Sarah Baartman District Municipality

Risk Profile Report based on the GreenBook

31 July 2023

Report compiled by the CSIR
Funded by the CDRF with Santam as collaborative partner

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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
DEM	Digital Elevation Model
DM	District Municipality
DRR	Disaster Risk Reduction
DWS	Department of Water and Sanitation
EcVI	Economic Vulnerability Index
EnVI	Environmental Vulnerability Index
GCM	General circulation model
GRiMMS	Groundwater Drought Risk Mapping and Management System
GVA	Gross Value Added
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
LiDAR	Light Detection and Ranging
LM	Local Municipality
MAR	Mean Annual Runoff
mm	Millimetre
NDMC	National Disaster Management Centre
PVI	Physical Vulnerability Index
RCP	Representative Concentration Pathways
SBDM	Sarah Baartman District Municipality
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)
SUDEM	Stellenbosch University Digital Elevation Model

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

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

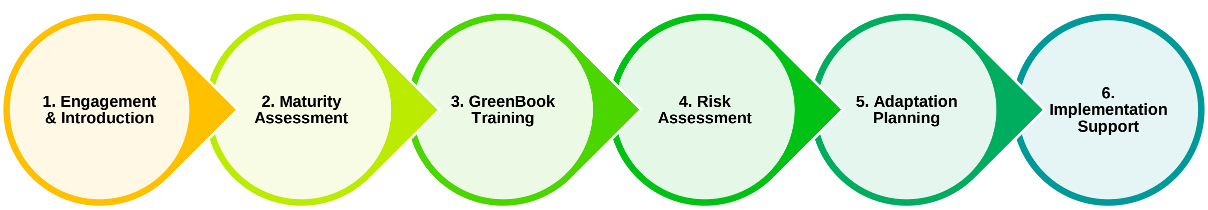

Figure 1: The Value-chain towards the implementation of climate change response and adaptation in municipalities

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

- Build and further the climate change response agenda,

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

1.1. Approach followed

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

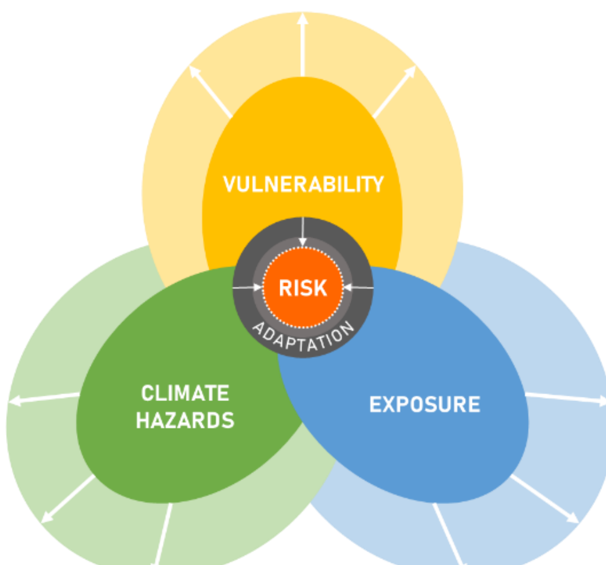

Figure 2: The interaction between the various components of risk, indicating the opportunity to reduce risk through adaptation (based on IPCC, 2014 and IPCC, 2021)

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. 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 takes it further by setting out reporting requirements on climate change response needs and interventions for every municipality in the country. The Bill also sets out requirements for every district intergovernmental forum to serve as a Municipal Forum on climate change that coordinates climate response actions and activities in its respective municipality.

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

1.3. District Municipal context

The Sarah Baartman District Municipality (SBDM) is the largest (58 243 km²) of the six District Municipalities (DMs) in the Eastern Cape Province. The District is situated in the western portion of the Province, bordering the Western Cape, Northern Cape and two other District Municipalities in the Eastern Cape, namely Chris Hani District Municipality and Amathole District Municipality (SBDM, 2022; CoGTA, 2020). The District has seven Local Municipalities (LMs), namely Blue Crane Route, Dr Beyers Naude, Sundays River Valley, Kouga, Kou-Kamma, Ndlambe, and Makana Local Municipalities. The District has a total population of 520 480, with 437 976 people located in settlements. The settlement-based population grew by 16.4 % between 2001 and 2011 and is projected to grow by 24.6 % between 2011 and 2030.

The District's major employing sectors are Trade (including retail and tourism), followed by Agriculture and then Community Services (including government). Unemployment is high at about 27,5 % of the population (CoGTA, 2020).

The biophysical environment of the District is dominated by semi-desert Karoo landscape in the inland areas, which are prone to drought conditions. The narrow coastal strip is low lying, and has higher, year-round rainfall, which provides opportunities for more diverse land uses and economic development. The District also has several prominent mountains and catchment areas, including the Kouga Mountains in the south and the Sneeuberge north of Graaff-Reinet. The District has a wide variety of vegetation types due to the diversity of geomorphology, topography, soil types, climate and rainfall patterns that occur in the region. The District includes elements of six biomes, namely Fynbos, Subtropical Thicket, Forest, Succulent Karoo, Savannah and Grassland, which occur along with coastal vegetation, wetlands, pans and riverine vegetation types (DEA, 2018).

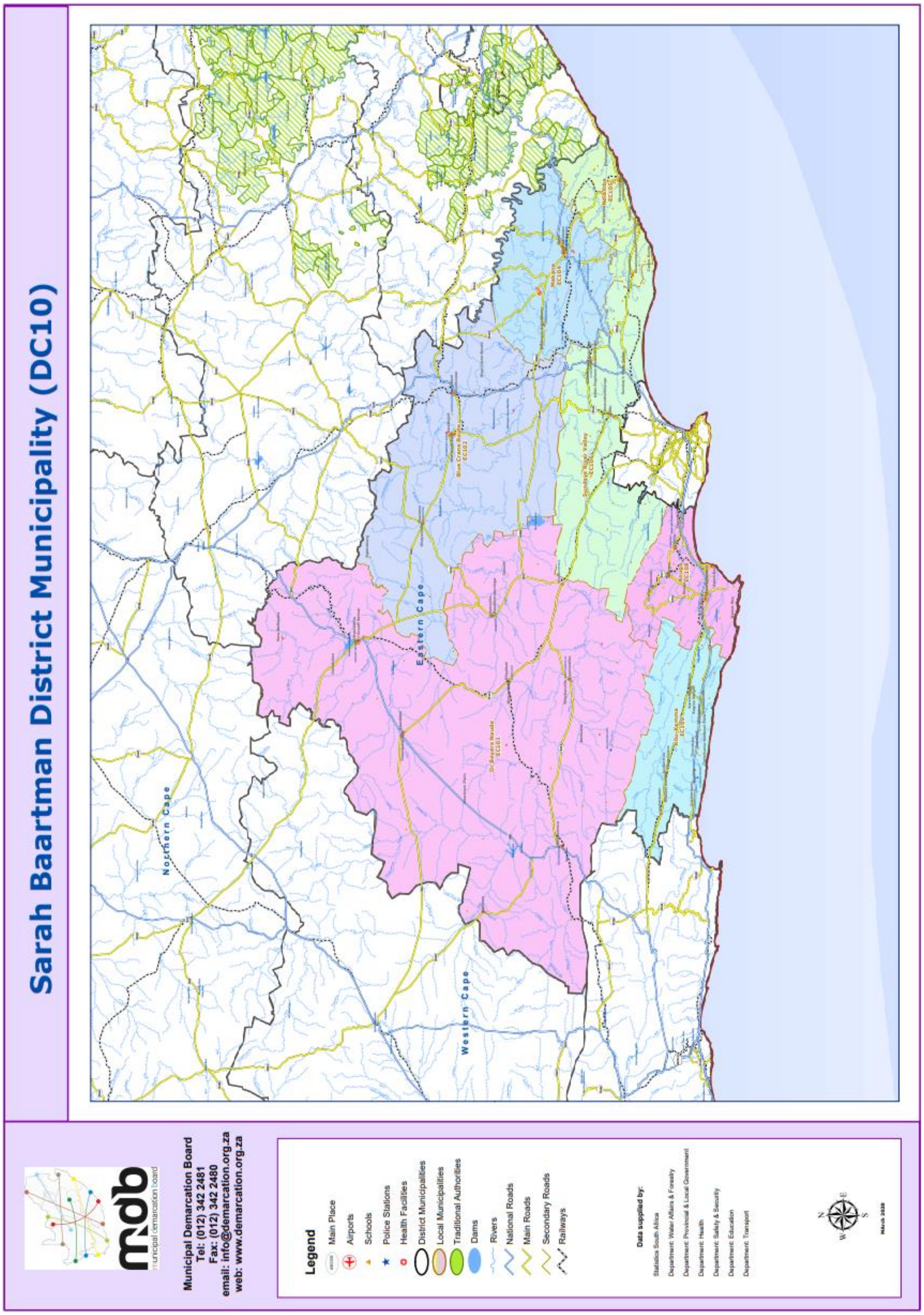

Figure 3: Sarah Baartman District Municipality (Municipal Demarcation Board, 2022), with Local Municipalities shaded in different colours

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, flooding, coastal flooding, and coastal erosion 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 Sarah Baartman 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 Sarah Baartman 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 Sarah Baartman 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 Sarah Baartman 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 Sarah Baartman District Municipality

LOCAL MUNICIPALITY	SEVI 1996	SEV 2011	Trend	EcVI 1996	EcVI 2011	Trend	PVI	Trend	EnVI	Trend
Blue Crane Route	6.2	4.9	↘	5.0	4.5	↘	5.4	N/A	1.9	N/A
Dr Beyers Naude	4.5	3.8	↘	5.0	4.7	↘	5.8	N/A	3.7	N/A
Sundays River Valley	6.4	5.1	↘	5.3	1.6	↘	6.3	N/A	2.8	N/A
Kouga	3.9	3.2	↘	3.3	3.9	↗	6.0	N/A	3.6	N/A
Kou-Kamma	4.5	3.6	↘	3.1	1.3	↘	6.5	N/A	5.7	N/A
Ndlambe	6.4	5.2	↘	5.6	7.6	↗	7.5	N/A	1.7	N/A
Makana	5.2	4.4	↘	5.2	5.9	↗	5.6	N/A	2.9	N/A

Socio-economic vulnerability (SEVI) has decreased (improved) across all Local Municipalities between 1996 and 2011. Ndlambe LM has the highest economic vulnerability in the District and the second highest in the Province. The SMDM experienced an average annual increase of 6.26 % in the number of unemployed people, higher than the provincial increase of 5.73 %. Unemployment is highest in Makana, Ndlambe, and Blue Crane Route Local Municipalities (SBDM, 2022). The Government and community, social and personal services sector is estimated to be the largest sector within the District in 2021, with a total share of 28.6 % of the total Gross Value Added (GVA) (as measured in current prices), growing at an average annual rate of 1.3 % (SBDM, 2022).

2.1.2. Settlement vulnerability

The unique set of indicators outlined below highlight the multi-dimensional vulnerabilities of the settlements within the Sarah Baartman 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 are experiencing growth pressures on top of the other dimensional vulnerabilities.

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 includes the settlement's (1) access to basic services (electricity, water, sanitation, and refuse removal), (2) settlement's access to social and government services (health access, emergency service access, access to schools, and early childhood development), (3) access to higher order education facilities, and (4) access to adequate housing.

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

Blue Crane Route

The major settlements in this Local Municipality are Somerset-East, Cookhouse, and Pearston with Somerset-East facing the greatest growth pressure, combined with high service access vulnerability. Pearston is the most remote settlement in the Municipality, with very high regional connectivity vulnerability as well as a very socio-economically vulnerable population.

Dr Beyers Naude

The major settlements in this Local Municipality are Graaff Reinet, Jansenville, Willowmore, Aberdeen, Steytlerville, Nieu-Bethesda, Kliplaat, and Rietbron. The settlement facing the greatest growth pressure is Graaff Reinet, which also has very high service access vulnerability. Steytlerville and Aberdeen experience very high socio-economic and economic vulnerability, while Nieu Bethesda has the greatest regional connectivity vulnerability in this Local Municipality.

Sundays River Valley

The major settlements in this Local Municipality are Kirkwood, Addo, Paterson, and Glenconner. Addo is facing the greatest growth pressure in the Local Municipality and has very high service access vulnerability, combined with a socio-economically vulnerable population.

Kouga

The major settlements in this Local Municipality are Jeffreys Bay, Humansdorp, Hankey, Patensie, and St Francis Bay. Patensie and St Francis Bay display very high environmental vulnerability, while Humansdorp face the greatest growth pressure in the Municipality.

Kou-Kamma

The major settlements in this Local Municipality are Joubertina, Kareedouw, and Louterwater. Kareedouw has the greatest growth pressure, while Joubertina and Louterwater have the greatest regional connectivity vulnerability. Additionally, Louterwater has very high service access vulnerability.

Ndlambe

The major settlements in this Local Municipality are Port Alfred, Kenton-on-Sea, Bushmans River Mouth and Alexandria. All settlements are experiencing high growth pressure, socio-economic, and economic vulnerability. Bushmans River Mouth has the highest service access vulnerability, while Alexandria has the highest environmental vulnerability.

Makana

The major settlements in this Local Municipality are Makhanda (Grahamstown), Alicedale and Riebeek-East, with Makhanda experiencing the greatest growth pressures. Alicedale has very high vulnerability in terms of service access, regional connectivity, the environment, socio-economic vulnerability and economic 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 their in- and out-migration assumptions. The medium growth scenario (Table 2) assumes that the peak of population influx from African and neighbouring 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 Sarah Baartman District Municipality

Population per municipality	2011	Medium Growth Scenario	
		2030	2050
Blue Crane Route	35 994	34 327	29 817
Dr Beyers Naude	79 258	83 799	82 518
Sundays River Valley	54 502	70 915	89 136
Kouga	98 543	153 294	233 424
Kou-Kamma	40 656	51 804	63627
Ndlambe	61 150	70 292	77 794
Makana	80 386	81 575	76 672
Sarah Baartman DM Total	450 489	546 006	652 988

The District's population is projected to increase by 49 % between 2011 and 2050, under a medium growth scenario. Most of this growth will take place in the settlements within the Kouga LM. Blue Crane Route and Makana LMs will possibly see a decline in population between 2011 and 2050 for all settlements within them. Figure 4 depicts the growth pressures that the settlements across the Local Municipalities in District will likely experience. The settlements that will see extreme growth pressures up to 2050 include Jeffreys Bay, Humansdorp, Hankey and Joubertina.

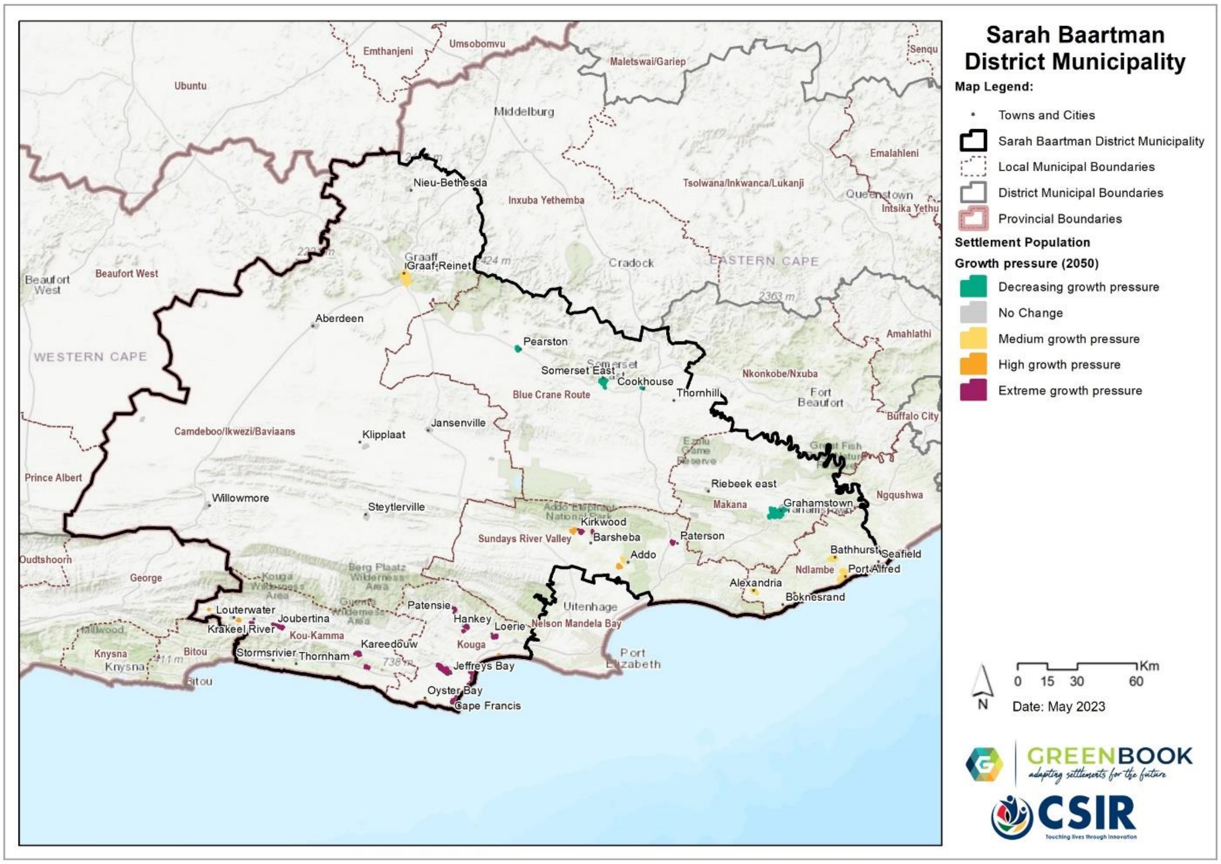

Figure 4: Settlement-level population growth pressure across Sarah Baartman District Municipality

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

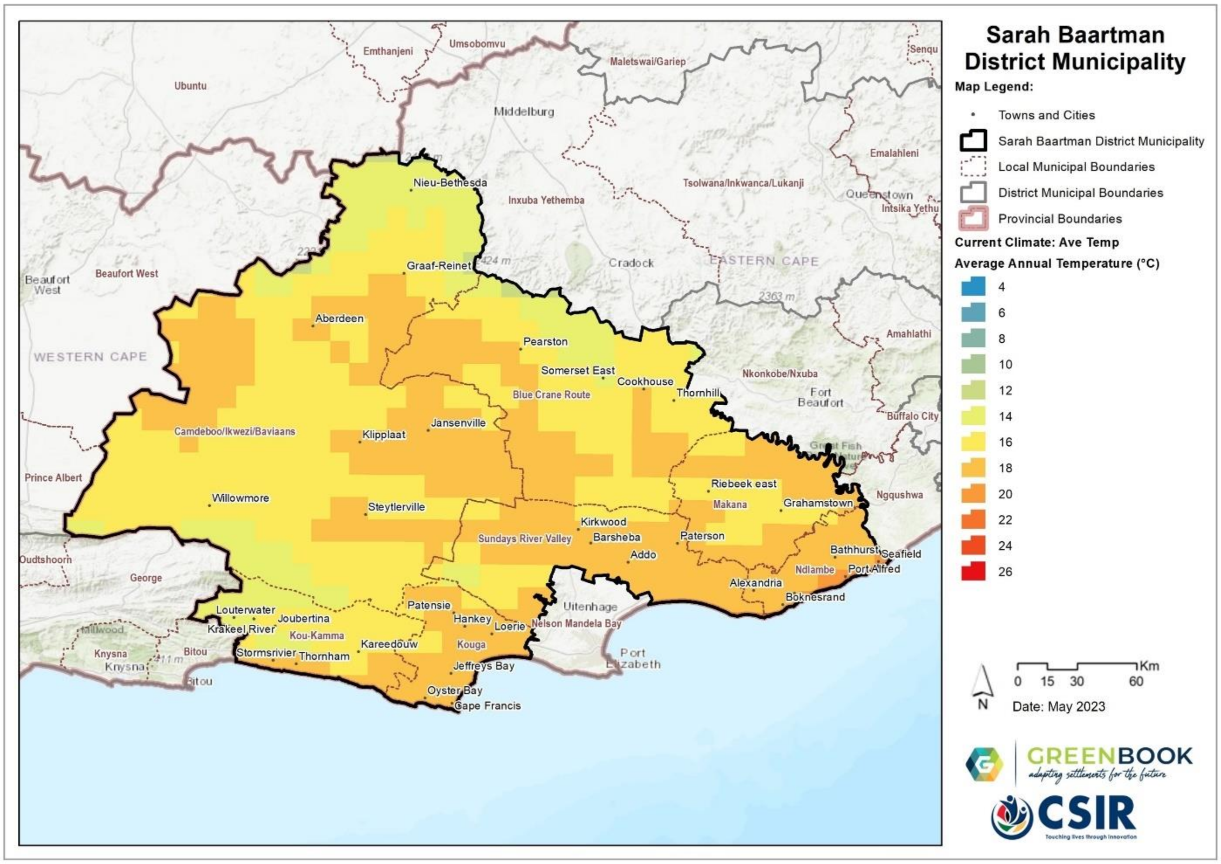

Figure 5: Average annual temperature (°C) for the baseline period 1961-1990 for Sarah Baartman District Municipality

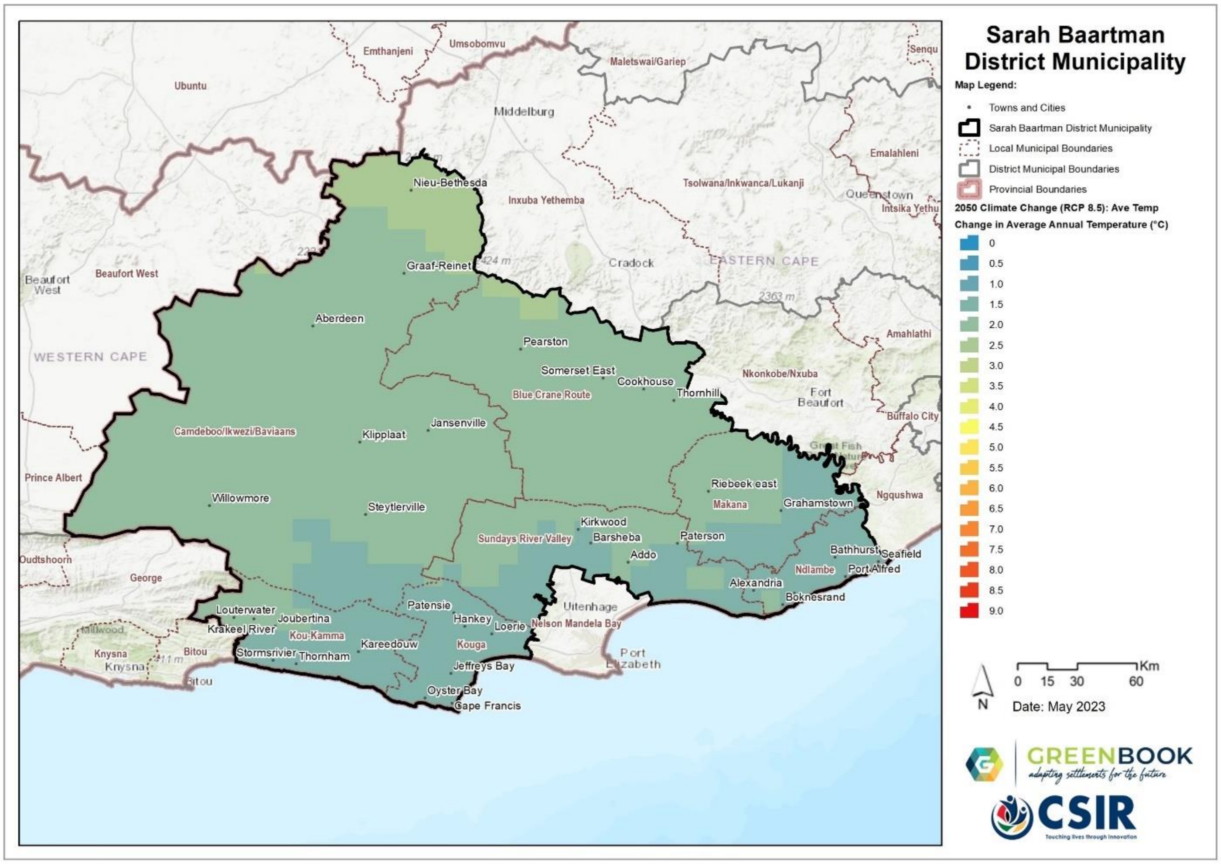

Figure 6: Projected change in average annual temperature (°C) from the baseline period to the period 2021-2050 for Sarah Baartman District Municipality, assuming an RCP 8.5 emissions pathway

The District experiences current average annual temperatures of between 14 and 20 °C, with higher averages found along the coast and within the Municipalities of Ndlambe, Kouga and Sundays River Valley. The projections show average annual temperature increases of between 1.55 °C and 2.78 °C across the District Municipality by 2050, under a low mitigation scenario. The greatest increases are expected to the north of the District around the towns of Nieu-Bethesda and Graaf-Reinet. Average annual temperature increases will be near the lower range along the coast.

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 a RCP8.5 emissions scenario.

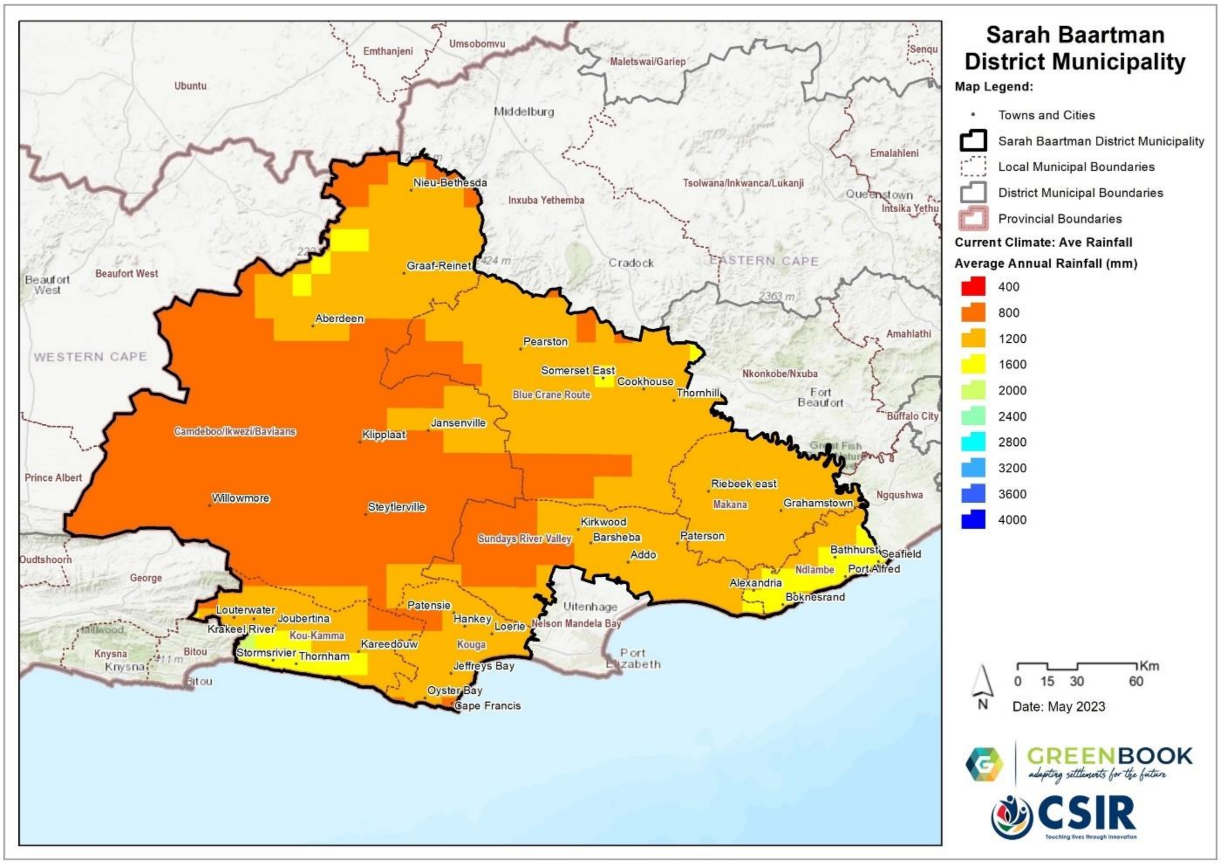

Figure 7: Average annual rainfall (mm) for the baseline period 1961-1990 for Sarah Baartman District Municipality

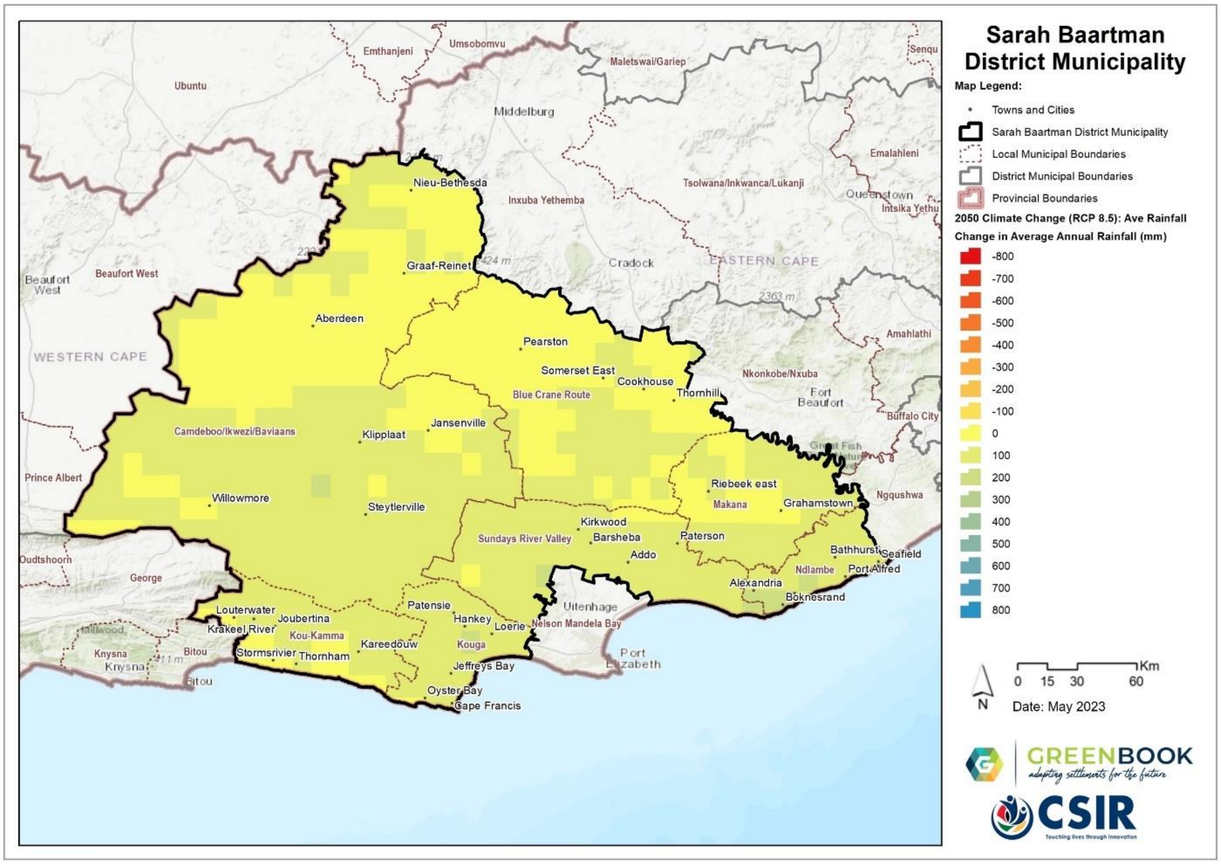

Figure 8: Projected change in average annual rainfall (mm) from the baseline period to the period 2021-2050 for Sarah Baartman District Municipality, assuming an RCP8.5 emission pathway

The District experiences current average annual rainfalls of between 800 and 1600 mm, with higher rainfalls found along parts of the coast and within the Local Municipalities of Ndlambe and Kou-Kamma. The projections show average annual rainfall changes of between 124 mm less and 185mm more across the District Municipality by 2050, under the low, i.e., "business as usual", emission scenario. Small increases in rainfall are expected more within the Sundays River Valley and Makana LMs, while the rest of the District will generally experience a lower average annual rainfall.

2.3. Climate Hazards

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

2.3.1.Drought

The southern African region (particularly 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 primarily uses 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 (scale). 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).

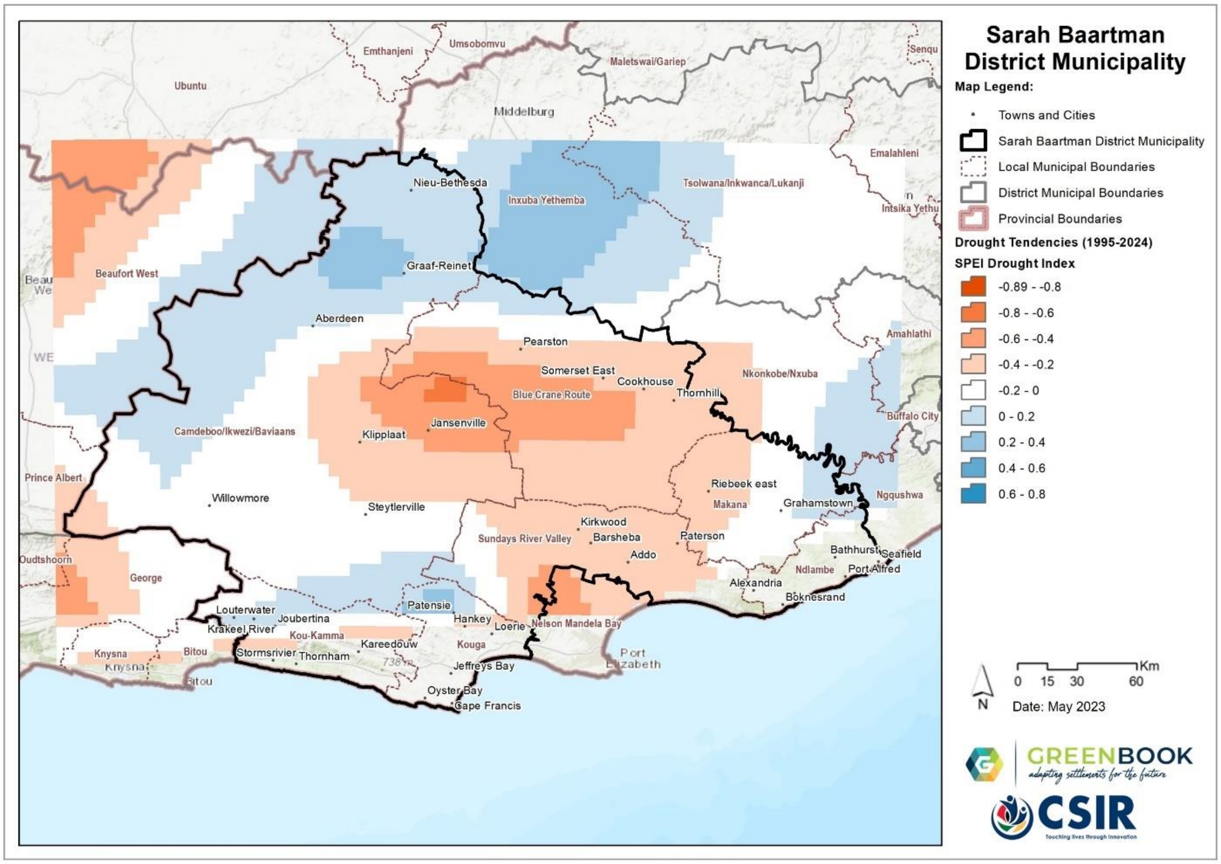

Figure 9: Drought tendencies for the period 1995-2024 relative to the baseline period across the Sarah Baartman District Municipality

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).

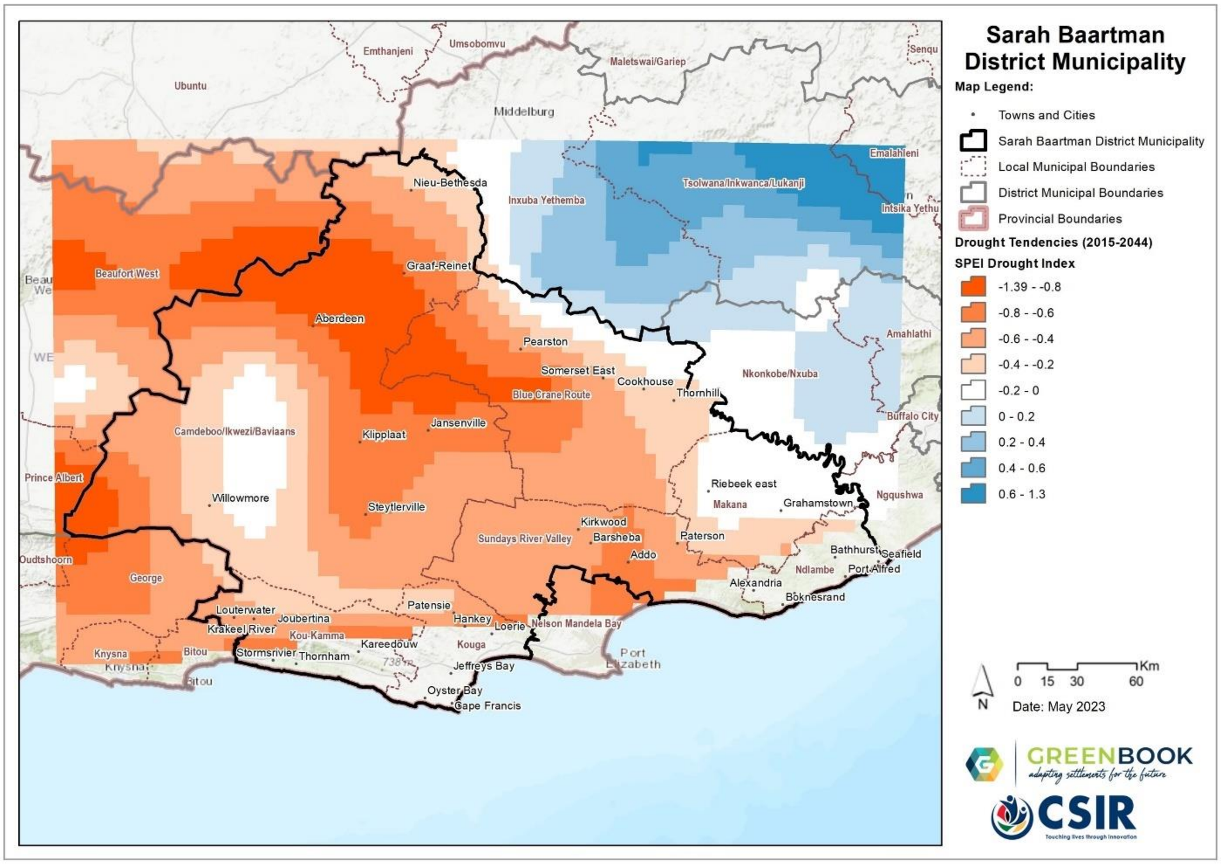

Figure 10: Projected drought tendencies for the period 2015-2044 relative to the baseline period for Sarah Baartman District Municipality

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

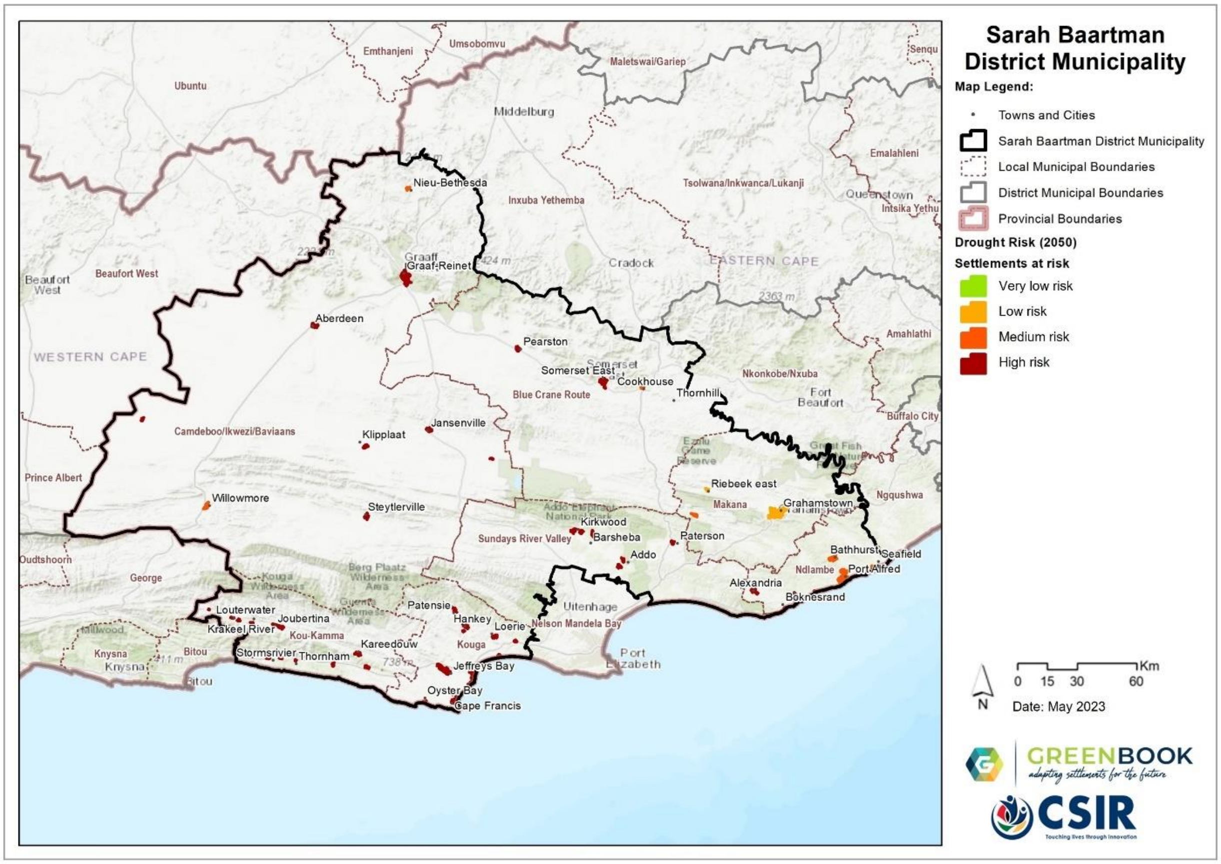

Figure 11: Settlement-level drought risk for Sarah Baartman District Municipality

All the settlements across the District and its Local Municipalities 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 (Figure 13). The annual heatwave days map under baseline climatic conditions (Figure 14) 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.

Under baseline climatic conditions, there are no more than approximately 30 very hot days experienced within the District. Very hot days are more likely to be experienced near the settlements of Jansenville and Klipplaat in the Dr Beyers Naude LM, and around Kirkwood in Sundays River Valley LM. The number of very hot days are projected to increase in the areas that are already more likely to experience extreme heat, while heatwave events are more likely to take place towards the north of the District, affecting the Blue Crane Route and Dr Beyers Naude LMs.

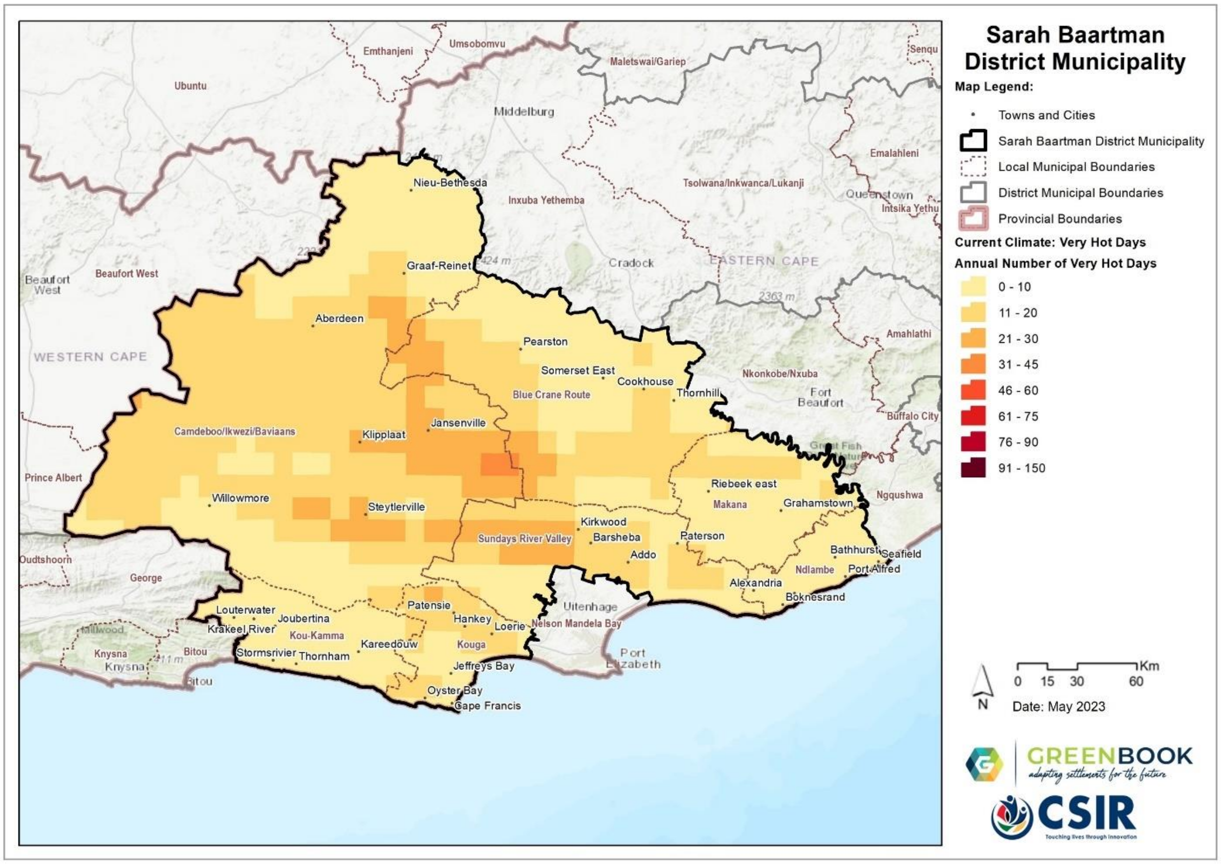

Figure 12: Annual number of very hot days across Sarah Baartman District Municipality with daily temperature maxima exceeding 35°C

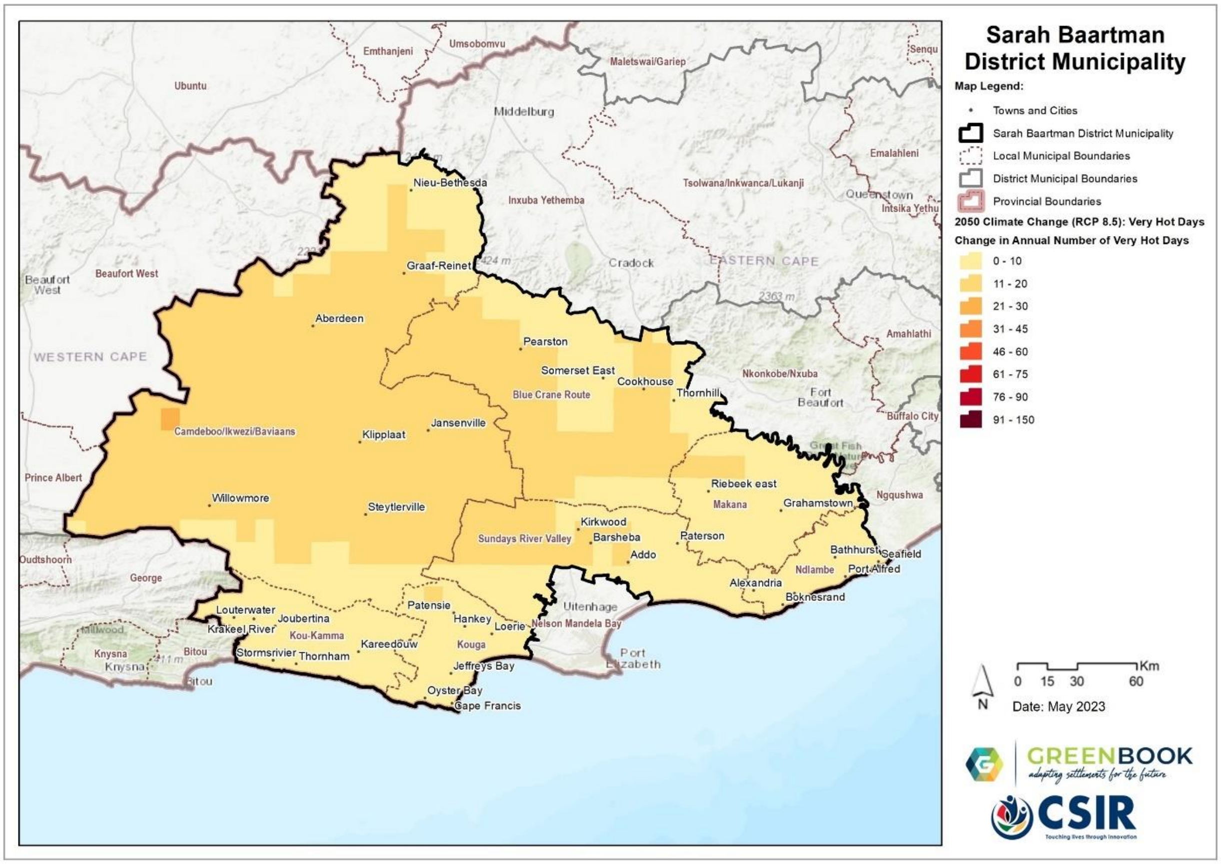

Figure 13: Projected change in annual average number of very hot days for the period 2021-2050 for Sarah Baartman District Municipality

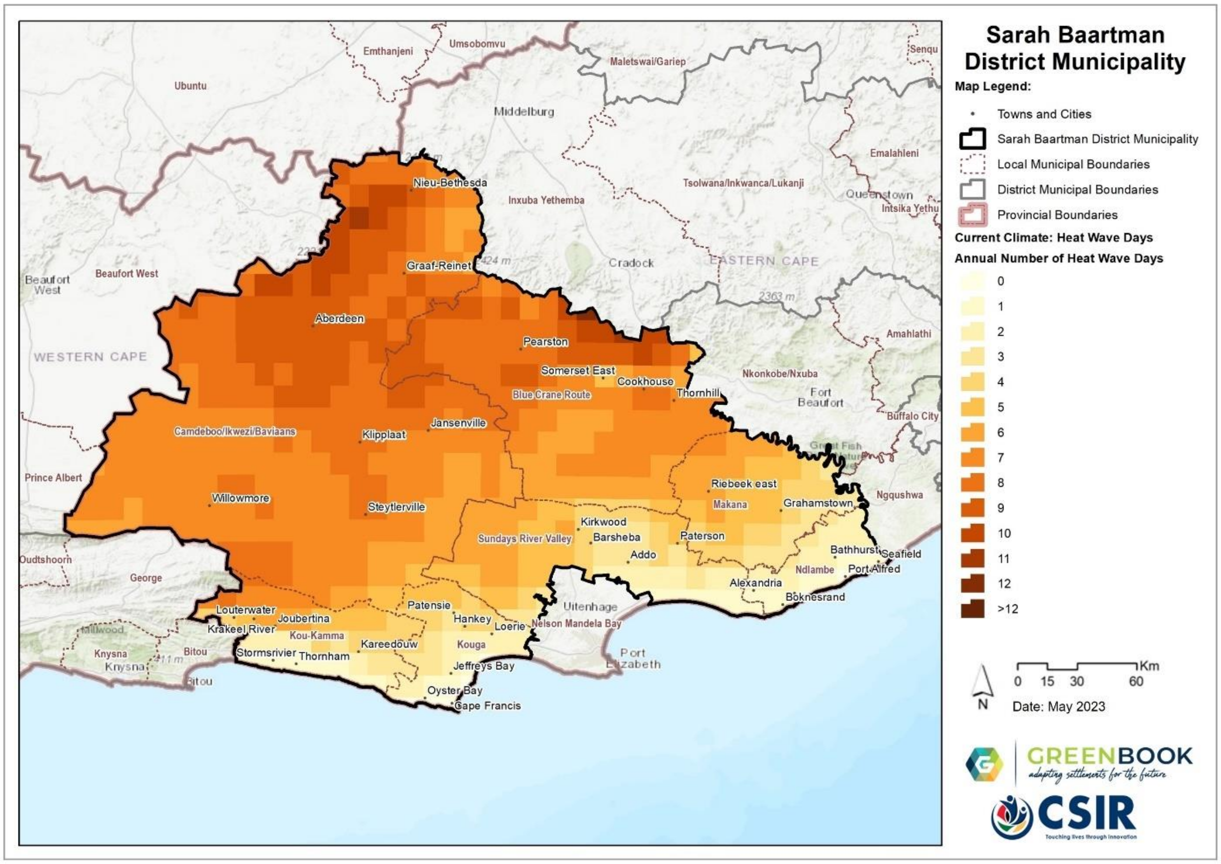

Figure 14: Annual number of very hot days across Sarah Baartman District Municipality with daily temperature maxima exceeding 35°C

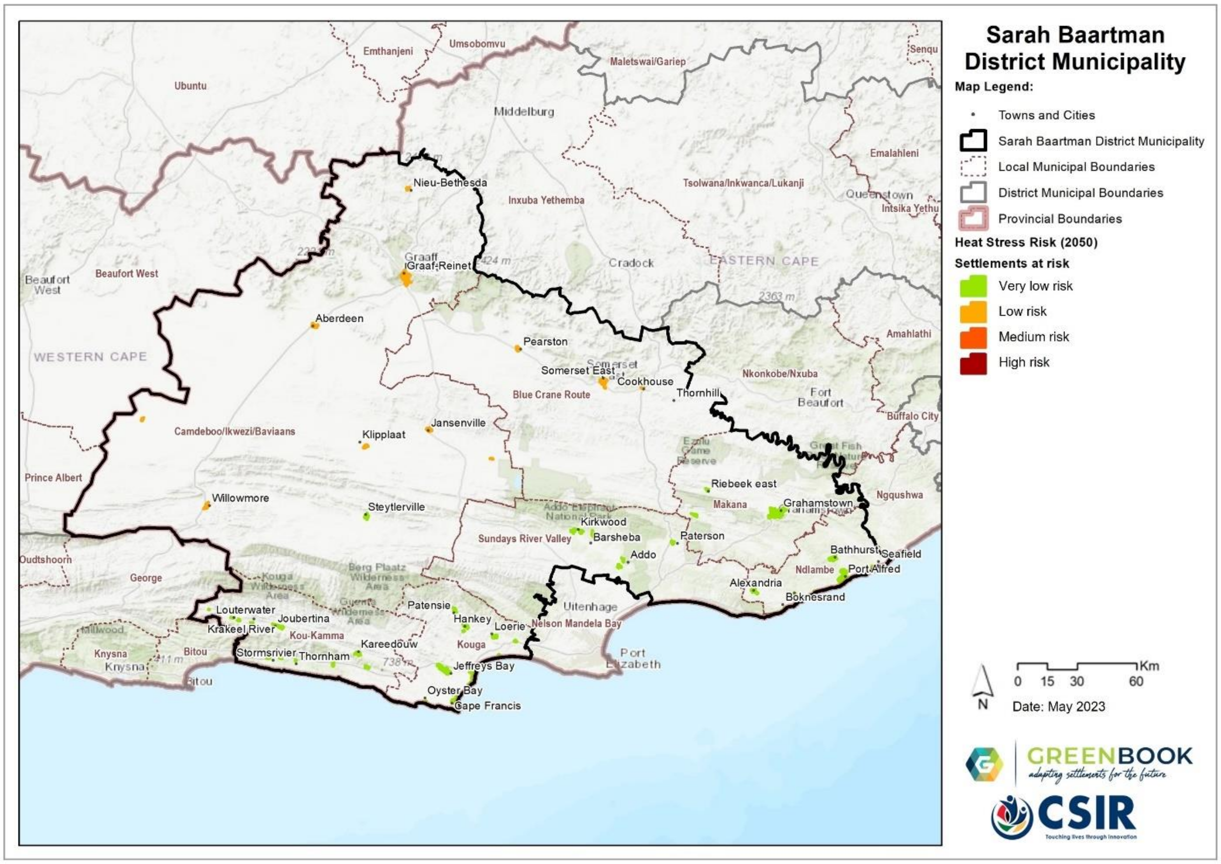

Figure 15: Heat risk across Sarah Baartman District Municipality at settlement level in the 2050s

Figure 15 depicts the settlements that are at risk of increases in heat stress. 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. Some of the settlements that would be most exposed to heat stress in the future in the District include Graaff Reinet, Somerset East, Nieu-Bethesda and Jansenville.

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.

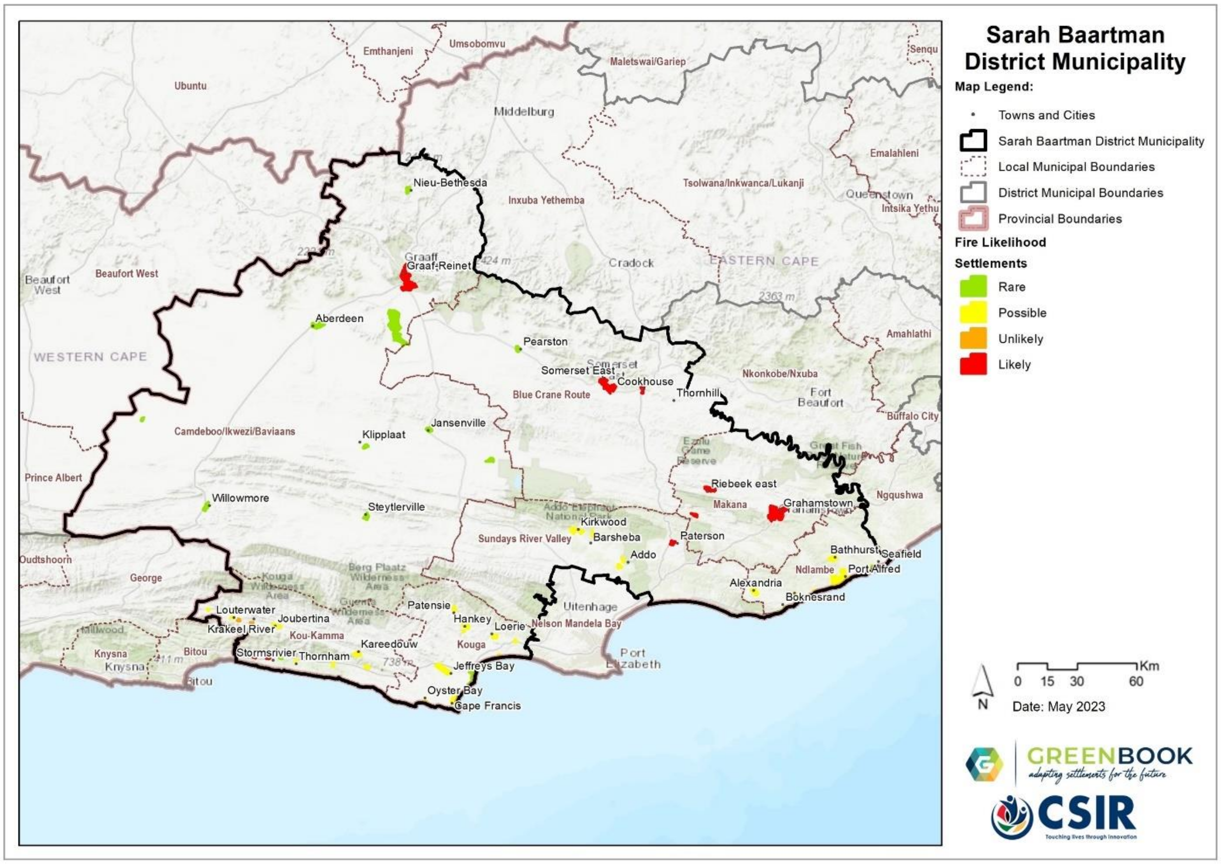

Figure 16: The likelihood of wildfires under current climatic conditions across settlements in Sarah Baartman District Municipality

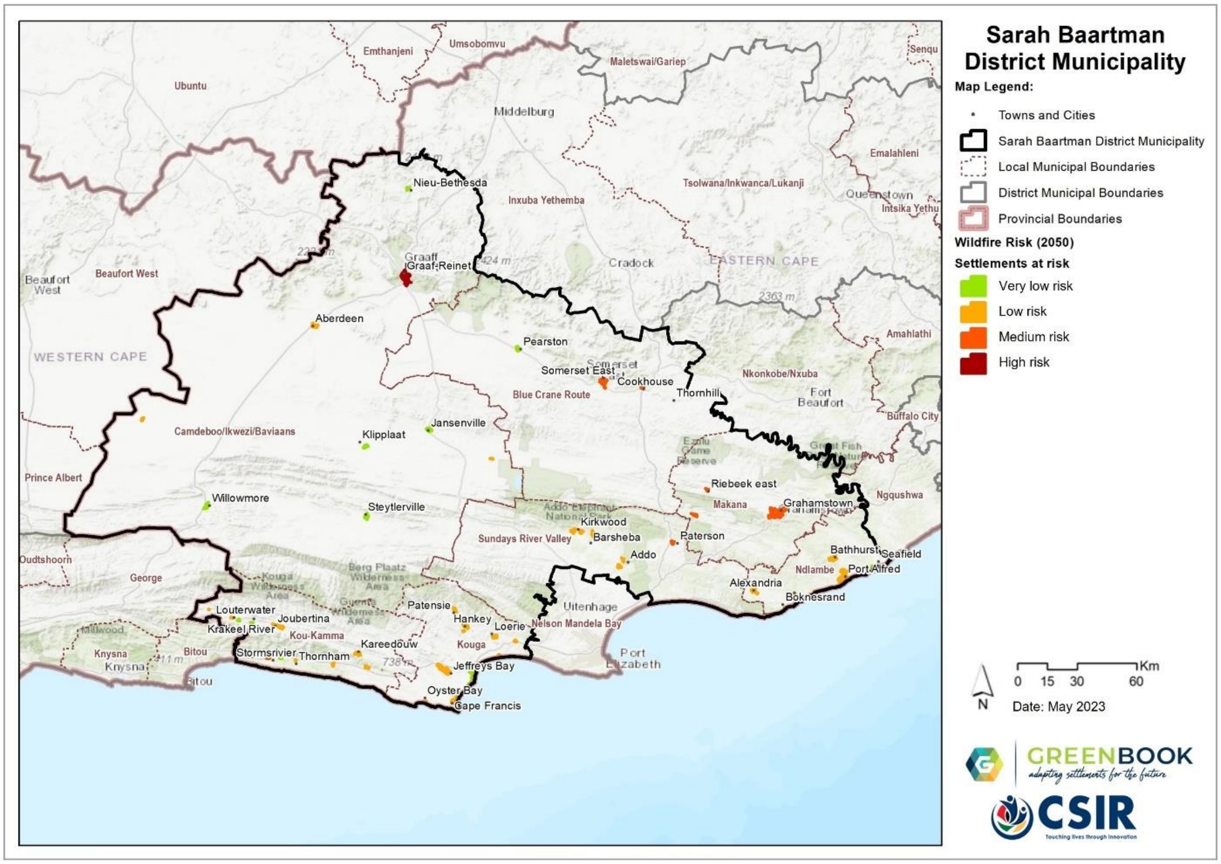

Figure 17: The likelihood of wildfires under projected future climatic conditions across Sarah Baartman District Municipality

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, while Figure 17 depicts the settlements that could be at risk of increases in wildfires by the year 2050. Settlements which are likely to experience wildfires on their wildland-urban interface include Graaff-Reinet, Somerset East, Cookhouse, Riebeek East, Grahamstown, and Paterson. It is projected that of these settlements, Graaff Reinet could see an extreme risk of wildfire in 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 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.

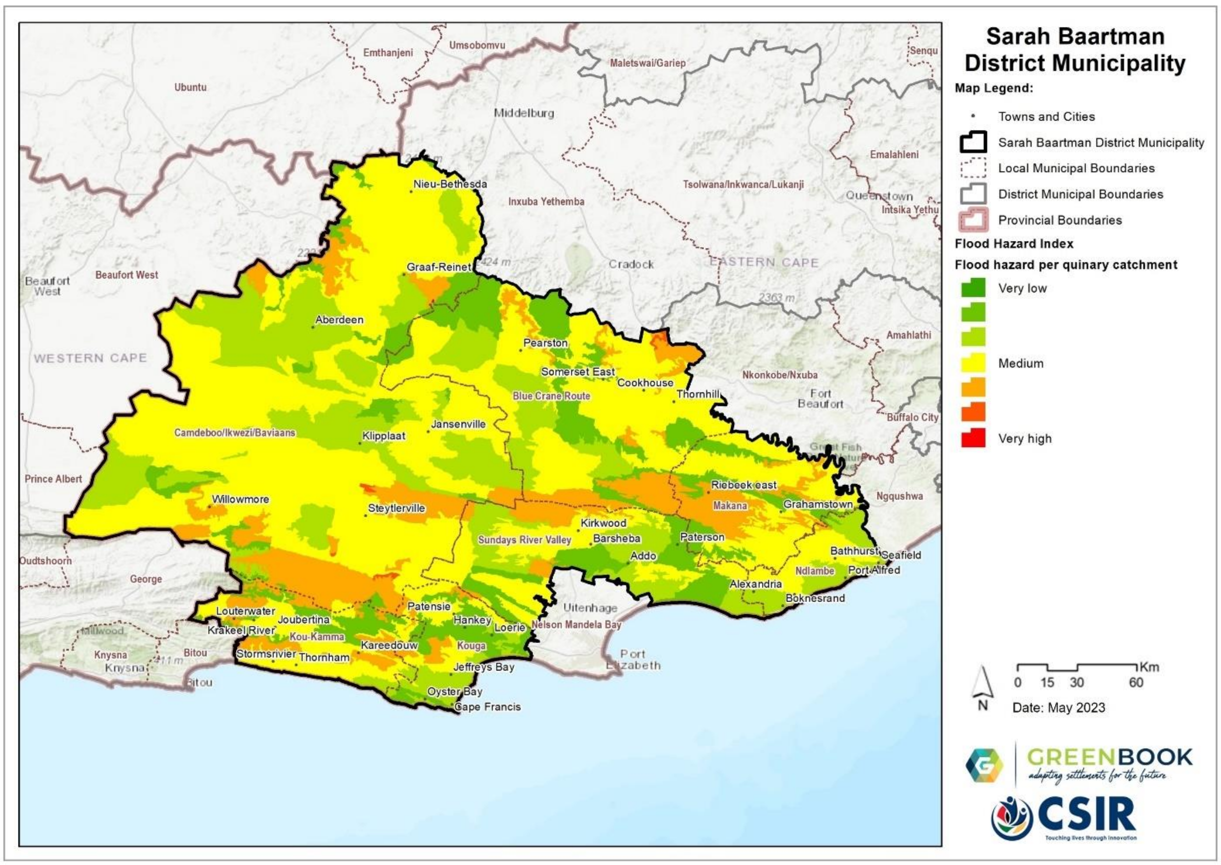

Figure 18: The flood hazard index across Sarah Baartman District Municipality under current (baseline) climatic conditions

Figure 18 depicts the flood hazard index of the different 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). Most parts of the District have a very low to medium flooding hazard, with pockets of medium to very high flooding hazard.

Figure 19 depicts the projected change for 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. 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 around Sundays River Valley and the southern parts of Dr Beyers Naude LMs.

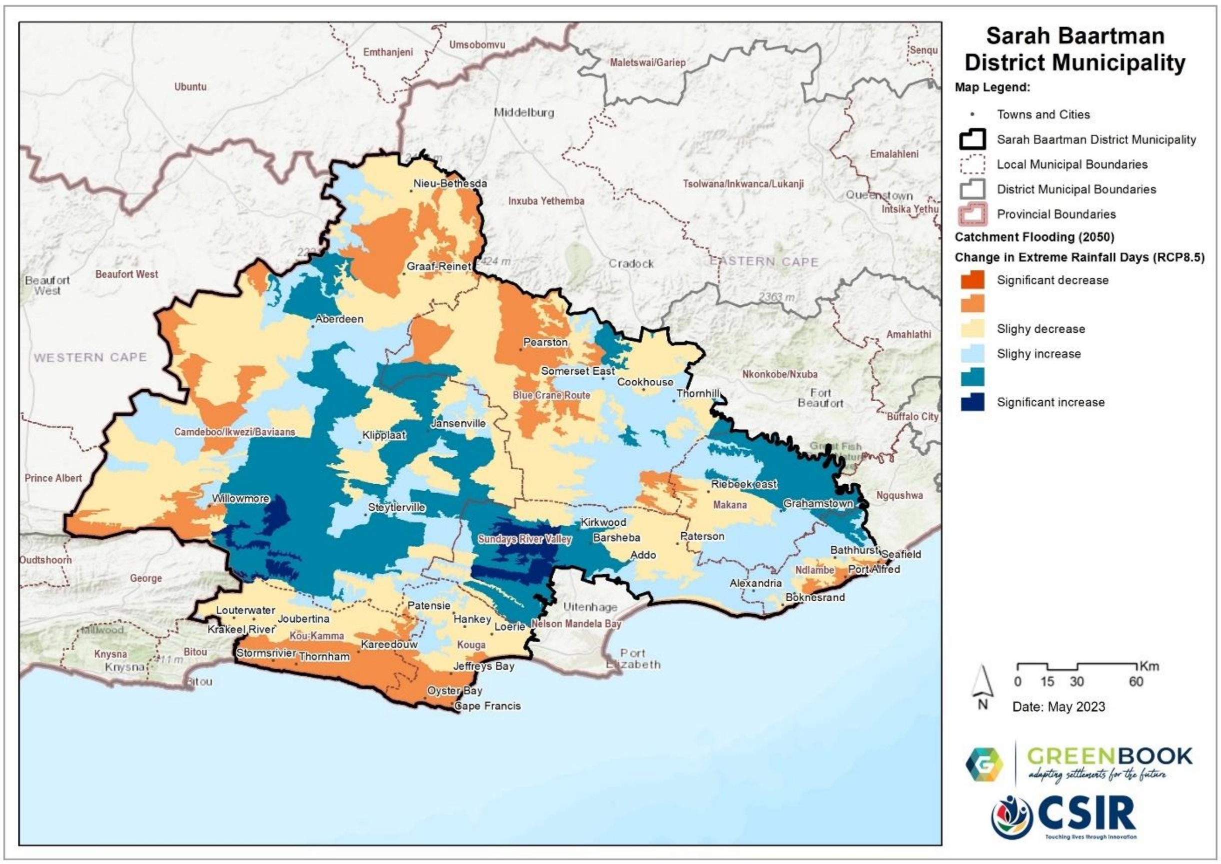

Figure 19: Projected change into the future in extreme rainfall days across Sarah Baartman District Municipality

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. In the SBDM, these include Jansenville, Kirkwood, Willowmore, and Grahamstown.

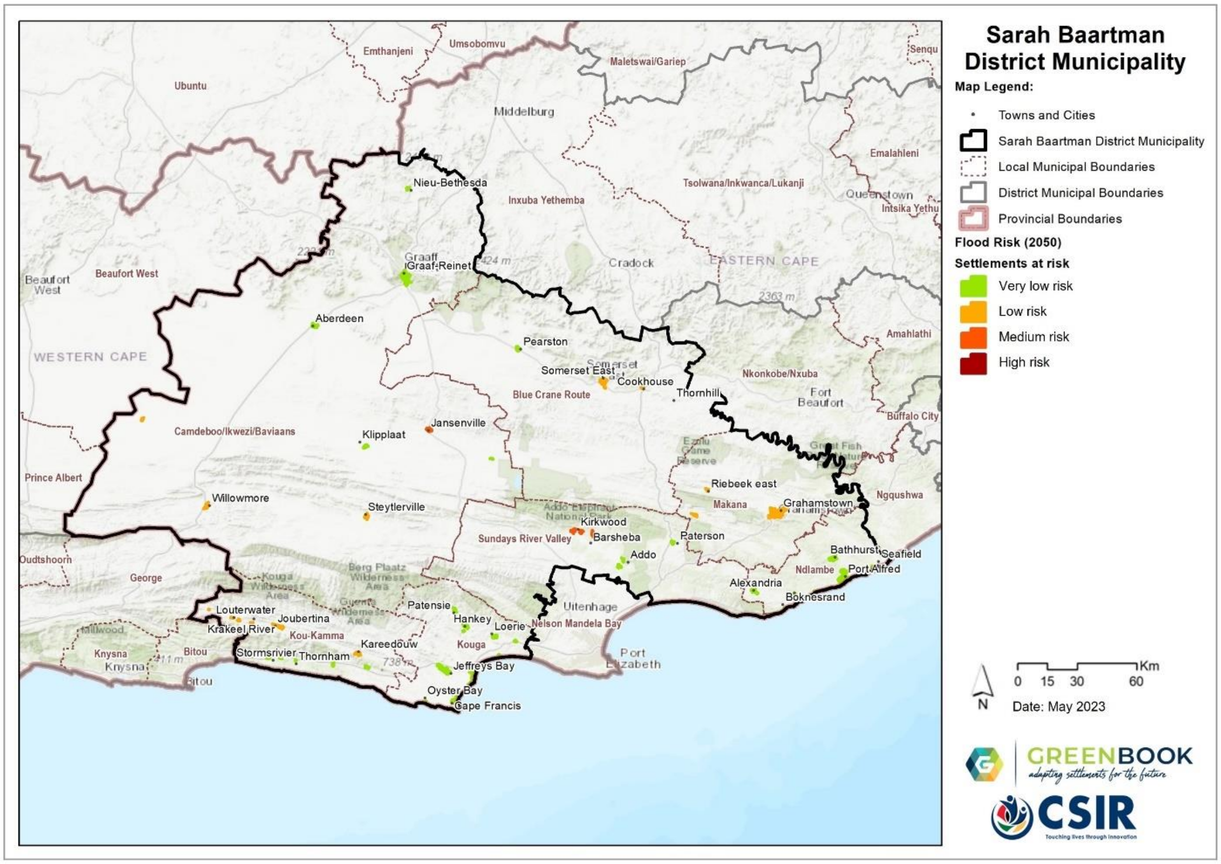

Figure 20: Flood risk into a climate change future at settlement level across Sarah Baartman District Municipality

2.3.5. Coastal flooding

The approach to coastal flooding is divided into two parts, 1) generating a coastal flood hazard index, and 2) performing risk assessment for coastal settlements. The generation of a coastal flood hazard index consists of 4 parts:

- Assessing the flood hazard exposure
- Generating elevation hazard risk assessment
- Generating coastal distance hazard risk assessment
- Generating final coastal flood hazard index

The basis for any coastal flood hazard assessment is detailed and precise information on the topography to accurately identify low-lying areas, usually derived from a Digital Elevation Model (DEM). The best results are achieved when using DEMs derived from airborne LiDAR data, which provide elevation information up to a square metre resolution. For this study, LiDAR-derived DEMs were available for about 50 % of the South African coast and data gaps were filled with the Stellenbosch University Digital Elevation Model (SUDEM). The LiDAR data used in this study were provided by ALEXCOR, Western Cape Province, City of Cape Town, KwaZulu-Natal Province and iSimangaliso Wetland Park. With all LiDAR point data, the respective “last return” or “ground cover” information was used to generate raster DEMs. The bit-depths and NoData values of the various LiDAR DEMs were standardised, and each DEM was re-sampled to a 5m resolution to allow for seamless fusion with the SUDEM.

From the resulting merged product, all areas with an elevation higher than 40 m above sea level were excluded, as these areas are assumed safe from coastal flooding. A further reduction of the area of assessment was achieved by excluding all areas that are not currently urbanised or within a 1 km distance of such settlements, formal or traditional. For the remaining urban and peri-urban areas, the coastal flood hazard assessment was conducted based on two assumptions, 1) low lying areas are at greater risk of flooding than higher areas, and 2) areas closer to the coast are at greater risk of flooding than areas further away. The final flood hazard index product was calculated as the average of the two individual indices for elevation and distance and resulted in five final flood hazard risk categories.

The risk assessment for coastal settlements considered the total spatial extent of each hazard risk class per province (urban and traditional settlements individually), and the total number of buildings per hazard risk class per province (urban and traditional settlements individually).

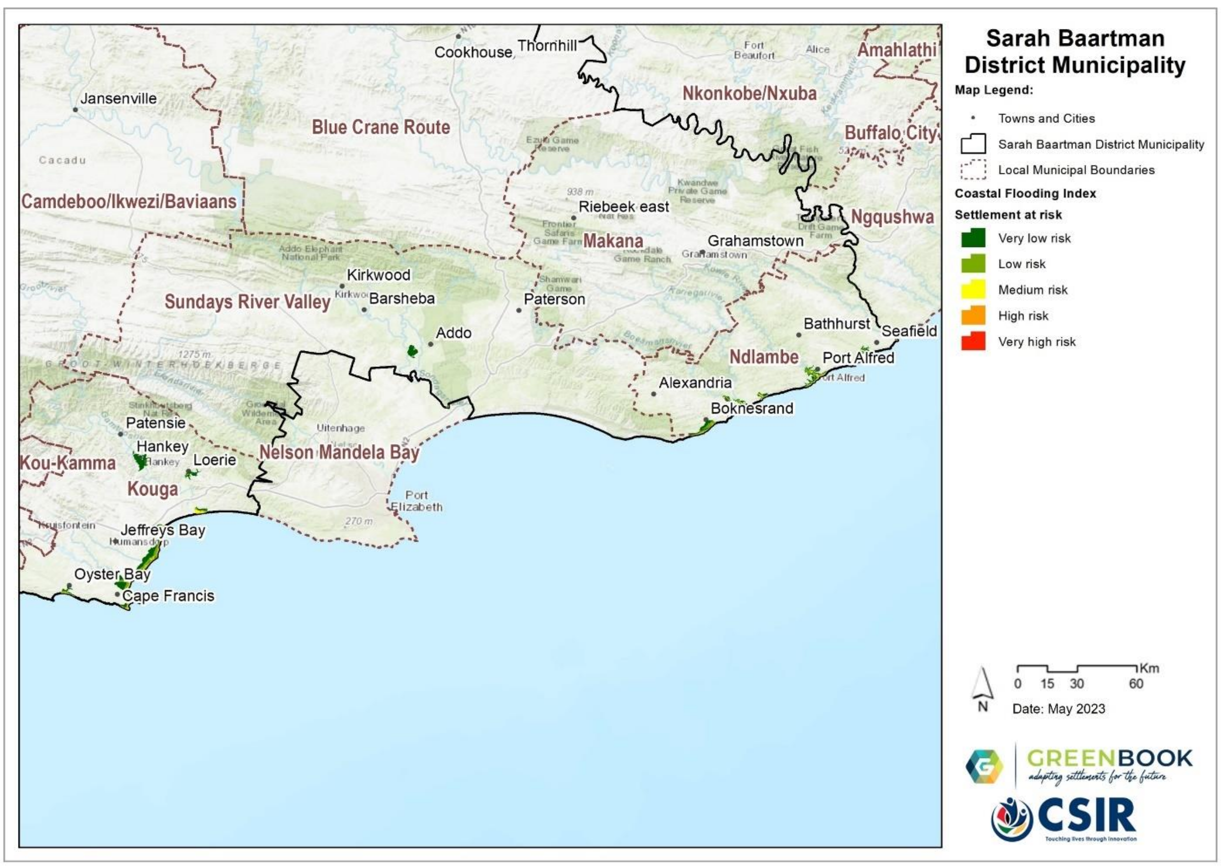

Figure 21: Coastal flooding index and settlements at risk under current (baseline) conditions

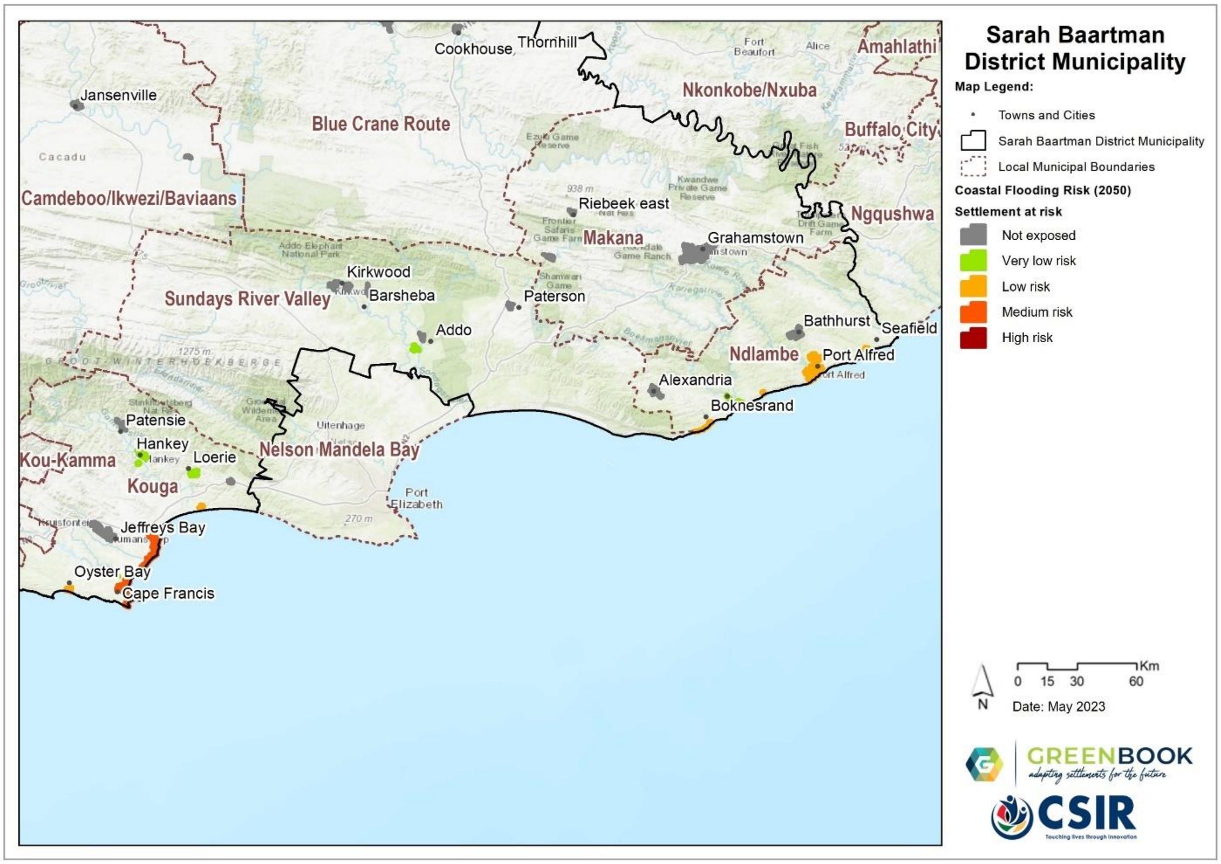

Figure 22: Settlements that are most exposed to coastal flooding by 2050.

Jeffreys Bay and Cape Francis will likely face high risk of coastal flooding by 2050, while Port Alfred will face a medium risk.

The GreenBook Municipal Risk Profile Tool contains updated information on coastal flooding and coastal erosion under the Hazards section. Detailed information for the coastal areas is available there. For the data that are viewable on the tool, the modelling of the flood extents followed a two-step approach. First, hydrodynamic modelling determined the water-level height on the coastline, based on statistically determined offshore wave conditions for the 1:10, 1:30, 1:50 and 1:100 years storm events, in combination with a medium-future sea-level rise and a long-term sea-level rise scenario. Those water-level heights were then extrapolated inland, using the enhanced BathTubModel in ArcGIS. The spatial accuracy for the flood extent maps depends greatly on the spatial detail of the used digital elevation model used, and the 5x5m resolution SUDEM was used, as no LiDAR data were available. Coastal local municipalities are encouraged to consider both the information available in this report and on the Municipal Risk Profile tool to understand exposure and risk of coastal flooding.

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 Sarah Baartman District Municipality.

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 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 whose 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 groundwater dependent. In the Sarah Baartman District, there is a mix of surface water and groundwater dependent towns.

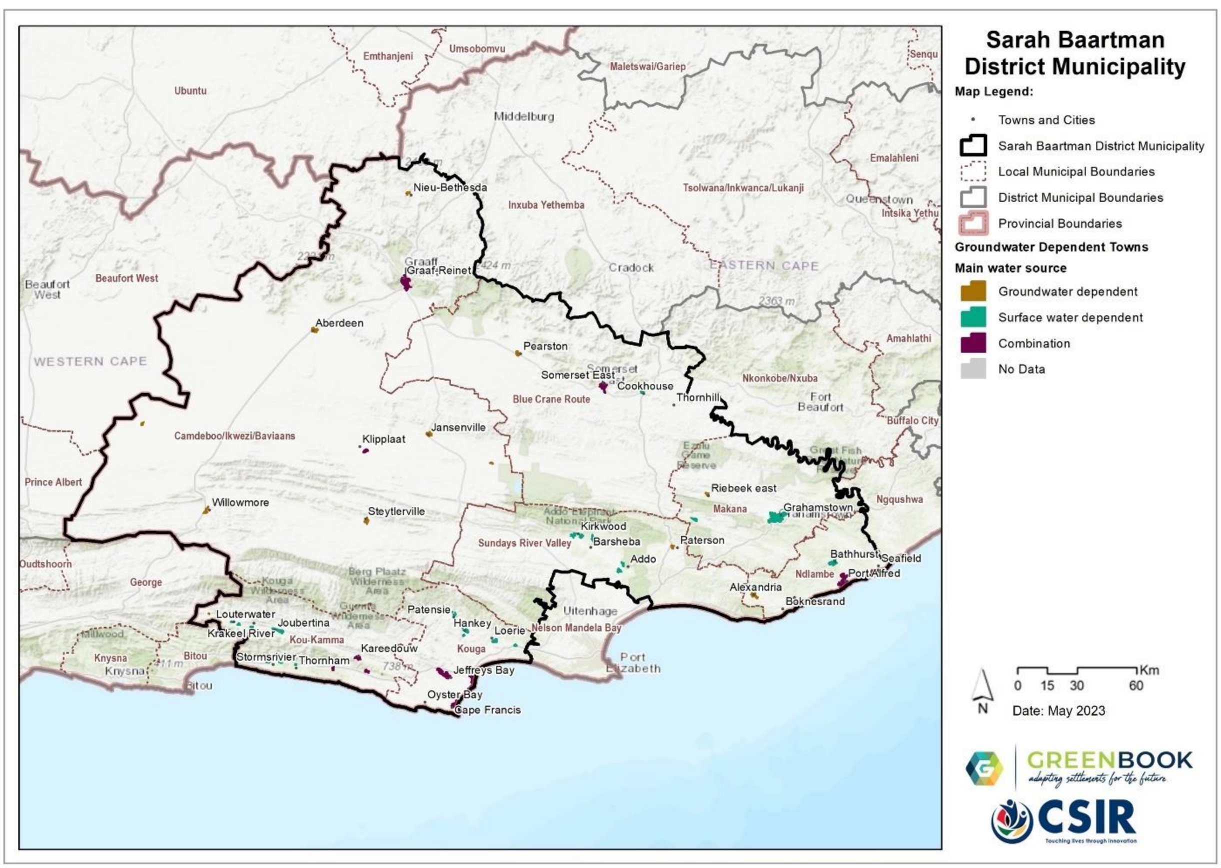

Figure 23: Main water source for settlements in the Sarah Baartman District Municipality

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 along the coast of the District, and lower towards the central and the west. Note that that recharge potential is lower very close to the coastline.

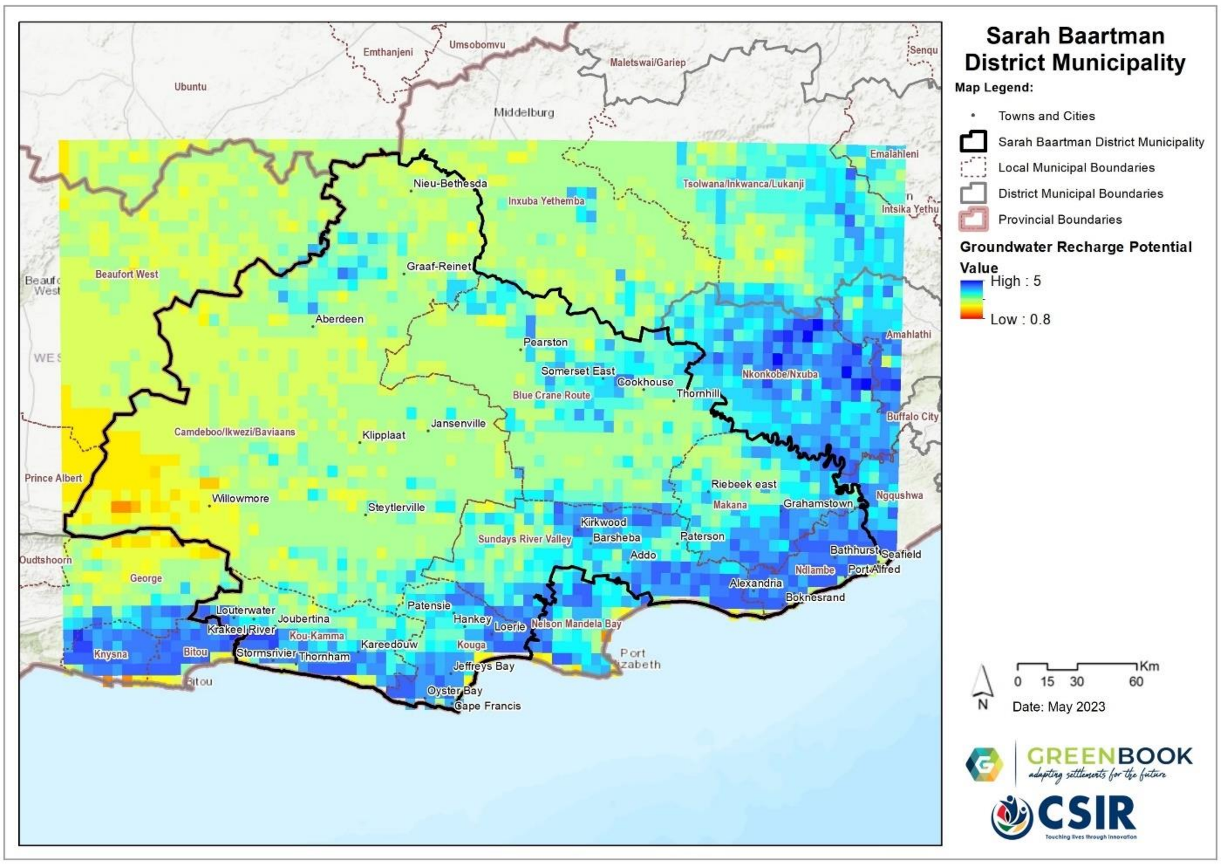

Figure 24: Groundwater recharge potential across Sarah Baartman District Municipality under current (baseline) climatic conditions

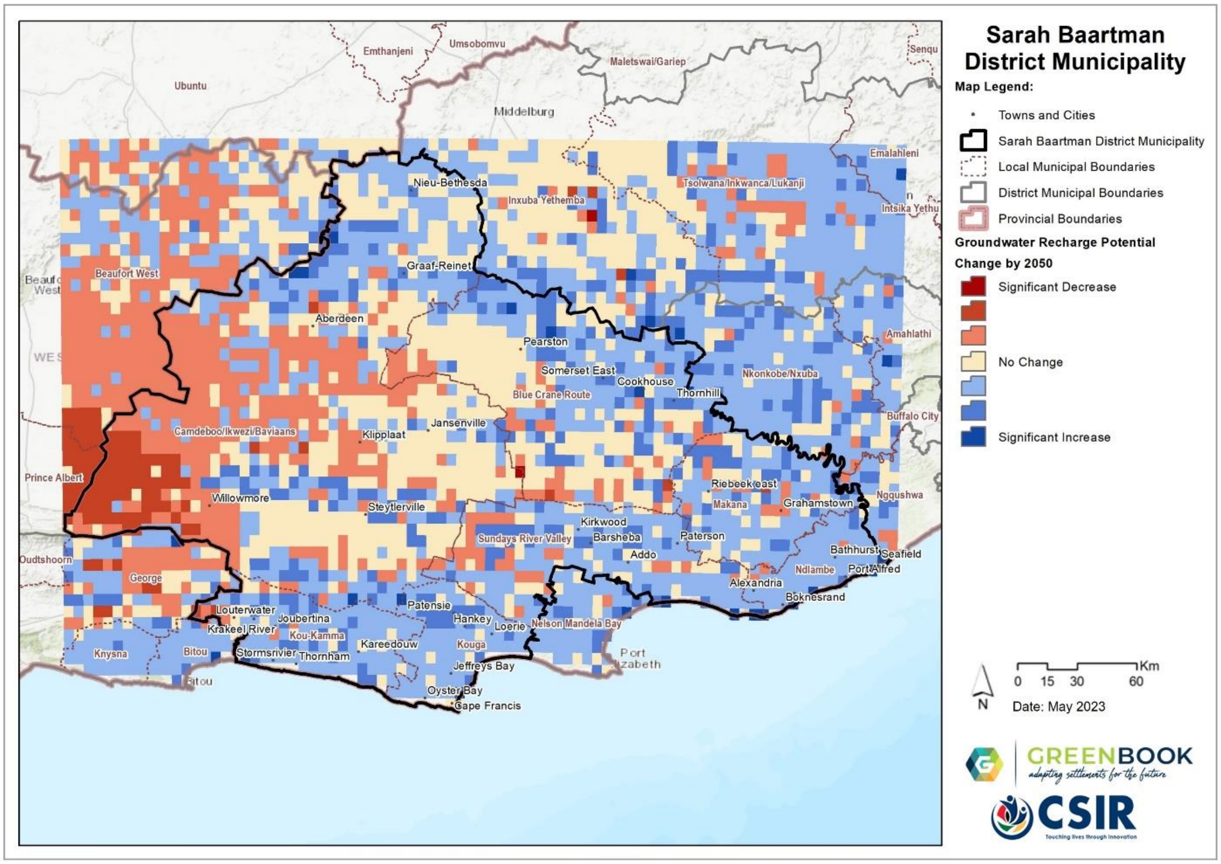

Figure 25: Projected changes in groundwater recharge potential from baseline climatic conditions to the future across Sarah Baartman District Municipality

Settlements in the Kouga LM have high to extreme risk of groundwater depletion, considering projected groundwater recharge potential combined with population growth. Other settlements that rely on groundwater that will face a medium risk to groundwater depletion include Port Alfred, Alexandria, and Graaf Reinet.

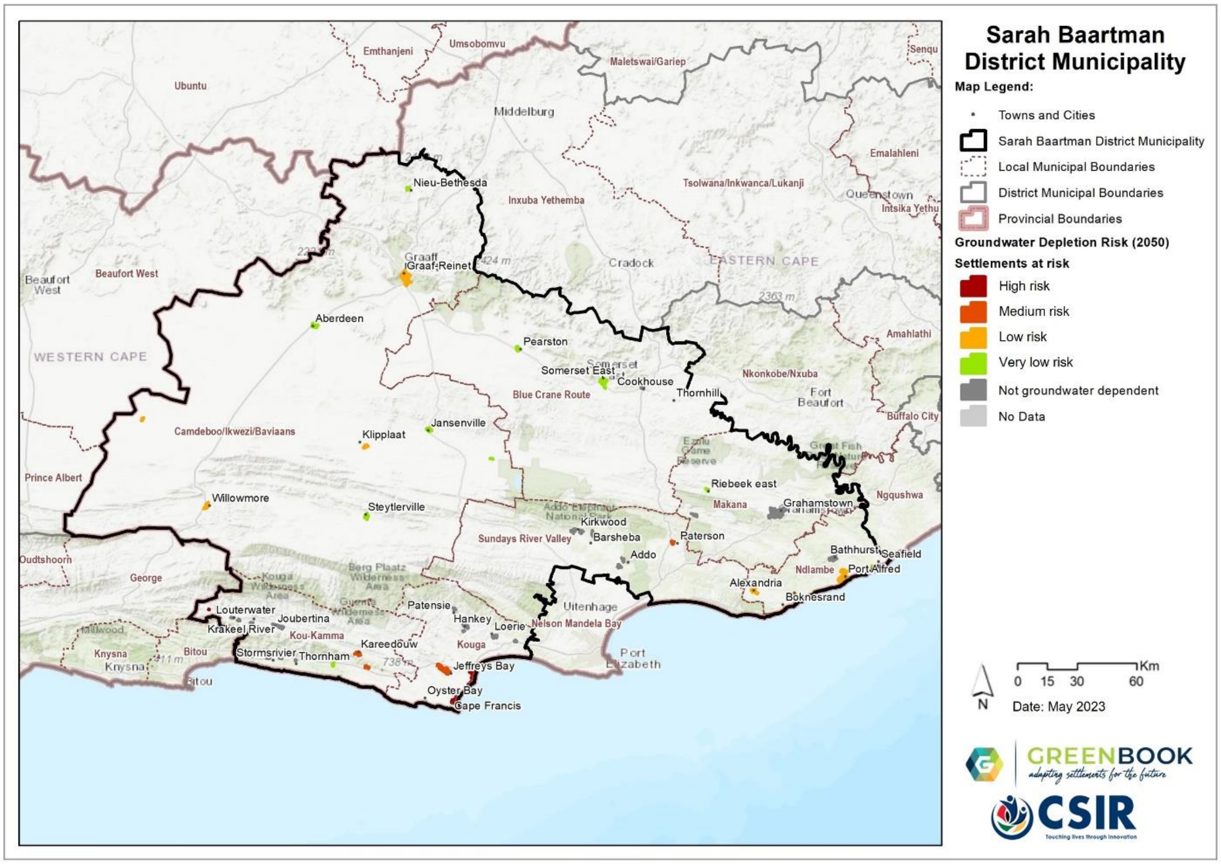

Figure 26: Groundwater depletion risk at settlement level across Sarah Baartman District Municipality

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

Local Municipality	Water Demand per Capita (l/p/d)	Water Supply per Capita (l/p/d)	Current Water Supply Vulnerability
Blue Crane Route	207.19	191.51	1.08
Dr Beyers Naude	240.62	276.65	0.87
Sundays River Valley	177.1	173.28	1.02
Kouga	180.52	199.73	0.9
Kou-Kamma	76.78	78.57	0.98
Ndlambe	136.61	193.46	0.71
Makana	132.85	135.78	0.98

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.

Blue Crane Route

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

Dr Beyers Naude

Water supply vulnerability is currently relatively low in the Municipality and because of the projected population decline, combined with increased mean annual runoff, water supply vulnerability is not expected to increase.

Sundays River Valley

Water supply is already vulnerable and is projected to increase to between 1.3 and 1.6 by 2050 if no intervention is made to significantly increase supply or limit demand.

Kouga

Water supply vulnerability is high and is expected to significantly increase to between 1.6 and 2.2 by 2050. Water supply vulnerability is driven by projected extreme population growth pressure, a decrease in average annual rainfall, increased evaporation, and a decrease in mean annual runoff.

Kou-Kamma

Water supply vulnerability is relatively high and is expected to significantly increase to between 1.3 and 1.6 by 2050. Water supply vulnerability is driven by projected extreme population growth pressure, a decrease in average annual rainfall, increased evaporation, and a decrease in mean annual runoff.

Ndlambe

Water supply vulnerability is currently relatively low in the Municipality and is not expected to increase to a level where demand would outstrip supply.

Makana

Water supply vulnerability is currently relatively high in the Municipality, but because of the projected decline in the population and increased rainfall and runoff, water supply vulnerability is projected to improve into the future.

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 we have 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 AFF sector contributes 28% to the local GVA of the District (Table 4, CoGTA, 2020, p 62). The potential impact of climate change and climate hazards on agriculture is notable considering that many households are dependent of the sector for employment. In Kou-Kamma LM, more than half of the labour force is employed in the sector, while it is close to half the labour force in the Sundays River Valley LM. The main agricultural commodities for each Local Municipality within the Sarah Baartman District Municipality are discussed below in terms of what the impact of climate change might be on those commodities under an RCP 8.5 i.e., "business as usual" GHG emissions, scenario.

Blue Crane Route

In Blue Crane Route LM, the Agriculture, Forestry and Fisheries (AFF) sector contributes 6.59 % to the local GVA, which is a contribution of 0.12 % to the national GVA for the AFF sector. Of the total employment, 26.87 % is within the AFF sector. The main agricultural commodities are sheep and beef cattle. Climate projections show a generally hotter and drier climate which could lead to reduced availability and quality of pastures due to decline in rainfall. The climate impact will also lead to reduced growth and reproductive efficiency due to heat and nutrition stress. Warmer winters could lower cold weather associated with livestock mortality but are also conducive to the survival of pests and parasites that threaten livestock.

Dr Beyers Naude

In the Dr Beyers Naude LM, the AFF sector contributes 5.45 % to the local GVA, which is a contribution of 0.24 % to the national GVA for the AFF sector. Of the total employment, 21.86 % is within the AFF sector. The main agricultural commodities are sheep and mohair. Climate projections show a generally hotter and wetter climate, becoming drier towards the end of the century. Increased heat stress on livestock can lead to reduced growth and reproductive efficiency. Warmer winters could lower cold weather associated with livestock mortality, but are also conducive to the survival of pests and parasites that threaten livestock. Angora goats are more sensitive to thermal and nutritional stress compared to sheep and other breeds of goats. Warmer winters could lower cold weather associated livestock mortality but are also conducive to the survival of pests and parasites that threaten mohair goats.

Sundays River Valley

In Sundays River Valley LM, the AFF sector contributes 13.86 % to the local GVA, which is a contribution of 0.34 % to the national GVA for the AFF sector. Of the total employment, 47.2 % is within the AFF sector. The main agricultural commodities are milk and cream, citrus, and game farming. 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.

Kouga

In the Kouga LM, the AFF sector contributes 26.55 % to the local GVA, which is a contribution of 0.42 % to the national GVA for the AFF sector. Of the total employment, 26.55 % is within the AFF sector. The main agricultural commodities are milk and cream, and citrus. 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. For citrus, hot and moist conditions will benefit a more heat-tolerant disease vector but will also lead to increased exposure to pests.

Kou-Kamma

In the Kou-Kamma LM, the AFF sector contributes 17.01 % to the local GVA, which is a contribution of 0.44 % to the national GVA for the AFF sector. Of the total employment, 50.58% is within the AFF sector. The main agricultural commodities are milk and cream, and deciduous fruits. Climate projections show a generally hotter and wetter climate, becoming drier towards the end of the century. As is the case with the other Local Municipalities, the hot and moist conditions will negatively affect dairy cattle. For deciduous fruits, a reduction in available winter chill and increased summer heat stress will lead to increased evapotranspiration and irrigation requirements. Production remains viable as long as heat stress is managed, and water is available.

Ndlambe

In the Ndlambe LM, the AFF sector contributes 3.81 % to the local GVA, which is a contribution of 0.14 % to the national GVA for the AFF sector. Of the total employment, 14.86 % is within the AFF sector. The main agricultural commodities are subtropical fruits such as pineapples, milk and cream, and beef cattle. Climate projections show a generally warmer and wetter climate. For pineapple production, hot and moist conditions increase the exposure to pests and diseases. Extreme temperatures can contribute to poor tree flowering, fruit set and decreases in production. Hot and moist conditions will also negatively affect dairy and beef cattle.

Makana

In the Makana LM, the AFF sector contributes 2.28 % to the local GVA, which is a contribution of 0.12 % to the national GVA for the AFF sector. Of the total employment, 11.57 % is within the AFF sector. The main agricultural commodities are milk and cream, subtropical fruits such as pineapples, and beef cattle. 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. These conditions can also contribute to poor tree flowering, fruit set and decreases in production of subtropical fruits. Hot and moist conditions cause increased spread of disease and parasites among beef cattle and lead to reduced growth and reproduction performance due to heat stress.

3. Recommendations

The greatest risks faced across the Sarah Baartman District are drought and increased temperatures, combined with population growth pressure in the coastal towns. Drought is one of the leading contributors of water scarcity as a result of decreased rainfall. Moreover, because the rate of evapotranspiration increases as the temperature increases, increased temperatures also reduce the quantity of water available in reservoirs, and for reliant ecosystems.

The towns that are currently seeing significant population growth are already experiencing service access pressure, and larger groups of people will become vulnerable and exposed to climate-related hazards. Physical vulnerability is relatively high across the entire District, indicating that the quality of (and access to) infrastructure and assets such as roads and housing, could be poor, thus also making the District's built-environment vulnerable to extreme events.

The generally drier and hotter climate over most parts of the District will also lead to increased risk of wildfire. An increase in wildfires raises the threat of fire to all heritage resources, natural and built, and poses health risks to populations from exposure to smoke and ash pollution. Additionally, certain parts of the District could experience more extreme rainfall events that could lead to flooding. Increase in intensity of rainfall and flooding could lead to increased surface runoff, resulting in increased soil erosion, soil loss and degradation; while increased wave energy and run-up (sea level rise and more storms) could lead to the degradation of natural coastal defence structures.

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

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

2. To protect natural resources and ecosystems: Protecting and restoring natural ecosystems such as wetlands and riparian areas, will enhance the District's biodiversity, support water resource management, and provide natural buffers against climate-related hazards such as wildfires and surface water flooding. Some of the actions that 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 such as more intense and frequent wildfires, storms and flooding events – it is essential to reduce the exposure and vulnerability of elements found in both human and natural systems present in the District, especially those that are likely to be affected by these hazards and extreme events. This will therefore involve a combination of infrastructural, behavioural, and institutional changes. For human systems, this might involve building climate-resilient infrastructure, developing or improving existing disaster risk reduction strategies, and enhancing social safety nets for the most vulnerable. For natural systems, this can involve protecting and restoring ecosystems that provide natural buffers against climate impacts, such as wetlands that absorb flood waters.

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

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

Department of Environmental Affairs (DEA). 2018. Sarah Baartman 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.

IPCC, 2022. Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group Report of the Intergovernmental Panel on Climate Change. Cambridge University Press., Cambridge, UK and New York, NY, USA.

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

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

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

Pieterse, A., 2020. Mainstreaming Climate Change Adaptation into Municipal Planning: Lessons from two South African Cases (PhD Thesis). University of Pretoria.

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.*

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

Sara Baartman District Municipality (SBDM). 2022. Integrated Development Plan 2022-2027. Available from: https://www.sarahbaartman.co.za/index.php?option=com_zoo&task=item&item_id=231&Itemid=1998&lang=en

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.