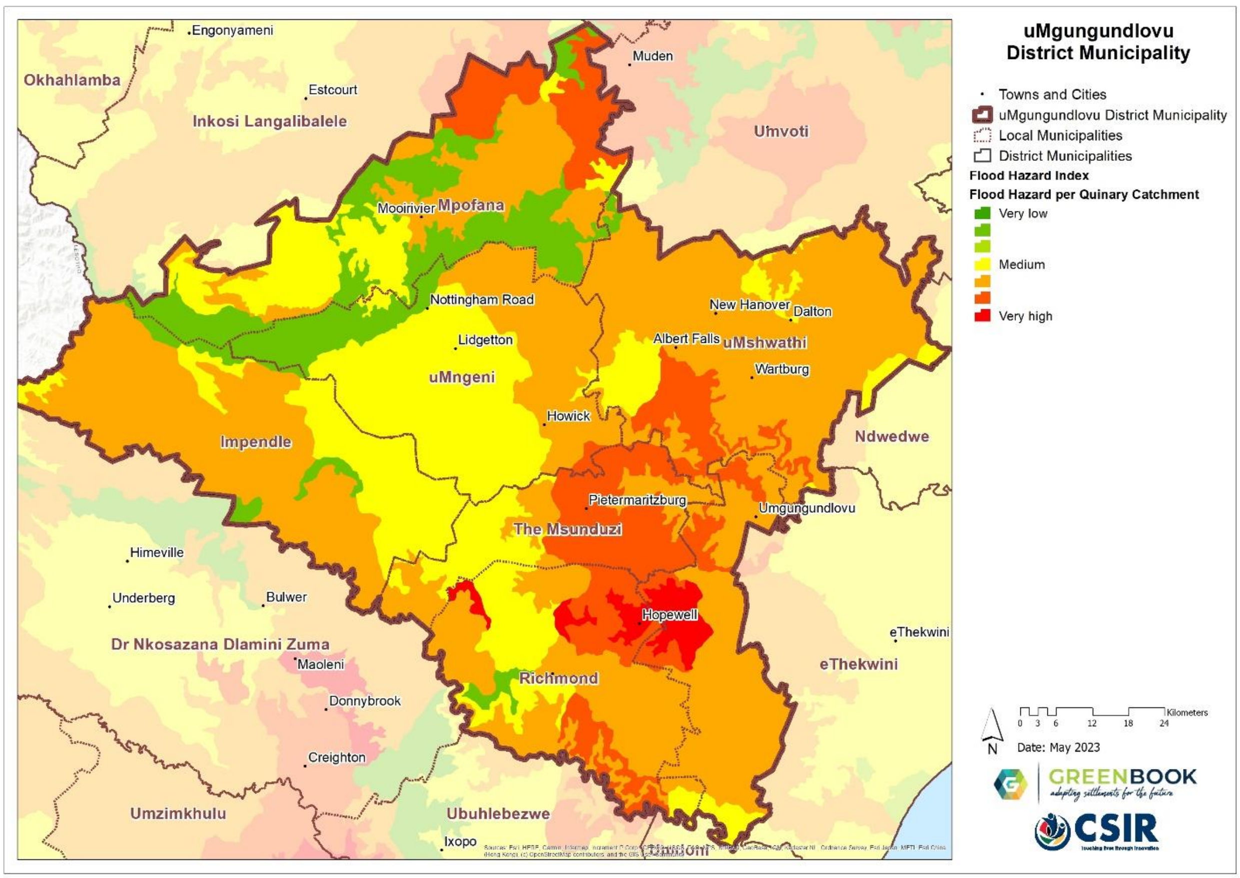


Figure 18: The current flood hazard index per Quinary catchment across uMgungundlovu District Municipality under current (baseline) climatic conditions

Figure 18 depicts the flood hazard index of the different individual Quinary catchments present or intersecting with the District. The flood hazard index is based on the catchment characteristics and design rainfall, averaged at the Quinary catchment level. Green indicates a low flooding hazard, while red indicates a high flood hazard. There is significant variation of the flood hazard index across the District (Figure 18). While there are pockets of the District that have a low to medium flooding hazard, large parts of the District have a medium to very high flooding hazard, especially in and around Pietermaritzburg and Hopewell.

Figure 19 depicts the projected change from the present to the year 2050 in extreme rainfall days for an 8 x 8 km grid. This was calculated by assessing the degree of change when future rainfall extremes (e.g., 95th percentile of daily rainfall) are compared with those under the current rainfall extremes. A value of more than 1 indicates an increase in extreme daily rainfalls. Slight to significant increases in the number of extreme rainfall days are expected in the southern Local Municipalities of Msunduzi, Richmond and Mkhambathini, as well as in the northern Municipality of Mpofana. According to the GCMs used in this study, the central, eastern and western parts of the District are projected to see slight to significant decreases in the number of extreme rainfall days by 2050 (Figure 19).

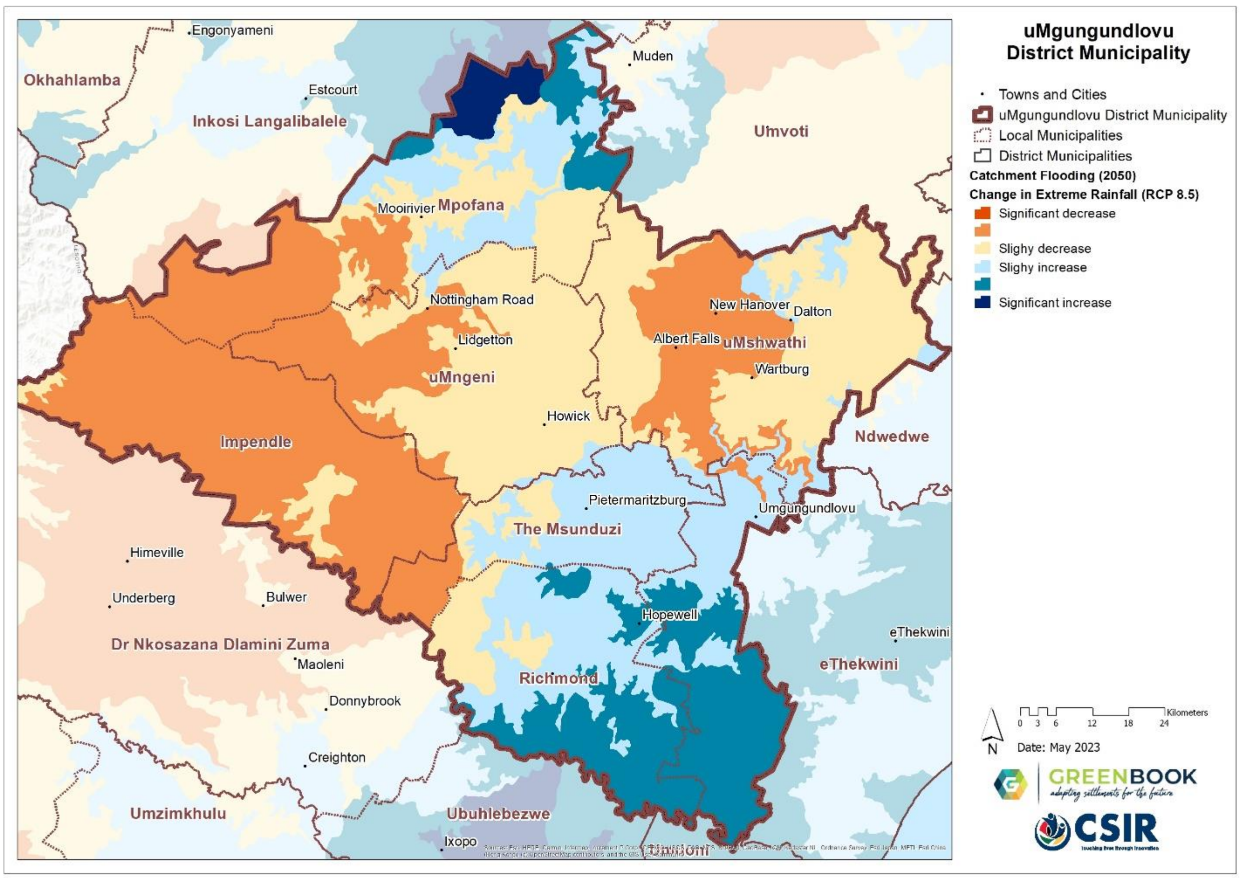


Figure 19: Projected change into future in extreme rainfall days across uMgungundlovu District Municipality

Figure 20 depicts the settlements that are at increased risk of flooding under an RCP 8.5 low mitigation (worst case of greenhouse gas emissions) scenario, which include Hilton, Richmond, Hopewell and Camperdown Local Municipalities.

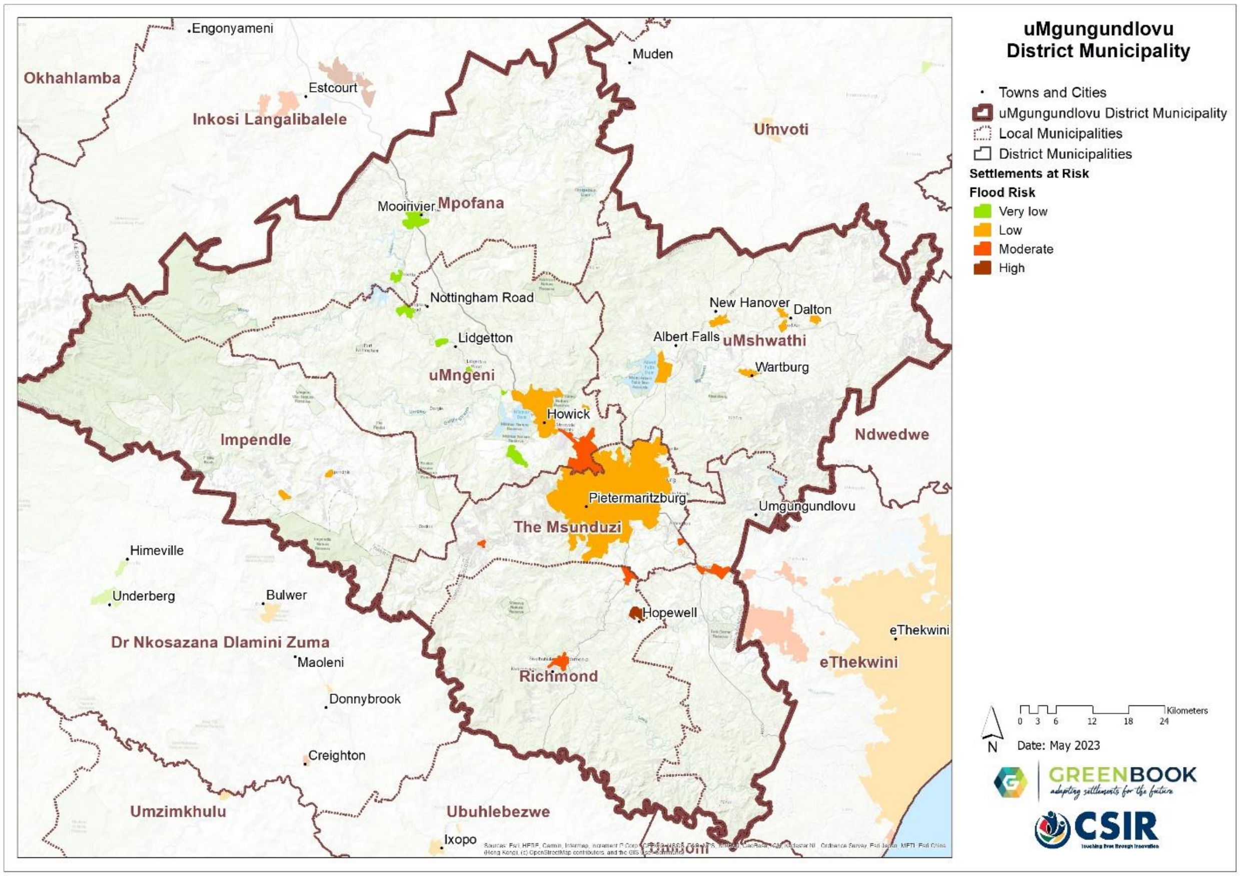


Figure 20: Flood risk into a climate change future at settlement level across uMgungundlovu District Municipality.

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 UMDM.

2.4.1. Water resources and supply vulnerability

South Africa is a water-scarce country with an average rainfall of only about 450 mm per year, and 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 north-west 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 20 year period 2031 to 2050 was compared with the historical period 1961 to 1990.

Figure 23 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 uMgungundlovu District, while many of the towns and cities get all of their water from surface water sources, some of the smaller towns rely on a combination of both surface water and ground water (Figure 23).

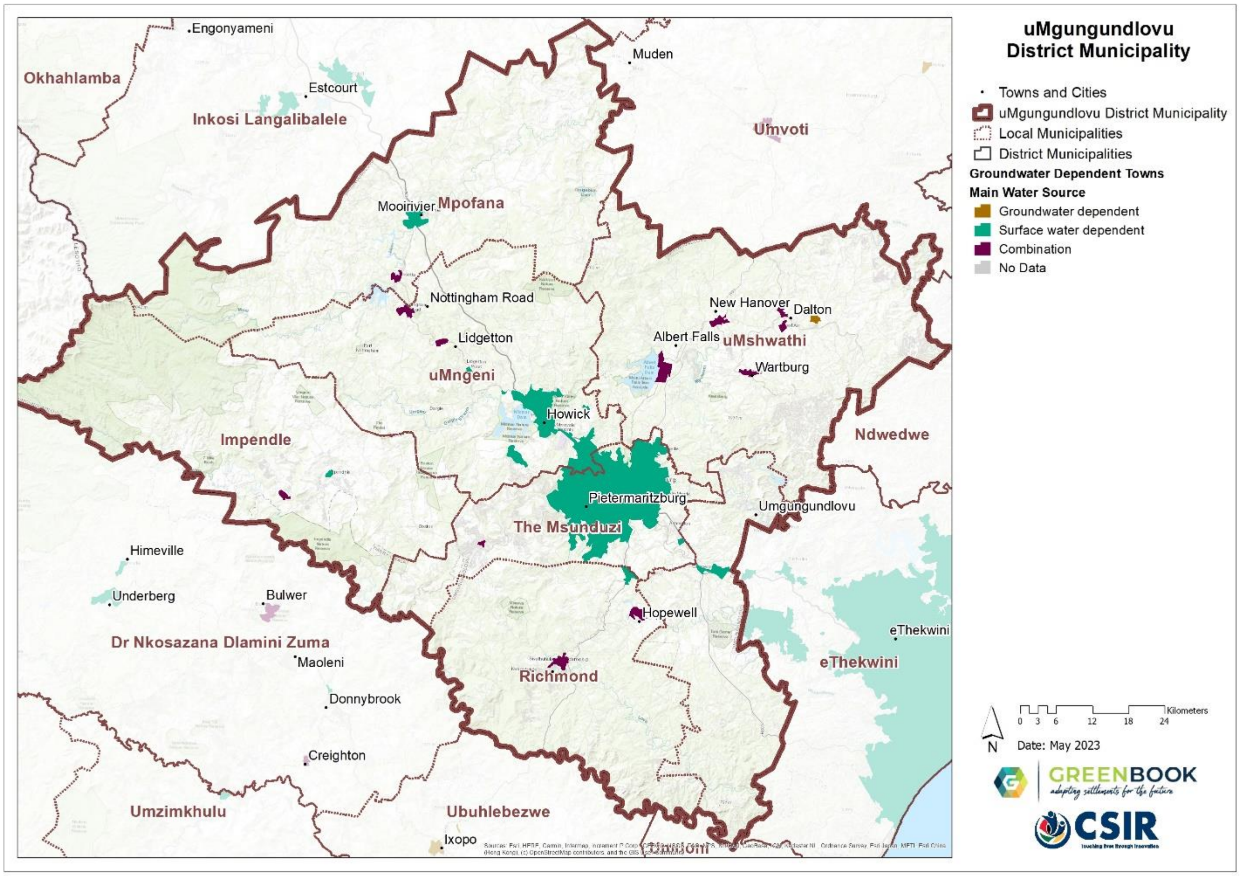


Figure 21: Main water source for settlements in the uMgungundlovu District Municipality

Figure 24 indicates the occurrence and distribution of groundwater resources across the District Municipality, showing distinctive recharge potential zones, while Figure 25 indicates the projected change in groundwater potential. Figure 26 indicates the groundwater dependent settlements that may be most at risk of groundwater depletion based on decreasing groundwater aquifer recharge potential and significant increases in population growth pressure by 2050. Groundwater recharge potential is high across all parts of the District (Figure 24).

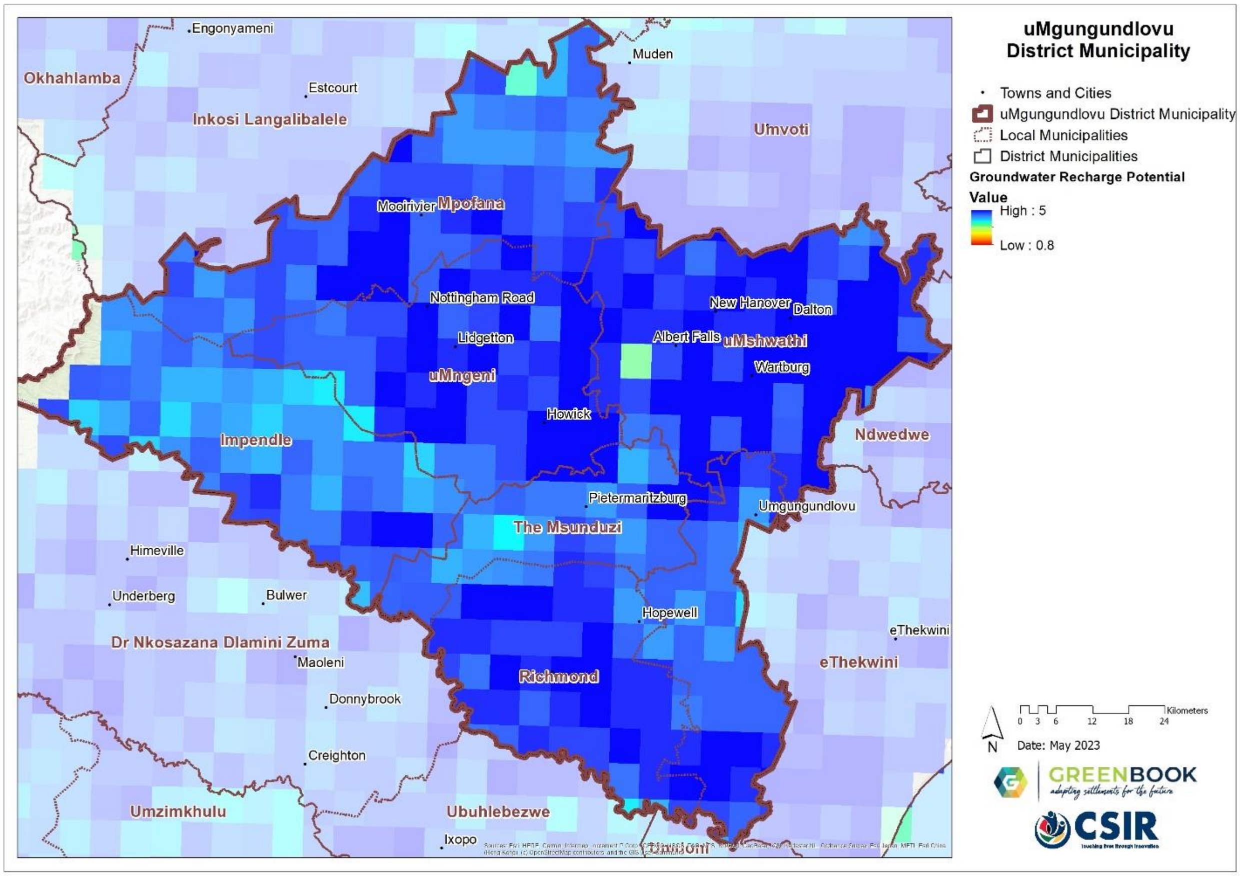


Figure 22: Groundwater recharge potential across uMgungundlovu District Municipality under current (baseline) climatic conditions

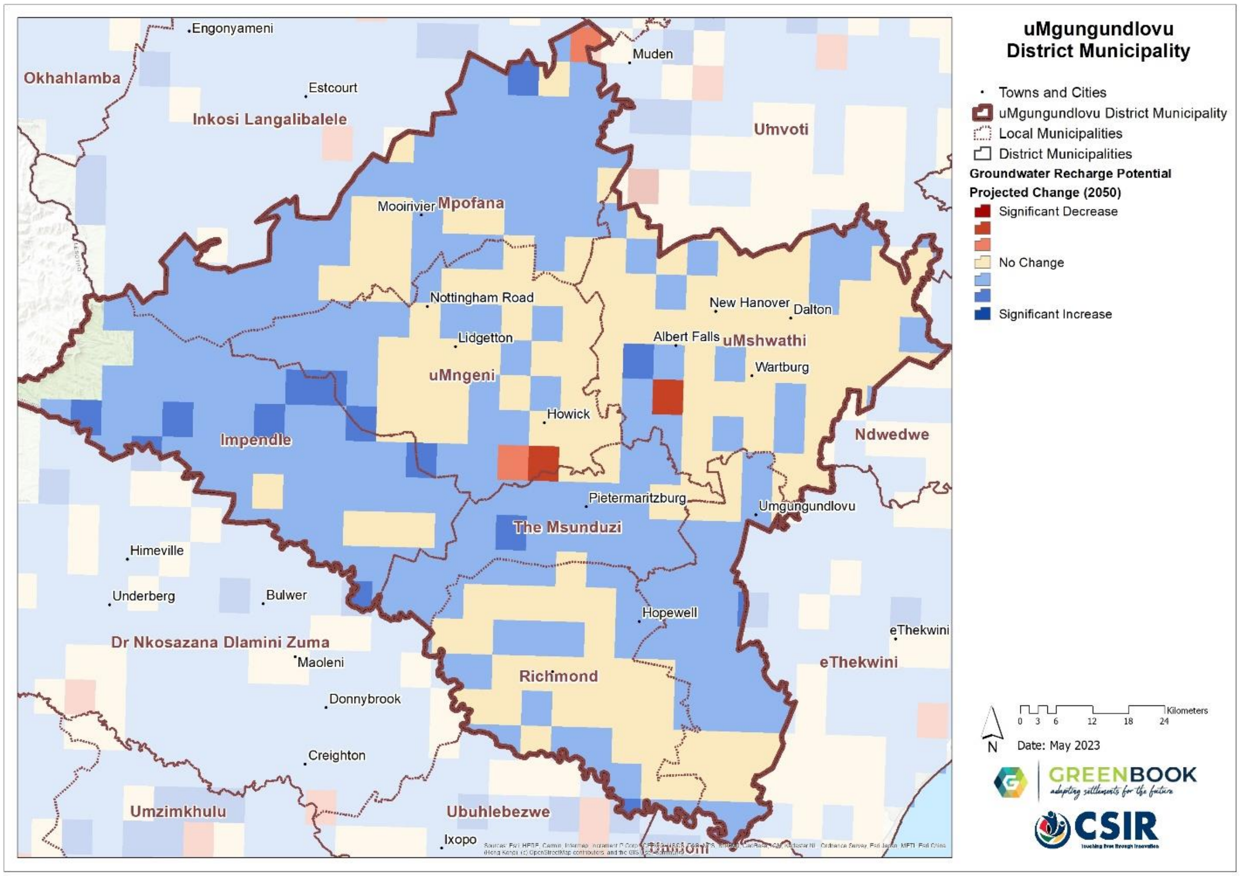


Figure 23: Projected changes in groundwater recharge potential from baseline climatic conditions to the future across uMgungundlovu District Municipality

There are no settlements with a high risk of groundwater depletion in the District (Figure 26). Settlements that rely on a combination of surface water and groundwater may face a high risk of groundwater depletion if their populations grow to a point where water demand outstrips supply, although for large parts of the District, groundwater recharge is projected to increase slightly by 2050 (Figure 25).

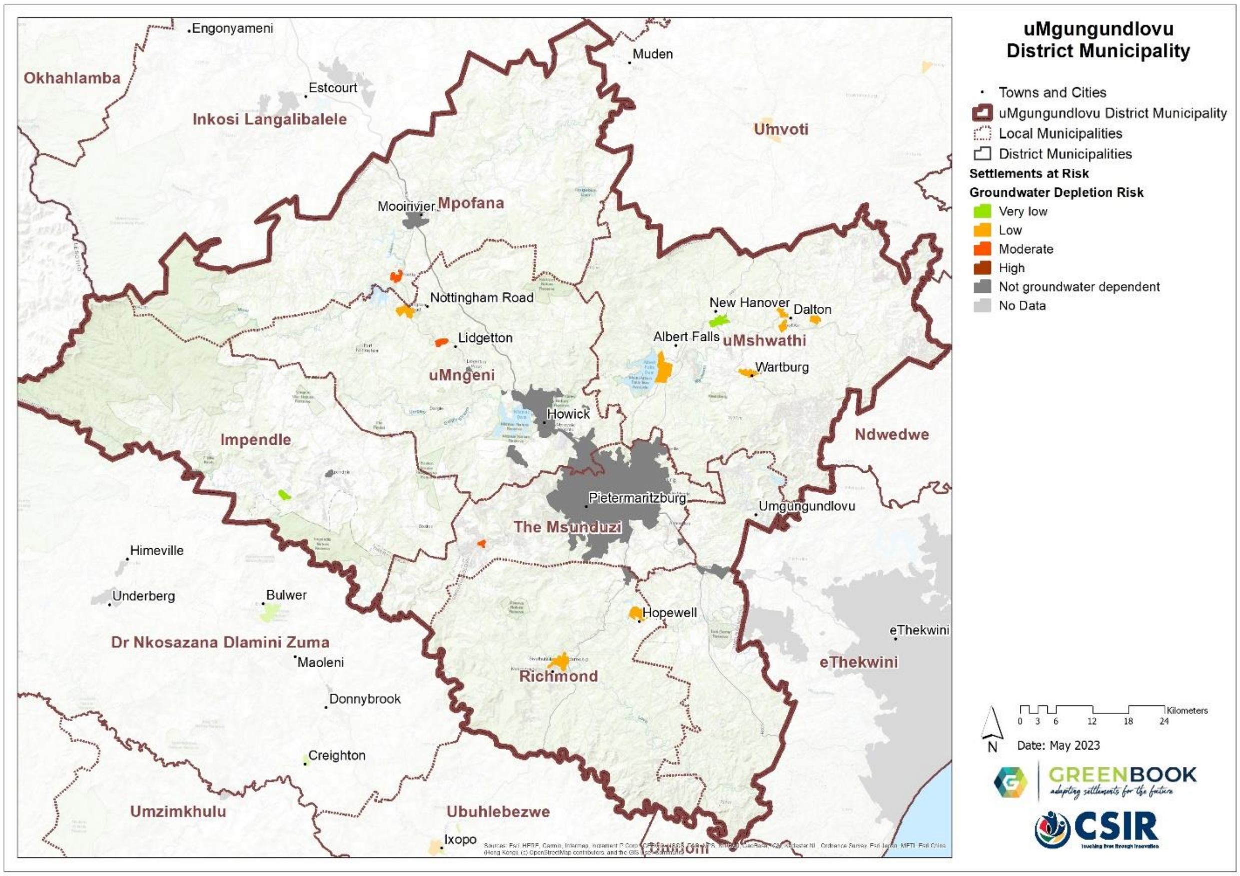


Figure 24: Groundwater depletion risk at settlement level across uMgungundlovu District Municipality

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

Local Municipality	Water Demand per Capita (l/p/d)	Water Supply per Capita (l/p/d)	Current Water Supply Vulnerability
Mpofana	259.57	259.57	1
Impendle	136.46	100.55	1.36
uMngeni	No data	No data	No data
uMshwathi	61.59	46.51	1.32
The Msunduzi	242.57	224.93	1.08
Richmond	104.36	122.31	0.85
Mkhambathini	No data	No data	No data

Current and future water supply vulnerability estimations are based on: 1) a local water supply perspective incorporating changes to population growth coupled with exposure to climate risk and 2) a regional water supply perspective, based on impacts of regional water supply assuming supply is part of the integrated regional and national bulk water supply network. The water supply vulnerability estimations do not consider the current state of water supply and reticulation infrastructure. The current context and conditions within each of the local municipalities need to be considered when interpreting the information provided in this report. Water supply vulnerability per local municipality is discussed below.

Mpofana

Mpofana LM currently gets 82 % of its water from surface water and 18 % from groundwater sources. Water demand per capita and water supply per capita are currently equal, although by 2050, water supply vulnerability may likely become an issue, with water demand projected to outstrip supply due to projected decreases in mean annual precipitation, mean annual runoff and regional urban water supply, while mean annual evaporation and population growth are projected to increase (Table 3).

Impendle

Impendle LM currently gets 100 % of its water from surface water sources. The area currently has some water supply vulnerability due to higher per capita demand relative to current supply, although due to projected declines in the population by 2050, water supply vulnerability is projected to improve into the future (Table 3).

uMngeni

uMngeni LM currently gets 100 % of its water from surface water sources. There are no data available for per capita demand, per capita supply or water supply vulnerability (Table 3).

uMshwathi

uMshwathi LM currently gets 100 % of its water from surface water. Water demand is currently higher than supply, making the Municipality vulnerable. Although water supply vulnerability is set to slightly decrease to between 1.3 and 1.2 by 2050, due to a projected increase in mean annual precipitation and mean annual runoff, and a decrease in population growth, the Municipality will likely remain vulnerable to water supply availability (Table 3).

The Msunduzi

The Msunduzi LM currently gets 100 % of its water from surface water sources. Currently, water demand per capita is only marginally higher than supply per capita, and the Municipality has a water supply vulnerability of 1.08. However, water supply vulnerability is expected to significantly increase to between 1.1 and 1.9 by 2050. Water supply vulnerability is driven by projected extreme population growth pressure, a decrease in mean annual precipitation and an increase in surface water evaporation (Table 3).

Richmond

Richmond LM gets 100 % of its water from surface water sources. It is the only Municipality in the District where water supply vulnerability is currently relatively low, with water supply greater than current demand. There is, however, a mixed signal regarding the projected water supply vulnerability of the Municipality by 2050, with some scenarios projecting a decrease in vulnerability (due to increases in average annual rainfall and runoff), and others projecting an increase to a level where demand would begin to outstrip supply (due to large population growth). Water resources in the Municipality thus need to be well managed into the future to avoid the Municipality becoming vulnerable in terms of water supply (Table 3).

Mkhambathini

Mkhambathini LM currently gets 100 % of its water from surface water sources. There are no data available for per capita demand, per capita supply or water supply vulnerability (Table 3).

2.4.2. Agriculture, forestry, and fisheries

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

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

The methodological approach to understanding the impact of climate and climate change on agriculture, forestry, and fisheries, consisted of four components. Firstly, the most important areas in terms of Gross Value Added (GVA) and employment for the agriculture, forestry and fisheries sector relative to the other sectors of the South African economy were determined. Secondly, an analysis of climate change scenarios was done using historical climate variables, as well as multi-model projections of future climates to help identify specific climate-related risk factors for agriculture within specific regions. Thirdly, crop suitability modelling was done to indicate how the area suitable for crop production under the present climate conditions might shift or expand under the scenarios of future climate change, in addition to using the

Temperature Humidity Index (THI) to assess heat stress in livestock. Finally, the climate change analysis was used in conjunction with the crop modelling outputs to assess the potential impacts of climate change over a specific area, or for a specific crop, to give more detail on how predicted climate changes translate into location/crop specific impacts. This was developed at a local municipal level and guided by the outcome of the agricultural industry sector screening and climate scenario analysis.

The UMDM primary sector constitutes 7 % of the economy and predominantly comprises agriculture and forestry. The District is an important agricultural hub and home to diverse agricultural activities, including crops such as maize, sugarcane, fruit and vegetables, farming of cattle and sheep, horse breeding, and timber plantations. Expanding this sector is core to the vision of the District (CoGTA, 2020). Given the District's overall agricultural land potential and local climates, much of the area is preserved for commercial farming (CoGTA, 2020). The potential impact of climate change and climate hazards on agriculture is notable considering that many households are dependent of the sector for employment.

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

Mpofana

In Mpofana LM, the AFF sector contributes 34.07 % to the local GVA, which is a contribution of 0.74 % to the national GVA for the AFF sector. Of the total employment, 37.42 % is within the AFF sector. The main commodities are milk and cream together with commercial forestry. Climate projections show a generally hotter and wetter climate but becoming drier towards the end of the century. The hot and moist conditions can cause increased spread of disease and parasites. Potential increases in heat stress could negatively affect conception rates, milk yield and milk quality.

Impendle

In Impendle LM, the AFF sector contributes 37.34 % to the local GVA, which equates to a contribution of 0.17 % to the national GVA for the AFF sector. Of the total employment in this LM, 34.63 % is within the AFF sector. The main agricultural commodities are milk and cream together with potatoes. Climate projections show a generally hotter and wetter climate. Hot and moist conditions are likely to cause increased spread of disease and parasites. Potential increase in heat stress could negatively affect conception rates, milk yield and milk quality. However, an increase in tuber yield is expected due to an increased concentration of CO_2.

uMngeni

In uMngeni LM, the AFF sector contributes 15.49 % to the local GVA, which is a contribution of 1.39 % to the national GVA for the AFF sector. Of the total employment, 20.68 % is within the AFF sector. The main commodities are milk and cream, beef cattle and sugar cane. Climate projections show a generally hotter and wetter climate, becoming drier towards the end of the century. Hot and moist conditions cause increased spread of disease and parasites, affecting dairy cattle. Potential increase in heat stress could further negatively affect conception rates, milk yield and milk quality. Increases in water availability and sugarcane yield are projected, however, exposure to pests such as eldana and chilo is expected to be enhanced.

uMshwathi

In uMshwathi LM, the AFF sector contributes 33.73 % to the local GVA, which is a contribution of 1.67 % to the national GVA for the AFF sector. Of the total employment, 45.04 % is within the AFF sector. The main commodities are sugarcane and beef cattle. Climate projections show a generally hotter and wetter climate. Hot and moist conditions are likely to cause increased spread of diseases and parasites. Reduced growth and reproduction performance due to heat stress are projected. Increased water availability and a potential increase in sugarcane yield are anticipated.

The Msunduzi

In The Msunduzi LM, the AFF sector contributes 2.5 % to the local GVA, which is a contribution of 1.33 % to the national GVA for the AFF sector. Of the total employment, 2.54 % is within the AFF sector. The main commodities are milk and cream, beef cattle and sugarcane. Climate projections show a generally hotter and wetter climate. Similar to the other Local Municipalities in the District, the hot and moist conditions will negatively affect dairy cattle performance as well as milk yield and quality due to heat stress. Production remains viable as long as heat stress is managed, and water is available. Potential increases in sugarcane yields are projected, however, increased exposure to pests such as eldana and chilo are also expected.

Richmond

In Richmond LM, the AFF sector contributes 37.13 % to the local GVA, which is a contribution of 1.09 % to the national GVA for the AFF sector. Of the total employment, 40.36 % is within the AFF sector. The main commodities are sugarcane, citrus and beef cattle. Climate projections show a generally warmer and wetter climate. The hot and moist conditions will benefit heat-tolerant disease vectors and may affect citrus yield. Extreme temperatures can contribute to fruit set and decreases in production. Beef cattle may face reduced growth and reproduction performance due to heat stress and increased spread of disease and parasites.

Mkhambathini

In Mkhambathini LM, the AFF sector contributes 35.2 % to the local GVA, which is a contribution of 0.86 % to the national GVA for the AFF sector. Of the total employment, 48.88 % is within the AFF sector. The main commodities are sugarcane and citrus. Climate projections show a generally warmer and wetter climate, with more extreme rainfall events. Hot and moist conditions will benefit more heat-tolerant disease vectors and ultimately increased exposure to pest. Increased exposure to diseases and pests will negatively affect citrus fruit set and yield. Potential increases are projected in sugarcane yield.

3. Recommendations

The main climate risks faced across the uMgungundlovu District Municipality are severe weather events, flooding, wildfires and droughts. In addition to being home to many vulnerable communities that are heavily dependent on natural resources and face high population growth pressures from increased migration to urban and peri-urban areas, the District also faces developmental challenges that increase its vulnerability and exposure to the impacts of climate-related hazards. Responding to climate change therefore needs to be a key priority for the UMDM.

It is predicted that climate change will result in the uMgungundlovu District becoming warmer and wetter until 2050 mid-century, but drier towards the end of the century. Certain parts of the District could experience more extreme rainfall events that may likely lead to increased risk of flooding if the high volumes of stormwater resulting from these events is not properly managed. This anticipated increase in intensity of rainfall and potential flooding could lead to increased surface runoff, resulting in increased soil erosion on land, sediment yield in streams, flooding of infrastructure, and pollution of water courses.

Dry conditions and high temperatures in the area create ideal conditions for fire. Wildfires are most common after dry winters, when temperatures begin rising and summer rains have not yet arrived. The increased risk of wildfires raises the obvious impact of loss of life, injury, and loss of property. It also poses health and safety risks, including poor air quality from smoke and ash pollution, as well as ecosystem degradation.

Large areas of the District support intensive farming and forestry activities, while the areas under traditional authorities are home to communities that are heavily dependent on natural resources for their livelihoods. A likely increase in drought risk will have implications for water security and quality, and will impact the agricultural sector's vulnerability, leading to higher levels of poverty and food insecurity.

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

1. To ensure water security in the face of climate change: Given the water scarcity challenges in the country, the role that the District plays in supplying water to the industrial and logistics hub of eThekwini, as well as the negative effects that some of the projected impacts of climate change may have on the District's water supply (e.g., increased drought tendencies) – developing comprehensive strategies for water resource management is crucial. These could include prioritising water infrastructure maintenance; investing in efficient water supply infrastructure to meet future demand; promoting water conservation practices by implementing strategies and interventions such as public awareness campaigns, leak detection and repairs, and water metering

and billing; as well as exploring measures to secure alternative water sources such as rainwater (harvesting), groundwater (recharge and extraction) and wastewater (reuse).

2. To protect natural resources and ecosystems: Parts of UMDM house very rich and complex ecological assets, with diverse topography, climate and soil. However, these assets are increasingly under pressure from rapid urbanisation, agricultural expansion and land use change. Moreover, the impacts of climate change further threaten the ability of ecosystems and ecological assets to maintain their essential functions. For instance, the catchment areas of Umkhomazi and Umgeni Rivers, have been flagged as critically stressed. Therefore, protecting and restoring natural ecosystems such as high priority biomes, wetlands, river ecosystems and riparian areas – i.e., to perform critical ecosystem services, enhance biodiversity, support water resource management, and provide natural buffers against climate-related hazards such as wildfires – will have to become a priority. Some of the actions that the District could take to realise this goal include establishing or expanding protected areas, enforcing regulations against harmful practices in such areas, and promoting the sustainable use of natural resources.

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

4. To increase resilience of the agricultural sector: Considering that the UMDM is an agricultural hub, and home to diverse agricultural opportunities, as well as the fact that the expansion of the sector forms part of the District's core vision – it is important to increase the sector's resilience to the impacts of climate change. The potential impact of climate change and climate hazards on agriculture is notable, when also considering that many households are dependent of the sector for employment. This can be done by providing farmers with (i) access to resilient crop varieties and efficient irrigation systems; (ii) training in sustainable farming techniques; (iii) financial risk management tools; and (iv) market opportunities, i.e., to help the agricultural sector withstand shocks and stresses such as climate change impacts, market fluctuations, and pest outbreaks.

These goals should be seen as potential elements of a more comprehensive approach, which could be complemented by additional strategies tailored to the unique context and needs of

UMDM. The key to achieving these adaptation goals lies in their integration into all aspects of municipal decision-making and operations, as well as in involving communities in these initiatives.

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