Namakwa District Municipality

Risk Profile Report based on the GreenBook

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Table of Contents

Figures

Tables

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
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
DDM	District Development Model
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
ICT	Information and Communications Technology
IDP	Integrated Development Plan
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
KZN	KwaZulu-Natal
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
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).

1. Introduction

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

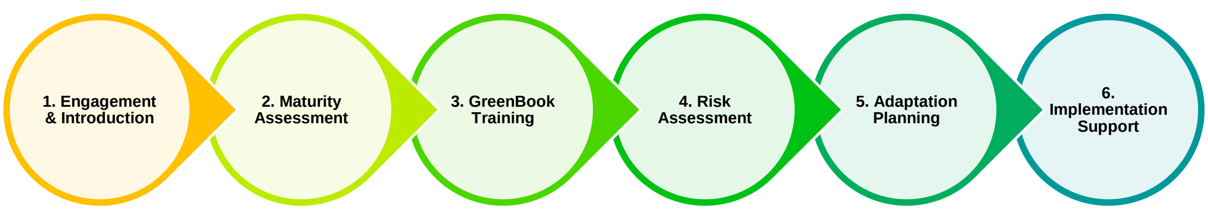

Figure 1: The Value-chain towards the implementation of climate change response and adaptation in municipalities

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, 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.

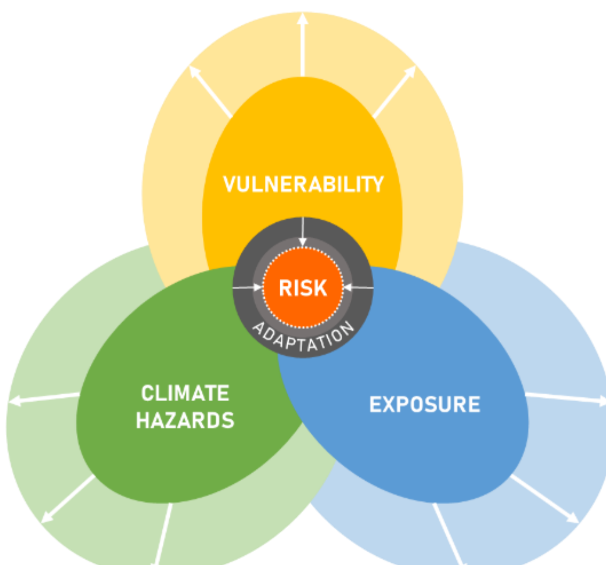

Figure 2: The interaction between the various components of risk, indicating the opportunity to reduce risk through adaptation (based on IPCC, 2014 and IPCC, 2021)

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. 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" (Republic of South Africa., 2013, p. 20) – 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 Namakwa District Municipality (NDM) is the largest District Municipal Area in the Northern Cape Province and consists of six Local Municipalities (LMs). These are the Richtersveld LM, Nama Khoi LM, Khai Ma LM, Kamiesberg LM, Hantam LM and Karoo Hoogland LM. The DM is located on the north-western side of the province bordering the west coast and stretches from the lower Orange River in the north to the Western Cape Province border in the south.

Although being geographically the largest DM in the Northern Cape Province, it is the least populated of the five DMs in the province, with a total population of 115 488 in 2016. Namakwa's population comprises 10% of the provincial total population.

With a GDP of R 10.7 billion in 2020, the NDM contributed 10.60 % to the Northern Cape Province's Gross Domestic Product (GDP). The NDM's economy is made up of various industries of which the mining sector is the largest, contributing 40.40 % to the Gross Value Added (GVA). The sector that contributes the second most to the GVA of the NDM is the community services sector at 16.70 %, followed by the agriculture sector with 10.20 %. The sector that contributes the least to the economy of NDM is the electricity sector, with a contribution of 1.70 % to the total GVA (NDM, 2022).

Having a semi-arid climate, the Namakwa District Municipal area is dominated by the Nama-Karoo and Succulent Karoo biomes, with the Desert biome present in the northern part of the District. The Nama-Karoo biome is species rich and has a high number of endemic species that are well adapted to the hot and dry climatic conditions. Towards the south and west of the District, some patches of Fynbos biome can be observed. Generally, the Namakwa District is characterised by vast open spaces, and is sparsely populated, with livestock farming being a prominent feature of the dry landscape.

As mentioned above already, the NDM comprises of six LMs, with their main town mentioned in brackets after each LM's name. Richtersveld Municipality (Port Nolloth), Nama Khoi Municipality (Springbok), Khai Ma Municipality (Pofadder), Kamiesberg Municipality (Garies), Hantam Municipality (Calvinia) and Karoo Hoogland Municipality (Williston).

The Richtersveld LM borders the Atlantic Ocean on the far western side and the Orange river on the northern part of the District. Porth Nolloth is a strategically important coastal town adjacent to the Atlantic Ocean, while Alexander Bay is next to the Orange River. The fishing industry plays an important role in the economy of the Richtersveld area.

The Nama Khoi LM borders on the Orange River in the north and is known as the land of the Nama people. The Orange River makes a significant contribution to the area's economy through tourism and agriculture.

The Khai-Ma LM also borders on the Orange River in the north, and the LM is similarly an important economic stimulus for the area with various irrigation projects. The Khai-Ma area also hosts mining activities in the area of Aggeneys.

The Kamiesberg LM has the Atlantic Ocean as its western border, with Hondeklipbaai, an important seaside town, hosting a harbour. The town of Springbok is the major business centre for the District Municipal Area.

The Hantam LM is the largest local municipality in the District, and has its administrative centre in Calvinia, which hosts several provincial government departments. The area is well known for livestock and rooibos tea production.

The Karoo Hoogland LM is situated in the most southern part of the NDM, which has its head office located in Springbok. The other three main towns in Karoo Hoogland are Williston, Fraserburg and Sutherland.

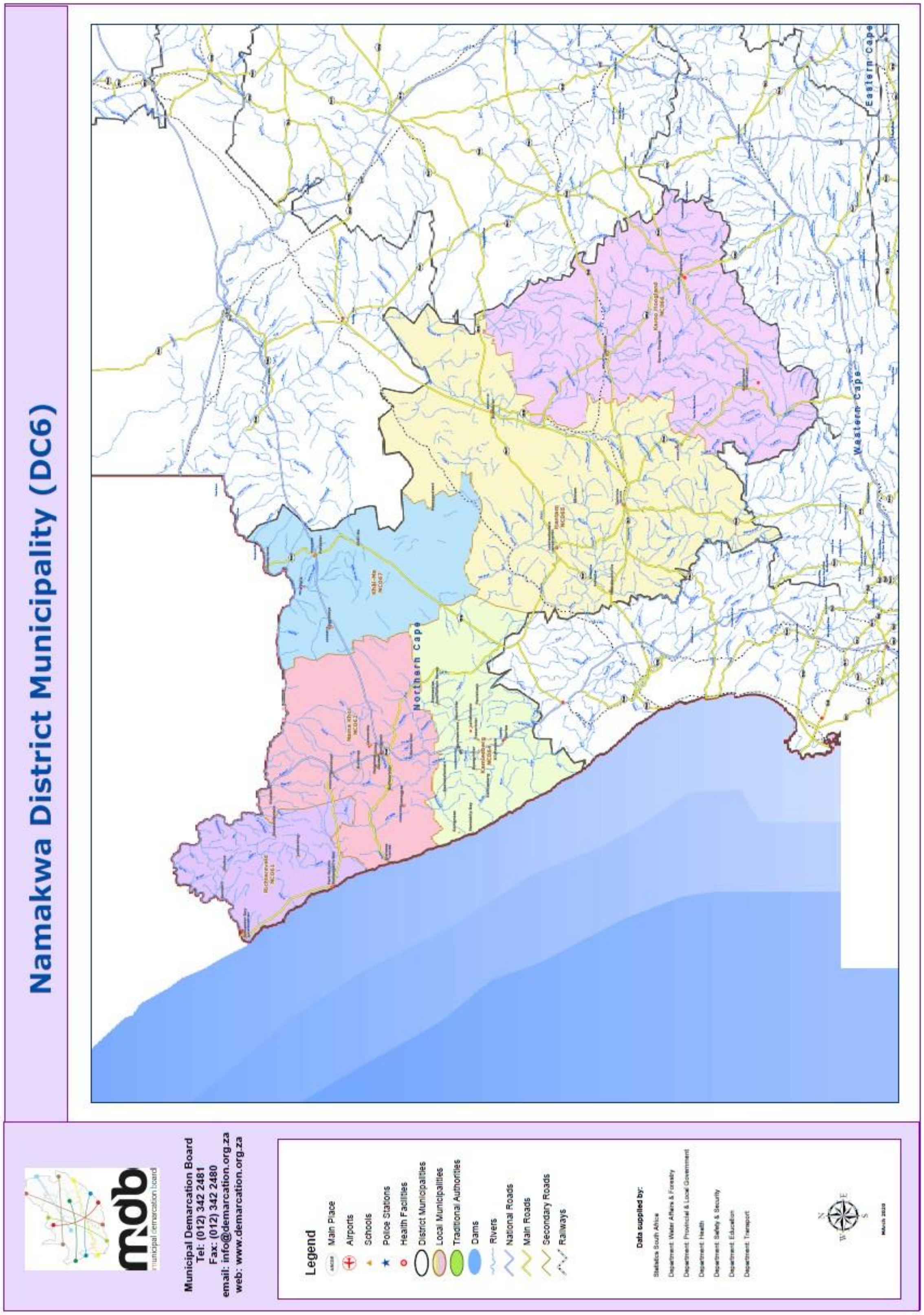

Figure 3: Namakwa District Municipality (Municipal Demarcation Board, 2022), with Local Municipalities shaded in different colours

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 Namakwa 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 Namakwa 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 Namakwa 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 each Local Municipality. It is a composite indicator that considers road infrastructure, housing types, the maintenance of the infrastructure, densities, and general accessibility. A high physical vulnerability score highlights areas of remoteness and or areas with structural vulnerabilities.

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

Each Local Municipality in the Namakwa 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 Namakwa District Municipality for 1996 and 2011

MUNICIPALITY	SEV 1996	SEV 2011	Trend	EVI 1996	EVI 2011	Trend	PV	Trend	EV	Trend
Hantam	4.33	2.69	↘	3.64	1.89	↘	5.97	No Trend	1.68	No Trend
Kamiesberg	4.26	3.84	↘	8.78	8.65	↘	7.85	No Trend	2.33	No Trend
Karoo Hoogland	4.75	3.31	↘	4.97	4.77	↘	6.20	No Trend	1.87	No Trend
Khai-Ma	3.05	2.56	↘	6.80	5.22	↘	5.85	No Trend	1.62	No Trend
Nama Khoi	2.90	2.19	↘	7.64	5.25	↘	6.85	No Trend	3.08	No Trend
Richtersveld	2.85	2.09	↘	8.44	5.73	↘	8.18	No Trend	4.96	No Trend

Socio-economic vulnerability has decreased (improved) across all Local Municipalities between 1996 and 2011. Kamiesberg LM has the highest economic vulnerability in the District and the third highest in the Northern Cape Province after Joe Morolong and Phokwane Local Municipalities. In 2020 there were around 44.50 % of people living in poverty in the Kamiesberg LM. Given the vast open spaces and sparsely populated landscape of the Northern Cape Province, especially in the Richtersveld LM. The latter LM has the highest physical vulnerability in the Northern Cape

Province. Moreover, due to pressures on the biodiversity hotspots in this region, Richtersveld LM also has the highest environmental vulnerability in the Northen Cape Province (NDM, 2022).

2.1.2. Settlement vulnerability

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

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

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

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

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

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

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

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

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

Richtersveld Local Municipality

The major settlements in this Local Municipality are Port Nolloth, Eksteenfontein, Sanddrif, Sendelingsdrif and Alexander Bay. Both Port Nolloth and Alexander Bay have elevated environmental vulnerability. Sanddrif experiences significant vulnerability in terms of access to services as well as growth pressure, combined with high economic and environmental vulnerability. Sendelingsdrif is the most remote settlement in the LM, with very high regional connectivity vulnerability as well as high economic vulnerability.

Nama Khoi Local Municipality

The major settlements in this Local Municipality are Springbok, Okiep, Kleinzee, Steinkopf, Nababeep and Vioolsdrift. Both Kleinzee and Vioolsdrift have the highest vulnerability in terms of regional connectivity, due to their remoteness and distance from other centres. Okiep and Vioolsdrift have the highest growth pressure. Being the administrative centre of this Local Municipality, Springbok does not face significant vulnerability in terms of most indicators except for environmental vulnerability.

Khai-Ma Local Municipality

The major settlements in this Local Municipality are Pofadder, Pella and Aggeneys. Pofadder has the highest vulnerability in terms of access to services and also faces significant socio-economic vulnerability. Pofadder, Aggeneys and Pella primarily service the agricultural and mining sectors. Pella has both high socio-economic as well as economic vulnerability. The key livelihood activities in Pella are agriculture-based and people engage in subsistence farming on the banks of the Orange River.

Kamiesberg Local Municipality

The major settlements in this Local Municipality are Garies, Kamieskroon and Hondeklipbaai. Hondeklipbaai faces the greatest vulnerability in terms of regional connectivity and together with Garies also faces significant growth pressure.

Hantam Local Municipality

The major settlements in this Local Municipality are Calvinia, Nieuwoudtville, Loeriesfontein and Brandvlei. Both Loeriesfontein and Calvinia has very high vulnerability in terms of access to services and regional connectivity. Brandvlei has the highest vulnerability in terms of economic, socio-economic and environmental indicators. It also faces the highest growth pressure in the municipality.

Karoo-Hoogland Local Municipality

The major settlements in this Local Municipality are Sutherland, Fraserburg and Williston. Sutherland has the highest economic, socio-economic and access to services vulnerability, while also facing the greatest growth pressure in the Municipality. Williston has the highest environmental and regional connectivity vulnerability within this Local Municipality.

2.1.3. Population growth pressure

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

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

Table 2: Settlement population growth pressure across Namakwa District Municipality

Settlement-based population per municipality	2011	Medium Growth Scenario	
		2030	2050
Richtersveld	11 981	12 481	12 605
Nama Khoi	47 035	44 505	40 359
Khai-Ma	12 426	12 266	11 725
Kamiesberg	10 169	7 993	5 888
Hantam	21 981	21 055	19 579
Karoo Hoogland	12 227	13 212	13 675
Namakwa DM Total	115 819	111 511	103 830

The District's settlement-based population is projected to decrease by 11 % between 2011 and 2050, under a medium growth scenario. Most of this decline will take place in the settlements of Kamiesberg LM. The same Local Municipality already has the lowest population in the District and is projected to decline by a further 42%. The only two Local Municipalities that will experience an increase in population are Richtersveld and Karoo Hoogland. Figure 4 depicts the growth pressures that the settlements across the Local Municipalities will likely experience. Most of the settlements in the District will experience decreasing growth pressure, with only a very few settlements that will see medium growth pressures up to 2050. These include Fraserburg, Sutherland and Williston.

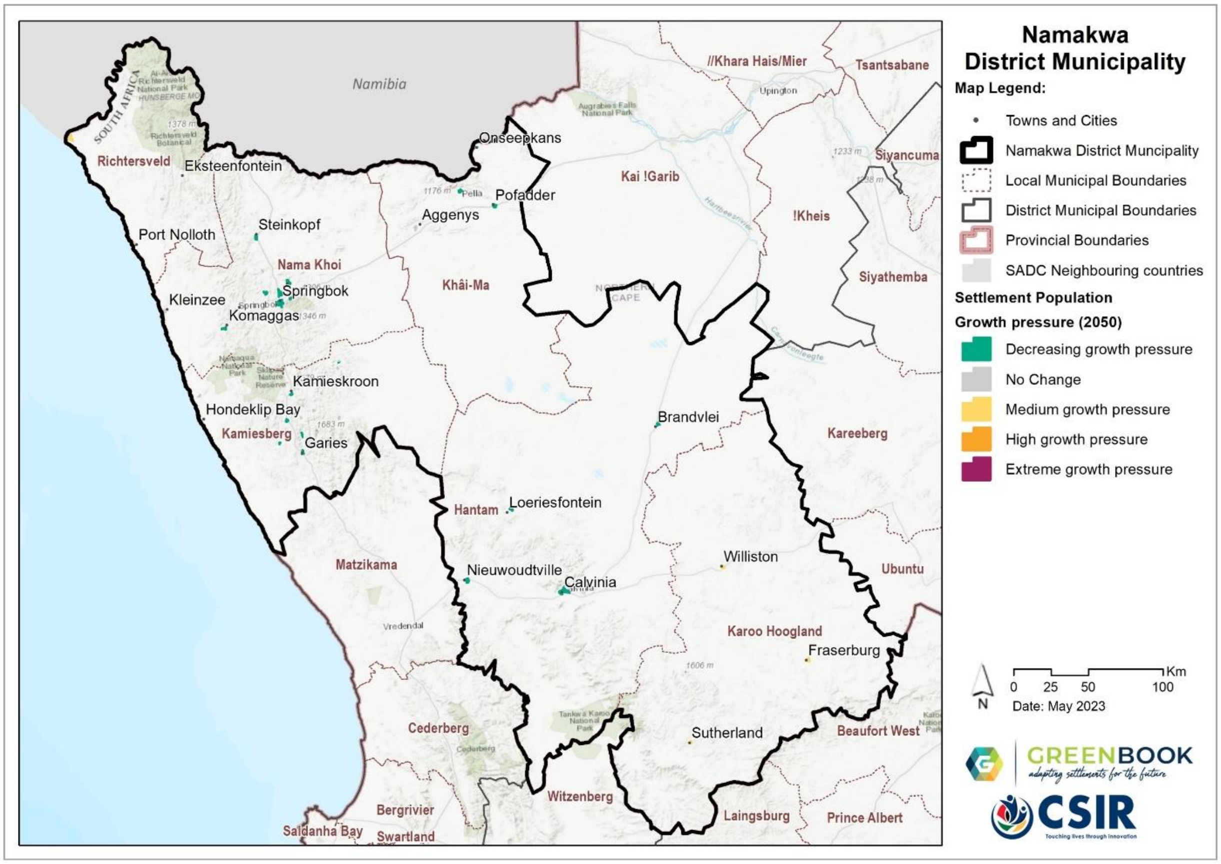

Figure 4: Settlement-level population growth pressure across Namakwa District Municipality

2.2. Climate

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

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

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

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

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

2.2.1.Temperature

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

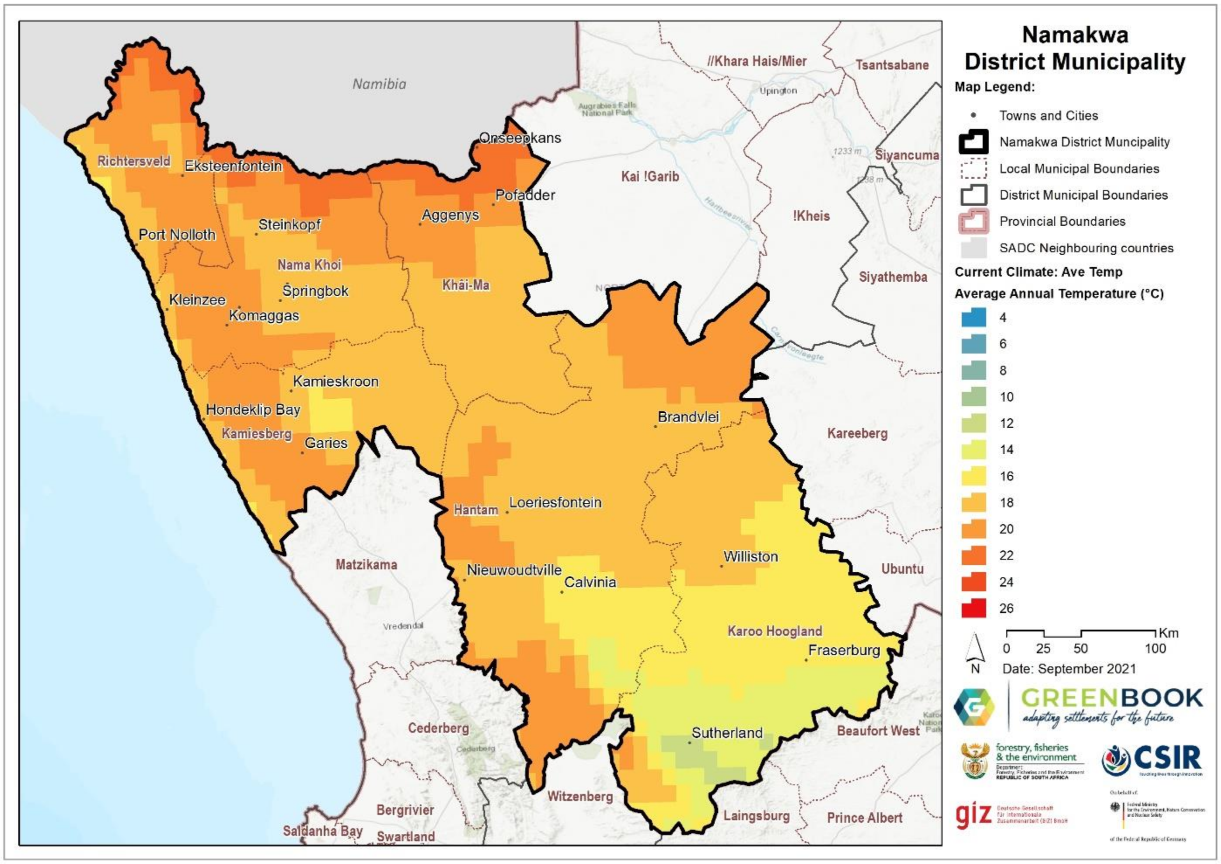

Figure 5: Average annual temperature (°C) for the baseline period 1961-1990 for Namakwa District Municipality

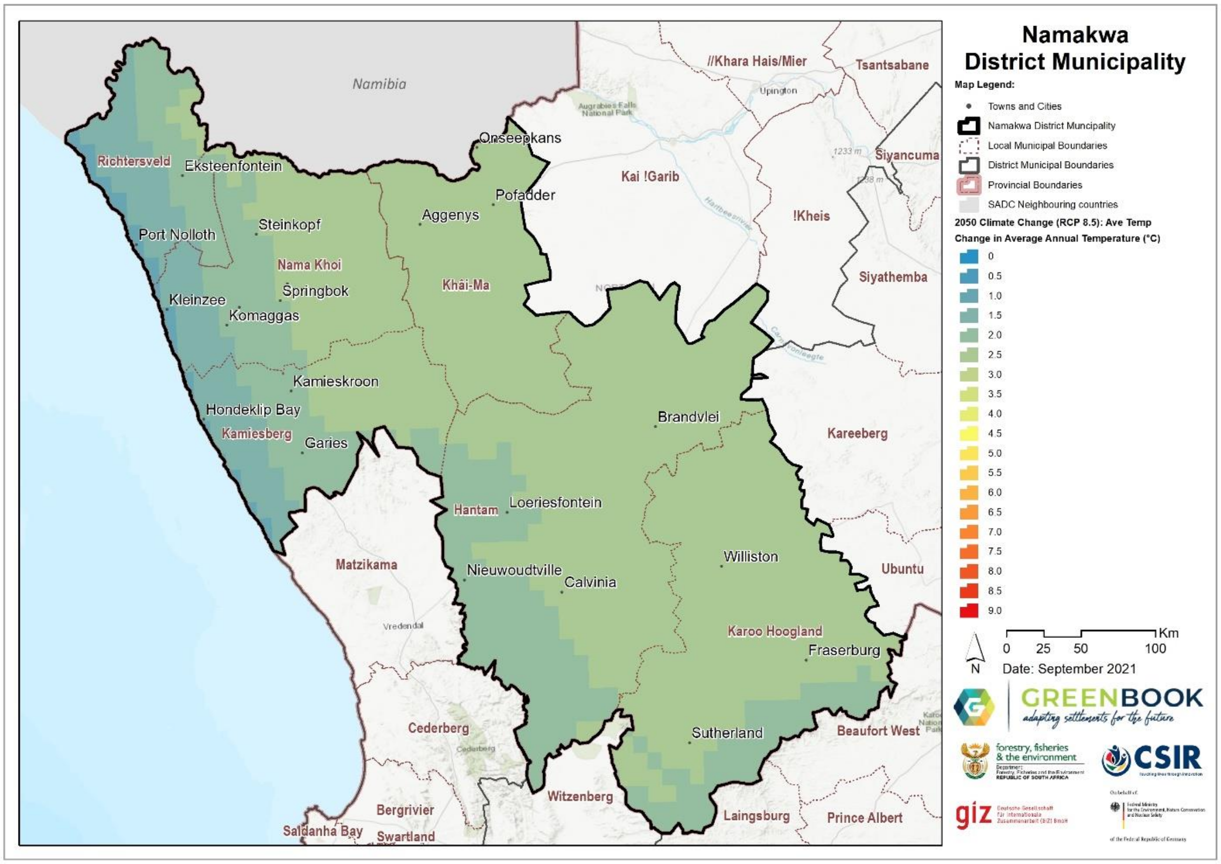

Figure 6: Projected changes in average annual temperature (°C) from the baseline period 1961-1990 to the future period 2021-2050 for Namakwa District Municipality, assuming an RCP 8.5 emissions pathway

The Namakwa District experiences a wide range in average annual temperatures of between 12 and 22 °C, with higher averages found in the far northern and western parts of the Namakwa District. During summer, temperatures may rise to 45°C and higher in the afternoon. Lower temperatures are experienced over the higher lying areas of the Hantam and Karoo Hoogland Local Municipalities. The projections show average annual temperature increases of between 1.50 °C and 2.80 °C across the District by 2050, under a low mitigation ("business as usual") scenario. The greatest increases are expected to the north-eastern parts of the District around the towns of Pofadder and Aggeneys. A lower range of temperature increases is projected to occur along the west 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 an RCP8.5 emissions scenario.

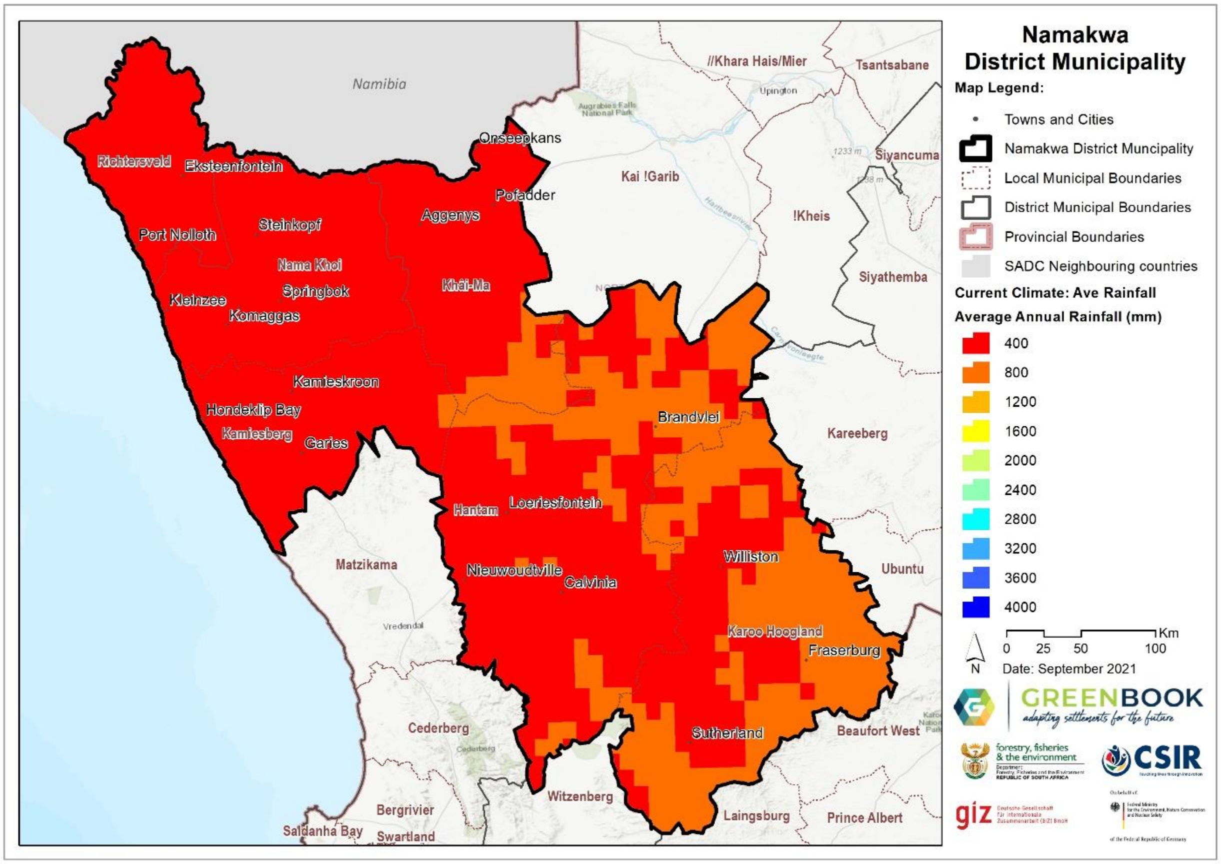

Figure 7: Average annual rainfall (mm) for the baseline period 1961-1990 for Namakwa District Municipality

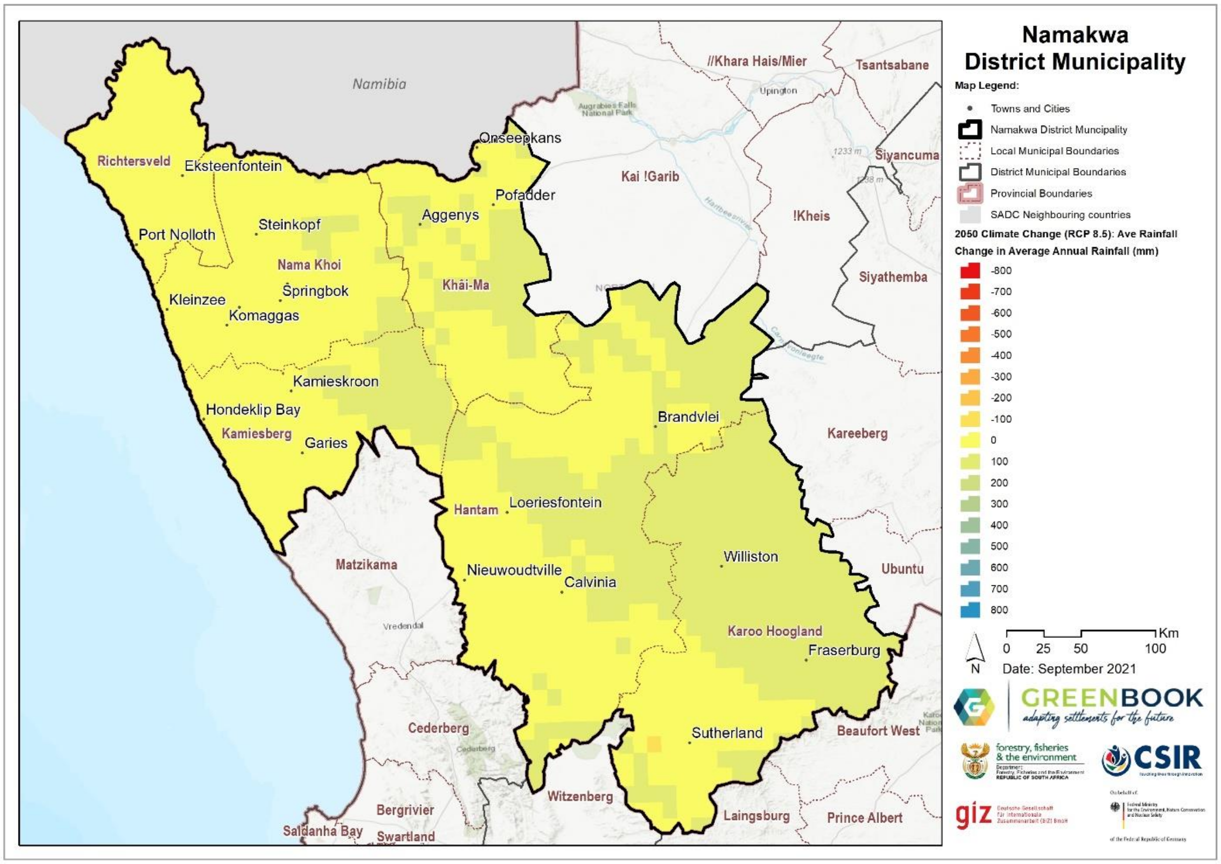

Figure 8: Projected change in average annual rainfall (mm) from the baseline period to the period 2021-2050 for Namakwa District Municipality, assuming an RCP8.5 emission pathway

The Namakwa District is generally a dry, semi-arid area and current average annual rainfall range from less than 400 mm to up to 800 mm, with the driest areas are found in the northwestern parts of the District, including the entire area of Richtersveld LM. Higher rainfall averages are found along the Bokkeveld escarpment of the Hantam LM.

2.3. Climate Hazards

This section showcases information with regards to Namakwa 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).

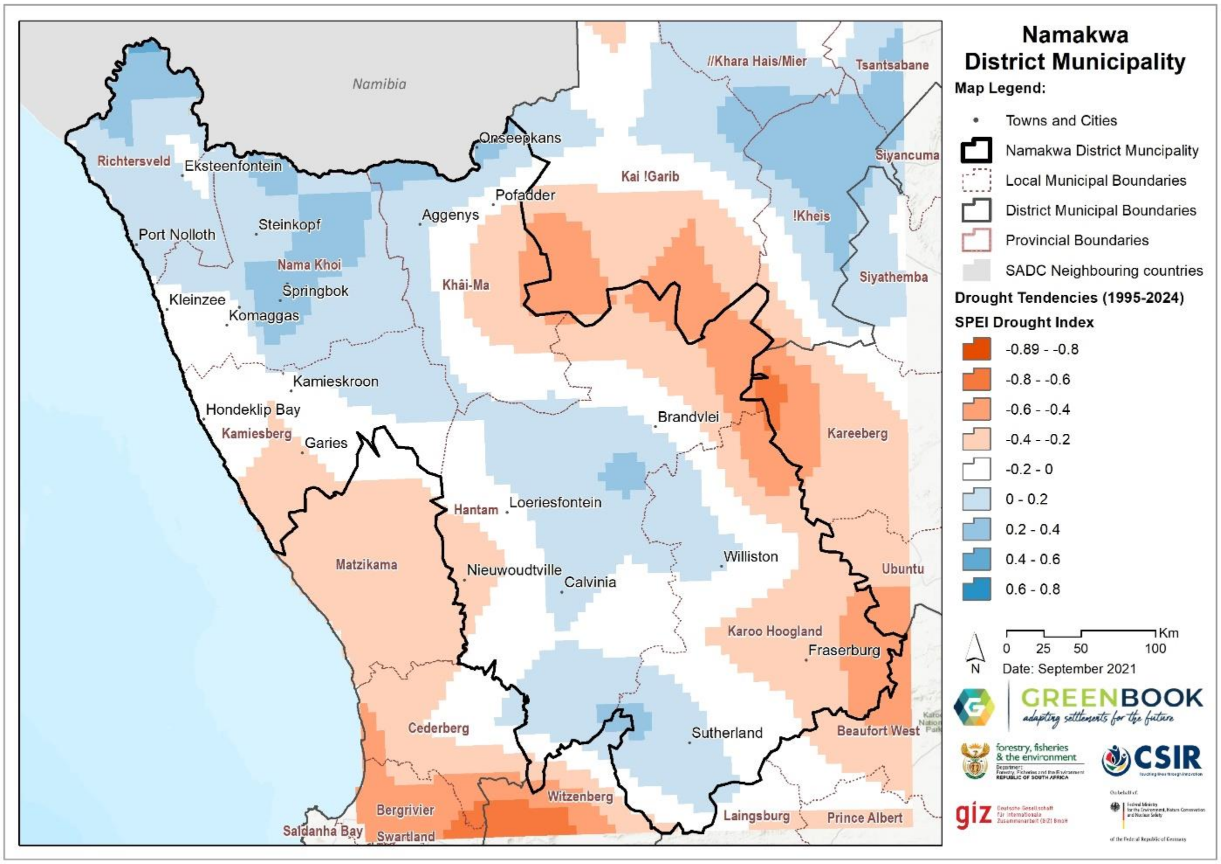

Figure 9: Projected changes in drought tendencies from the baseline period (1986–2005) to the current period (1995-2024) across Namakwa District Municipality

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 an RCP 8.5 "business as usual" emissions scenario (RCP 8.5). A negative value is indicative of an increase in drought tendencies per 10 years (more frequent than the observed baseline).

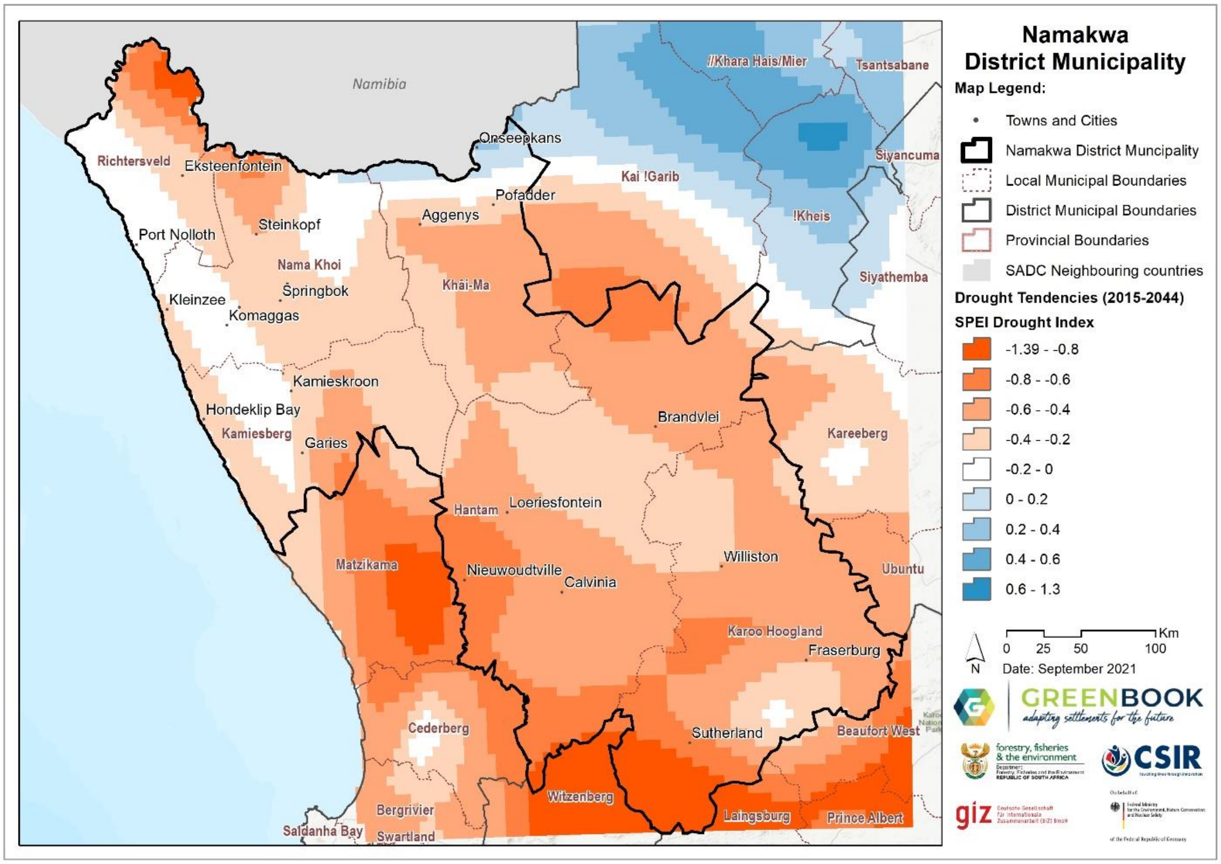

Figure 10: Projected changes in drought tendencies from the baseline period (1986–2005) to the future period (2015–2044) for Namakwa District Municipality

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.

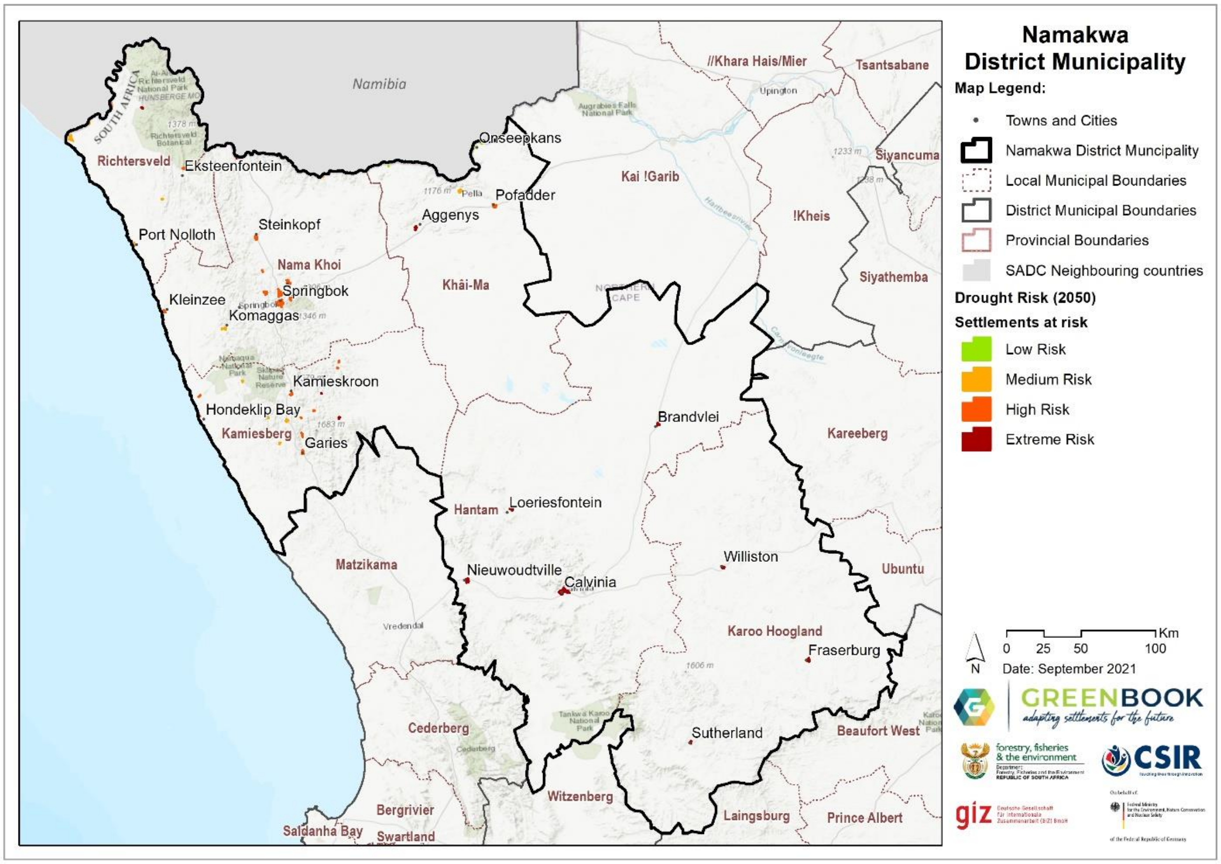

Figure 11: Settlement-level drought risk for Namakwa District Municipality

Under a baseline climate, the District is generally prone to drought, except for parts in the central region. However, in the future, drought tendencies are projected to increase significantly across the District. Most settlements across the District and its Local Municipalities face extreme to medium drought risk towards 2050. Predictions are for more intense droughts into the future.

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 changes for 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.

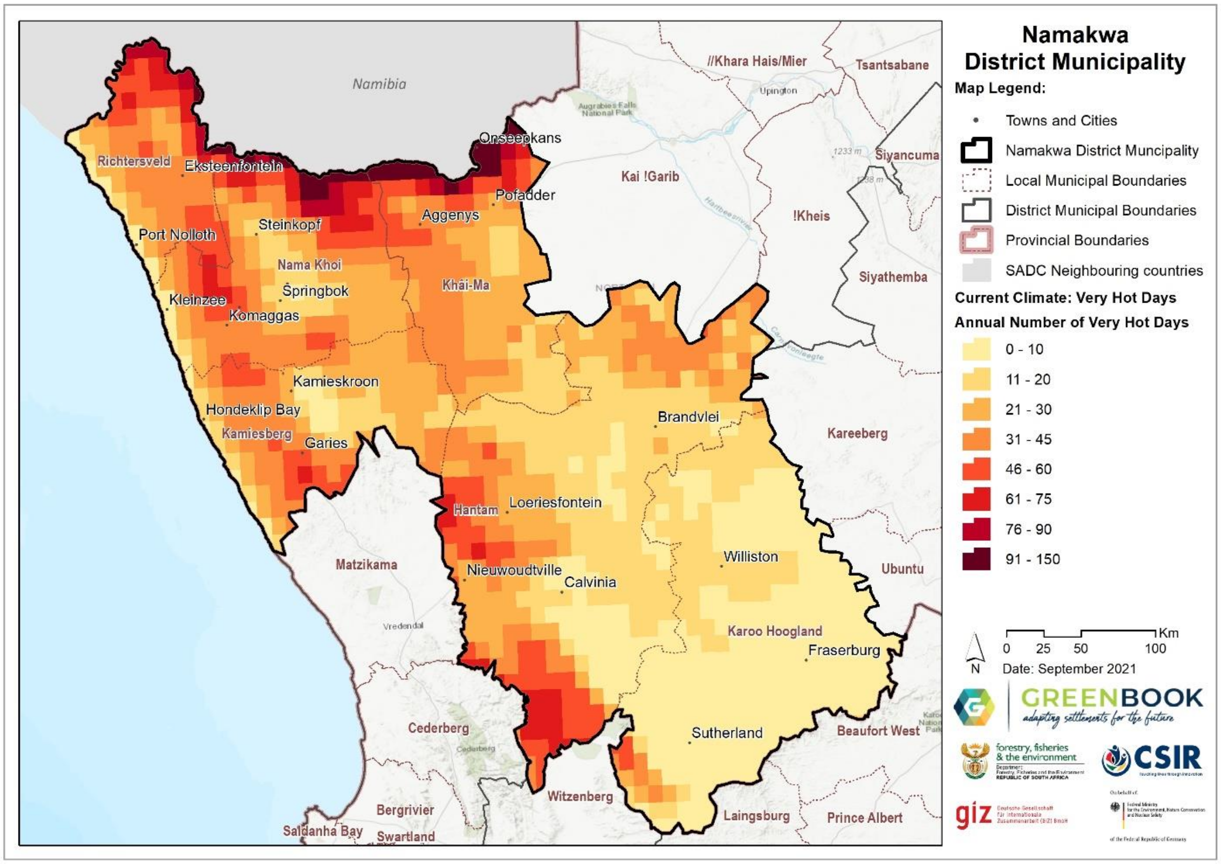

Figure 12: Annual number of very hot days across Namakwa District Municipality with daily temperature maxima exceeding 35°C

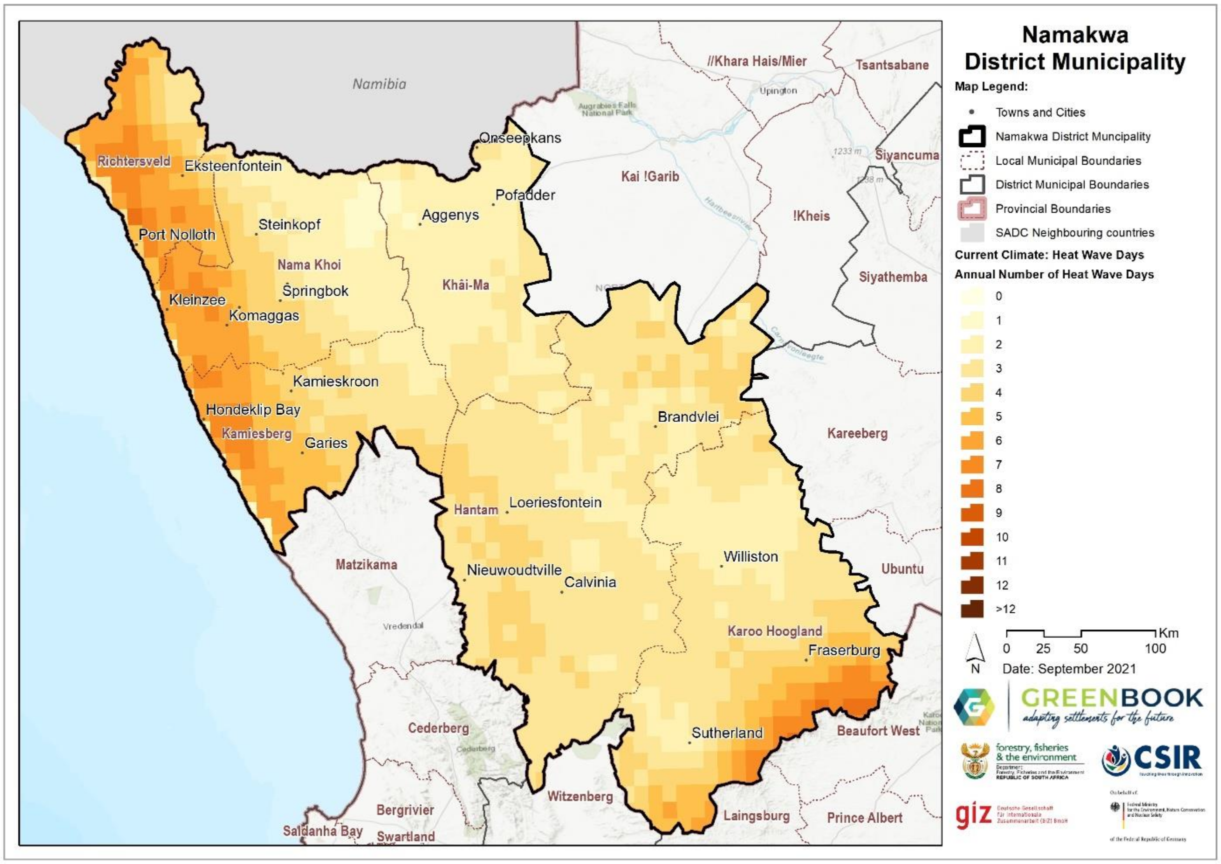

Figure 13: Number of baseline annual heatwave days across Namakwa District Municipality

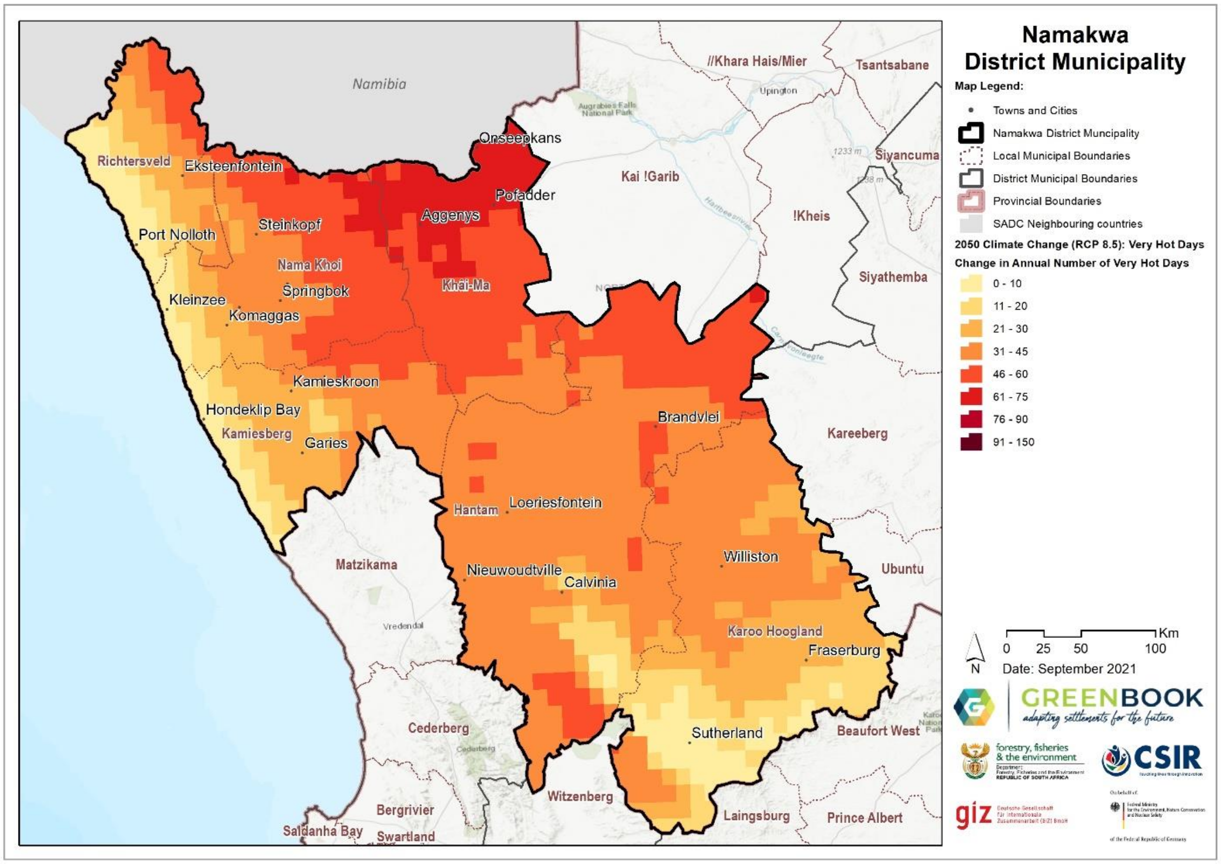

Figure 14: Annual number of very hot days across Namakwa District Municipality with daily temperature maxima exceeding 35°C

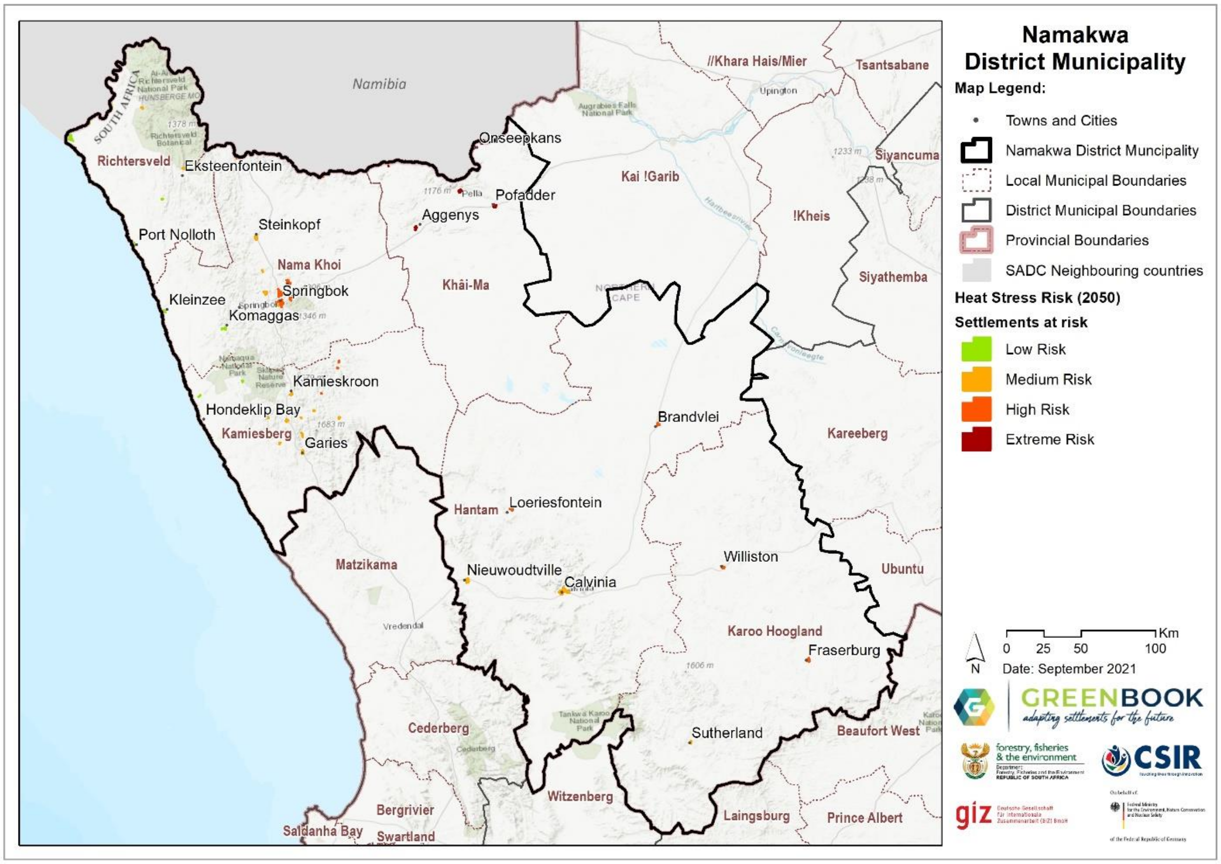

Figure 15: Heat risk across Namakwa District Municipality at settlement level

The Namakwa District is subject to severe heat stress, especially in the far north of the District on the boundary with Namibia. Under baseline climatic conditions, some of these areas north of Pofadder and Aggeneys experience more than 100 very hot days annually with daily maxima exceeding 35°C. Settlements experiencing more than 50 very hot days are in the areas of Loeriesfontein, Garies, and south of Nieuwoudtville. Future increases in very hot days are expected to be most pronounced in the north of the District in the areas where extreme heat is already prevalent under baseline conditions. In these areas the number of very hot days increases by up to 50 days. Heatwave events are more likely to be experienced south-west of the settlements of Fraserburg and Sutherland as well as on the west coast of the District.

Figure 15 depicts the settlements that are at risk of increases in heat risk. With the changing climate, it is expected that the impacts of heat will only increase in the future, and not decrease. 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 this DM is likely to significantly increase the risk of extreme heat in several settlements. Consistent with the increases in very hot days, the settlements of Pella, Pofadder and Aggeneys are projected to experience an extreme risk to heat stress in the future. Only coastal settlements such as Port Nolloth and Kleinzee will have a low risk to 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. A scale was used where the likelihood was rated from 'rare' to 'almost certain' and the consequences were rated from 'insignificant' to 'catastrophic' to determine a level of fire risk which ranged from 'low' to '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.

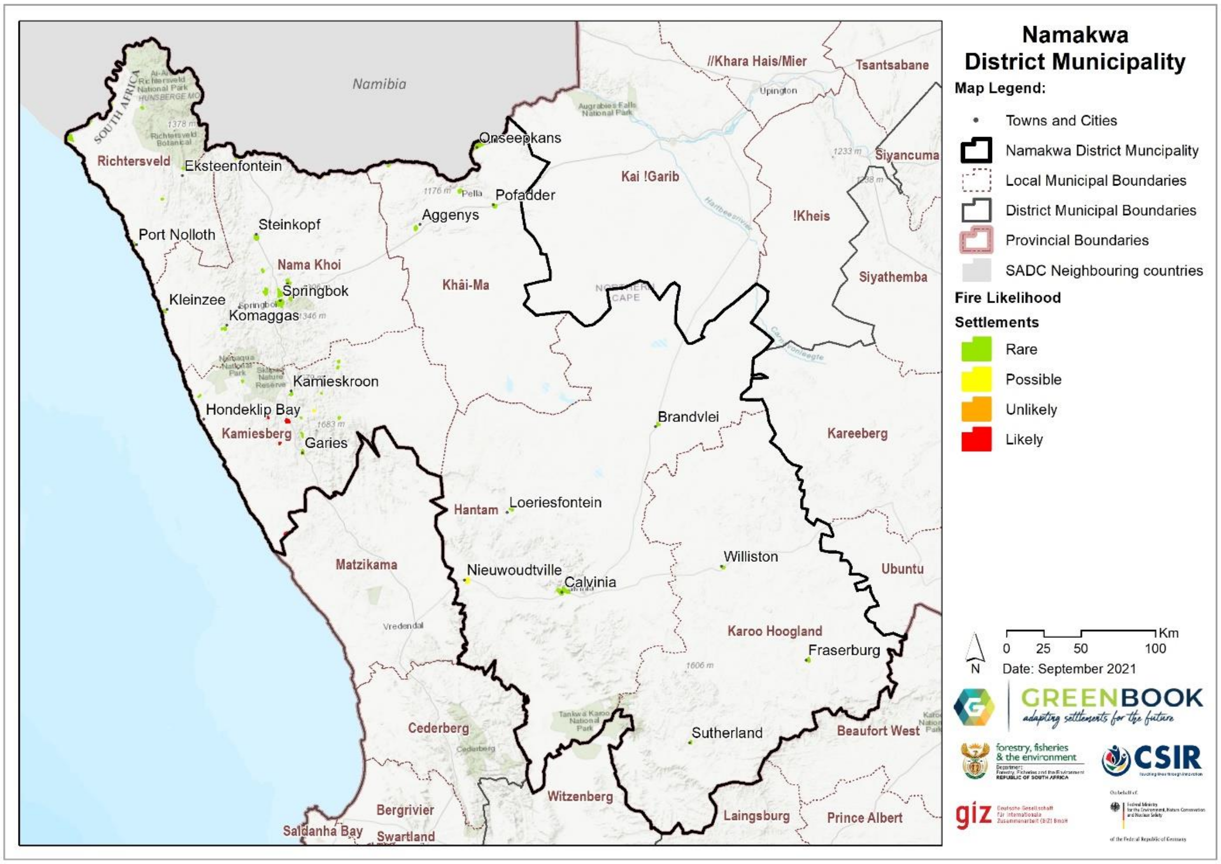

Figure 16: The likelihood of wildfires under current climatic conditions across settlements in Namakwa District Municipality

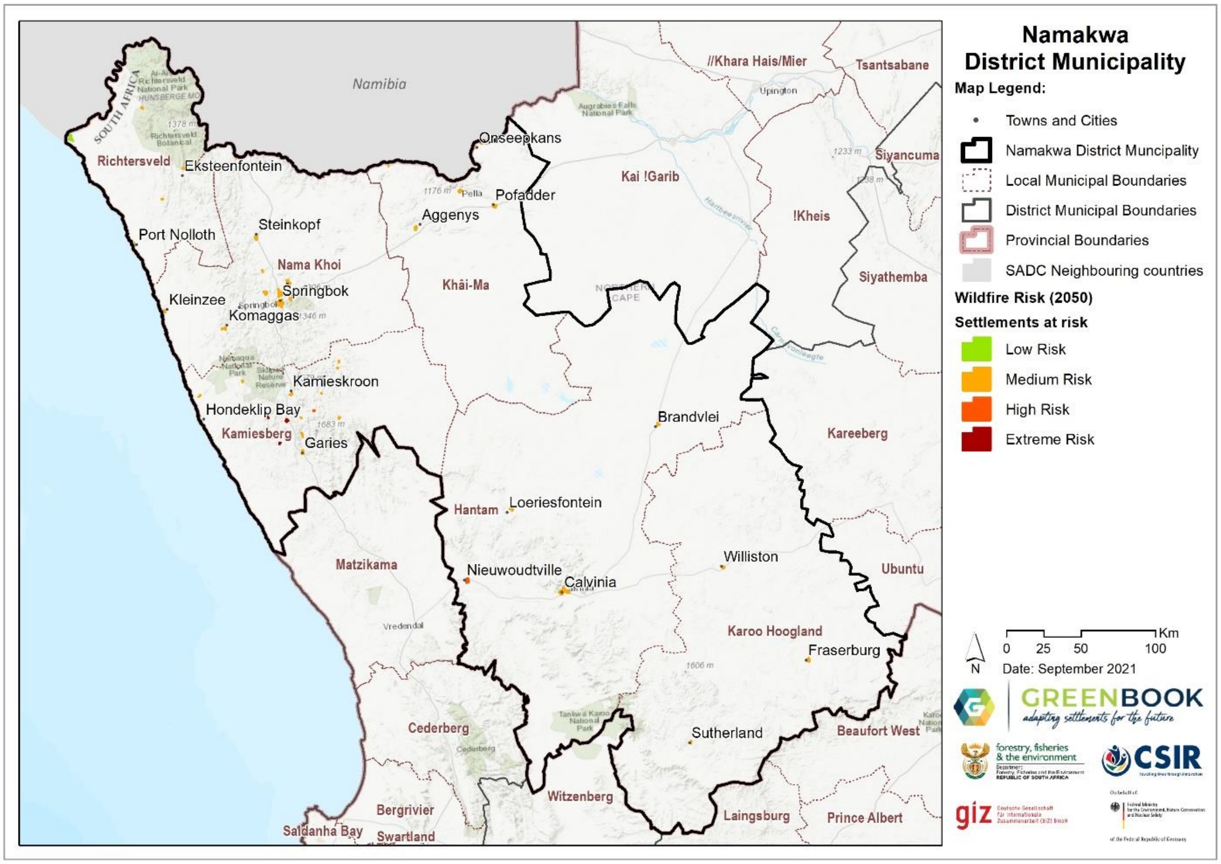

Figure 17: The likelihood of wildfires under projected future climatic conditions across settlements in Namakwa District Municipality

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. Under baseline conditions the likelihood of fires in the District is low, except for areas in the Kamiesberg mountains and Nieuwoudtville where there is a possibility of fires to occur. However, the risk of wildfires is expected to increase for all settlements across the District. It is projected that these settlements could see a medium risk of wildfires 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, it is projected that flood events are likely to increase into the future. Estimates of the extreme daily rainfall into the future were obtained from high-resolution regional projections of future climate change over South Africa. The settlements that are at risk of an increase in floods were identified using a risk matrix, that considered the flood hazard index and the projected change in extreme rainfall days from 1961-1990 to the 2050s.

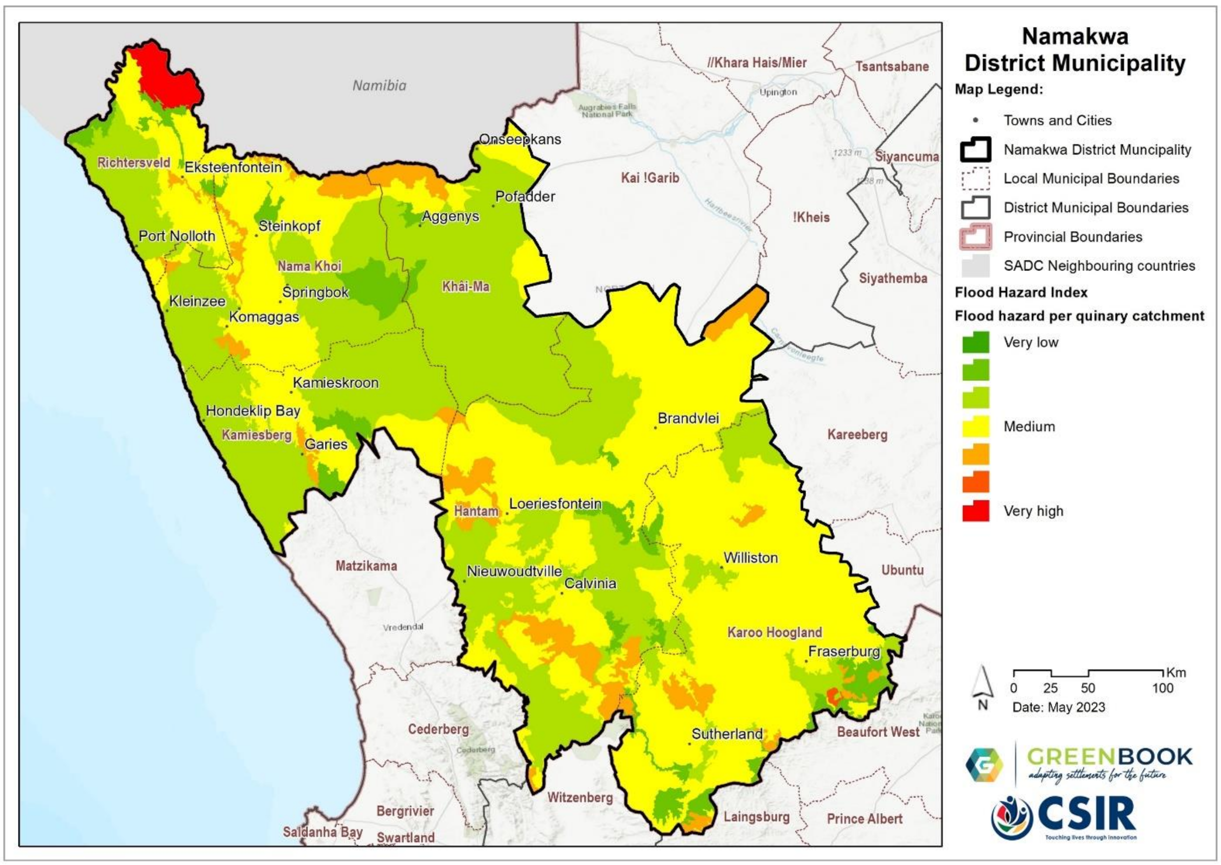

Figure 18: The flood hazard index across Namakwa District Municipality under current (baseline) climatic conditions

Figure 18 depicts the flood hazard index of the individual Quinary catchments present or intersecting with the District. The flood hazard index is based on the catchment characteristics and design rainfall, averaged at the Quinary catchment level. Green indicates a low flooding hazard, while red indicates a high flood hazard. There is significant variation of the flood hazard index across the DM. Most parts of the District have a low to medium flooding hazard, with pockets of medium to high flooding hazard.

Figure 19 depicts the projected change into the future in extreme rainfall days for an 8 x 8 km grid. This was calculated by assessing the degree of change when projected future rainfall extremes (e.g., 95th percentile of daily rainfall) are compared with those under the current rainfall extremes. A value of more than 1 indicates an increase in extreme daily rainfalls. Slight to significant decreases in the number of extreme rainfall days are expected across the District except for some increases north of Brandvlei and around Fraserburg and Sutherland. The overall decrease in extreme rainfall days is consistent with the projected decrease in annual rainfall over the DM. Decreases are most pronounced in the far north of the District.

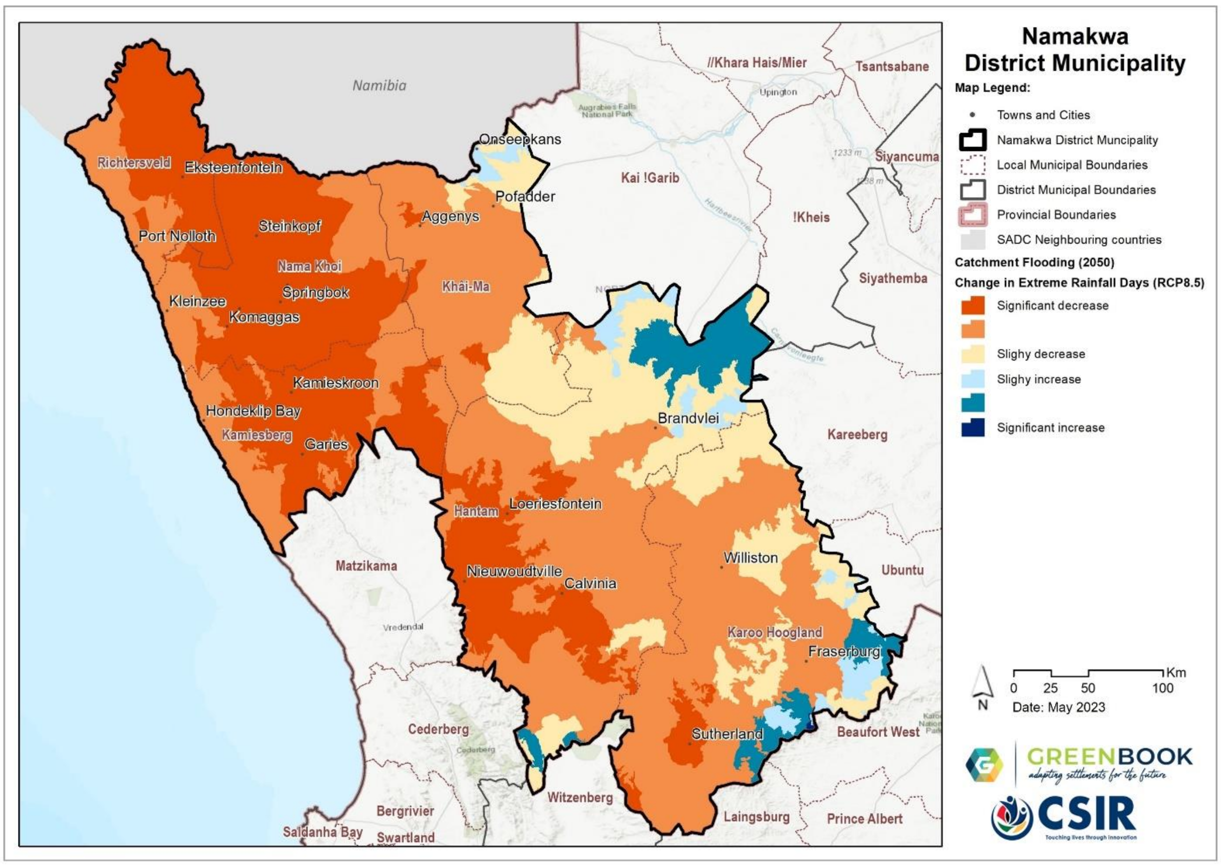

Figure 19: Projected changes into the future in extreme rainfall days across Namakwa District Municipality

Figure 20 depicts the settlements that are at risk of flooding under an RCP 8.5 low mitigation (worst case of greenhouse gas emissions) scenario. Most settlements show a very low risk except for Fraserburg and Loeriesfontein which have a somewhat elevated risk compared to the baseline climate.

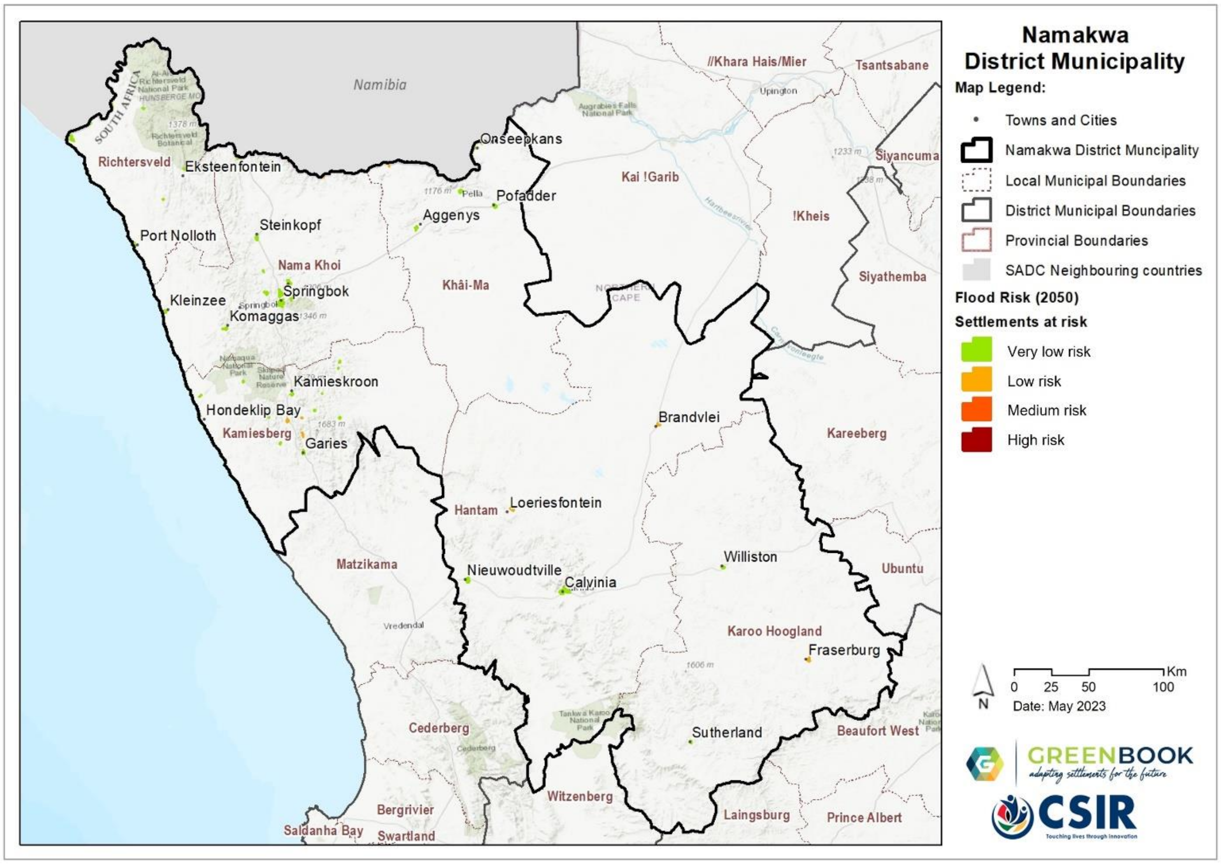

Figure 20: Flood risk into a climate change future at settlement level across Namakwa District Municipality.

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 an elevation hazard risk assessment,
- Generating a coastal distance hazard risk assessment, and
- Generating a 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 5 m 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).

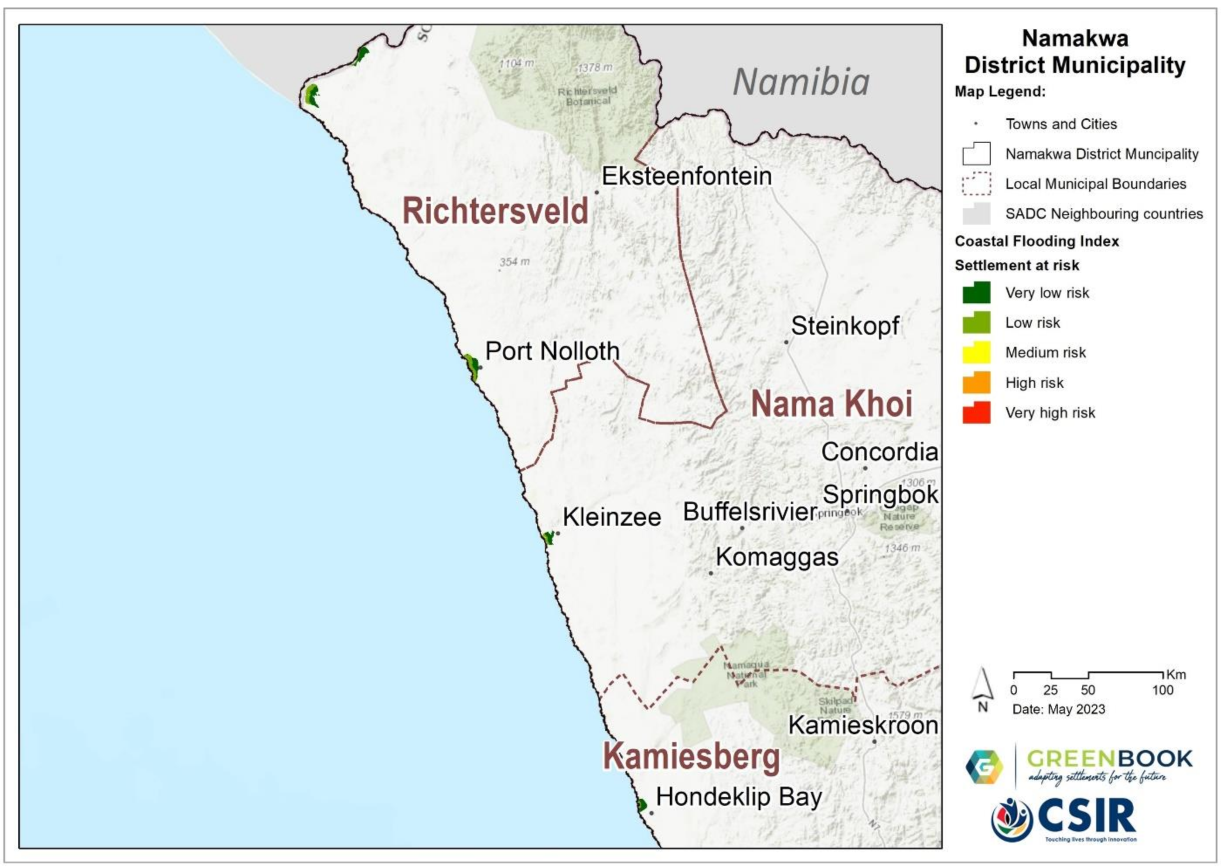

Figure 21: Coastal flooding index and settlements at risk under current (baseline) conditions

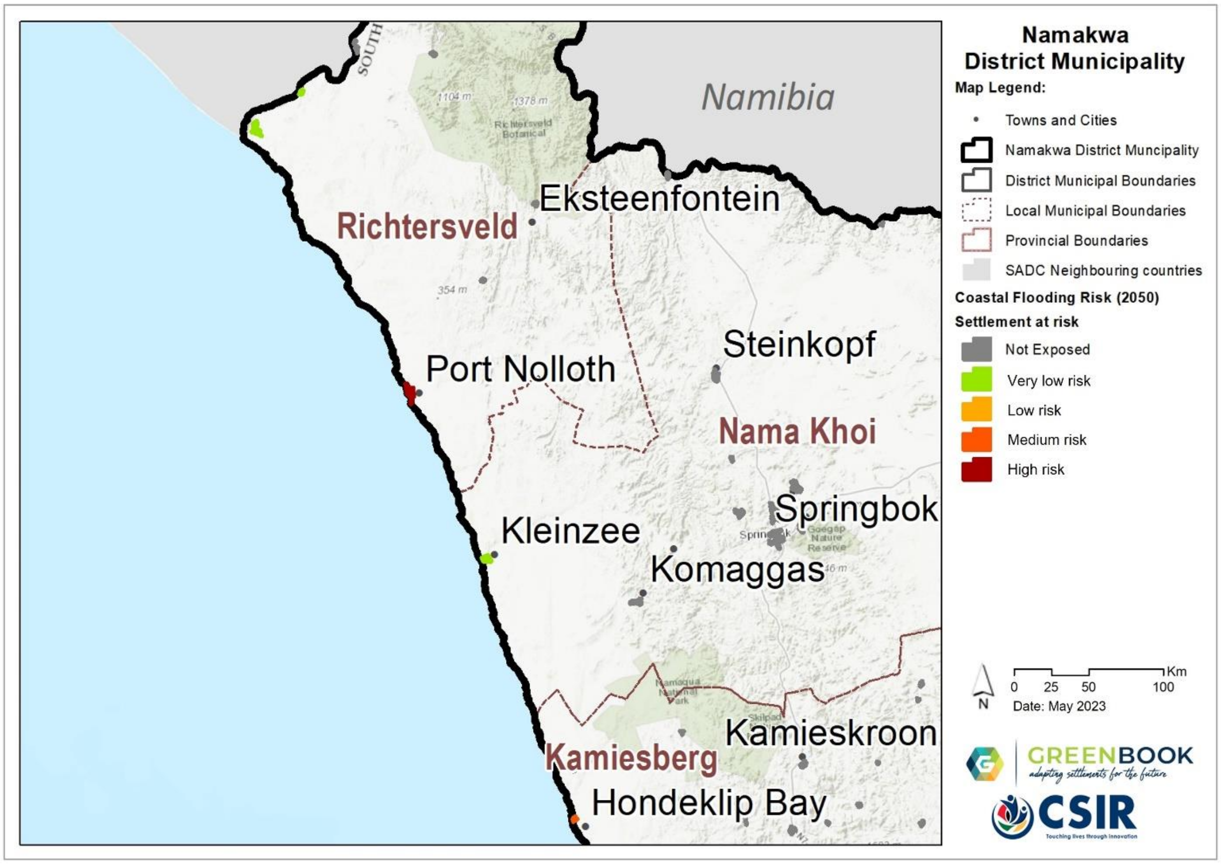

Figure 22: Settlements that are most exposed to coastal flooding by 2050.

Under a baseline climate, all coastal settlements show a very low risk of coastal flooding. However, looking into the future, Port Nolloth will likely face a high risk of coastal flooding by 2050, while Hondeklipbaai 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 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 Namakwa District Municipality.

2.4.1. Water resources and supply vulnerability

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

Water availability is directly impacted by the climate and climate change. It is not just changes in precipitation that need to be considered, but also increasing temperatures that will lead to increased evaporation which could further reduce runoff and increase water losses from dams. Increasing temperatures will also impact on water demand, particularly for irrigation, but also from urban and industrial users. This could also contribute to reduced water security if existing systems are not able to meet these increasing demands. Increasing air temperatures will also increase water temperatures and hence increase pollution and water quality risks.

To obtain a high-level first order assessment of the relative climate change risks for water supply to different towns and cities across South Africa, a general risk equation was developed to determine the current and future surface water supply vulnerability that combines both climate change and development risks (i.e., due to an increase in population and demand). The current vulnerability of individual towns was calculated based on the estimated current demand and supply as recorded across the country by the Department of Water and Sanitation's (DWS) All Towns Study of 2011 (Cole, 2017). The future vulnerability was calculated by adjusting the water demand for each town proportional to the increase in population growth for both a high and medium growth scenario. The level of exposure was determined as a factor of the potential for increasing evaporation to result in increasing demands, and for changes in precipitation to impact directly on the sustainable yield from groundwater, and the potential for impacts on surface water supply. These were then multiplied by the proportion of supply from surface and groundwater for each town. Exposure to climate change risk for surface water supply was calculated in two ways. The first was by assuming surface supply was directly related to changes in streamflow in the catchment in which the local municipality was located (E1) and alternatively (E2) taking into account the potential benefits offered by being connected to a regional water supply system by using the result from a national study of climate change impacts on regional water supply derived from a high level national configuration of the water resources yield model

(WRYM) that calculated the overall impacts on urban, industrial and agriculture water supply to each of the original 19 (now 9) Water Management Areas (WMAs) in South Africa.

In South Africa, groundwater plays a key strategic role in supporting economic development and sustaining water security in several rural and urban settlements that are either entirely or partially dependent on groundwater supply. Groundwater is, however, a natural resource, the availability and distribution of which are highly influenced by climate variability and change. An analysis of the impact of climate change on potential groundwater recharge was conducted for the period 2031 to 2050. The Villholth GRiMMS (Groundwater Drought Risk Mapping and Management System) formulation (Vilholth et al., 2013), which implemented a composite mapping analysis technique to produce an explicit groundwater recharge drought risk map, was adapted to formulate a series of potential groundwater recharge maps for the far-future across South Africa. Finally, the future period 2031 to 2050 was compared with the historical period 1961 to 1990.

Figure 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 Namakwa District, there is a mix of surface water and groundwater dependent towns (See Figure 23).

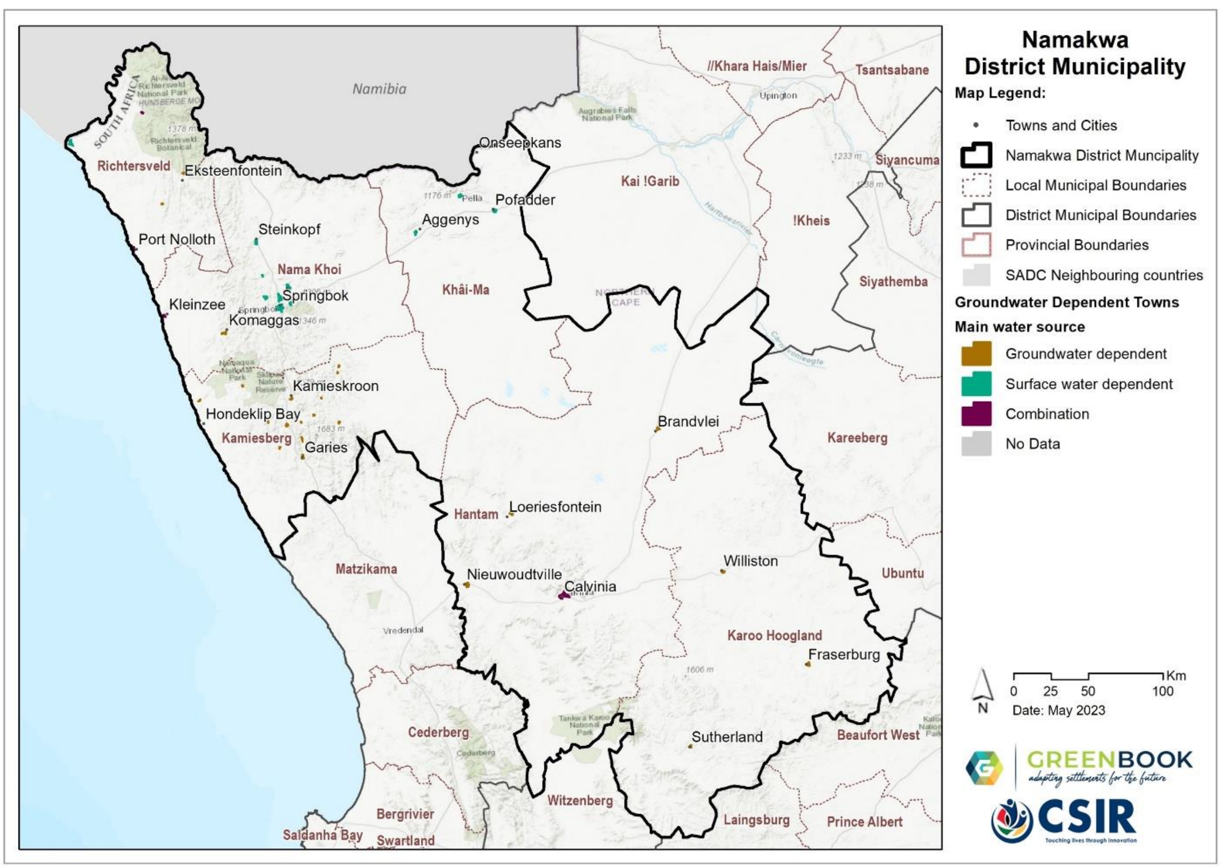

Figure 23: Main water source for settlements in the Namakwa District Municipality

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 low along the west coast, especially towards the north-west of the District. Recharge potential is somewhat higher over the interior and eastern parts of the District. Groundwater recharge potential is, however, projected to decrease over most parts of the District except for small areas in the south of the District along the escarpment.

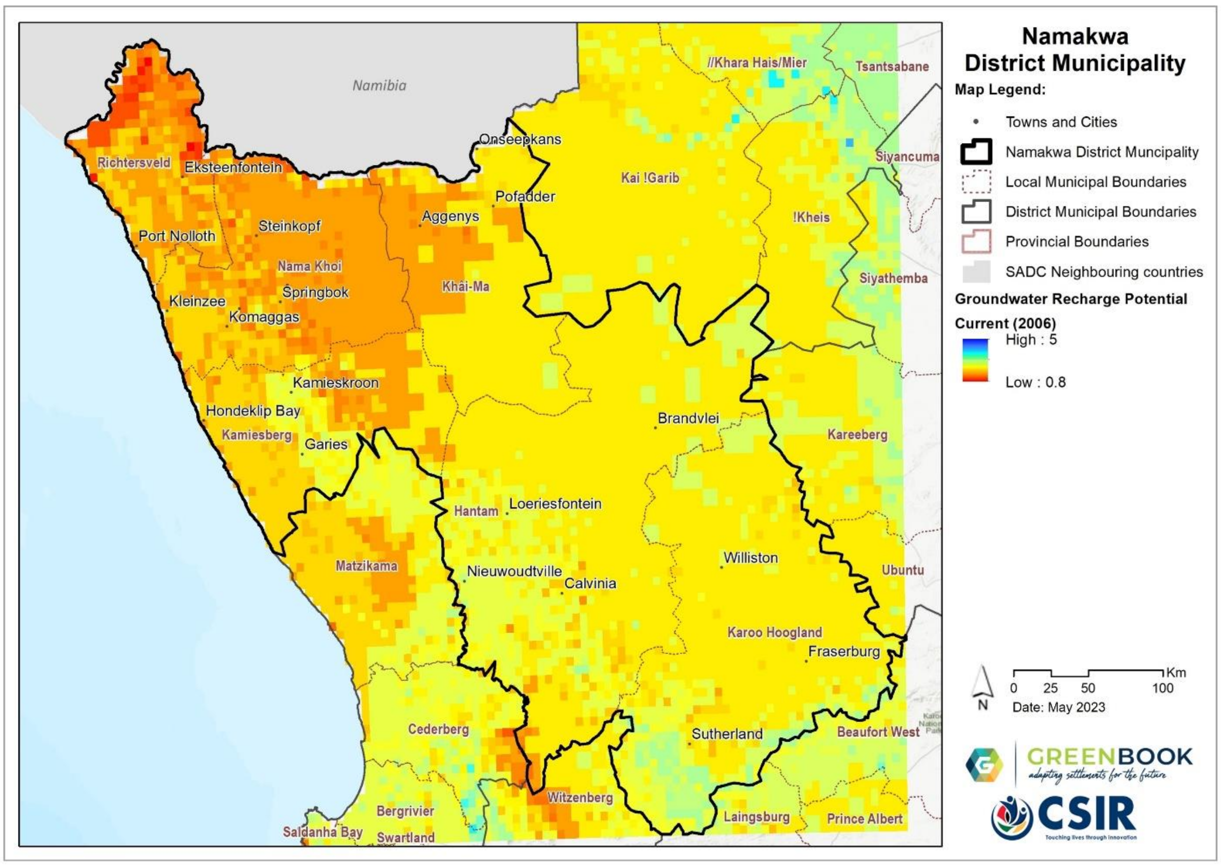

Figure 24: Groundwater recharge potential across Namakwa District Municipality under current (baseline) climatic conditions

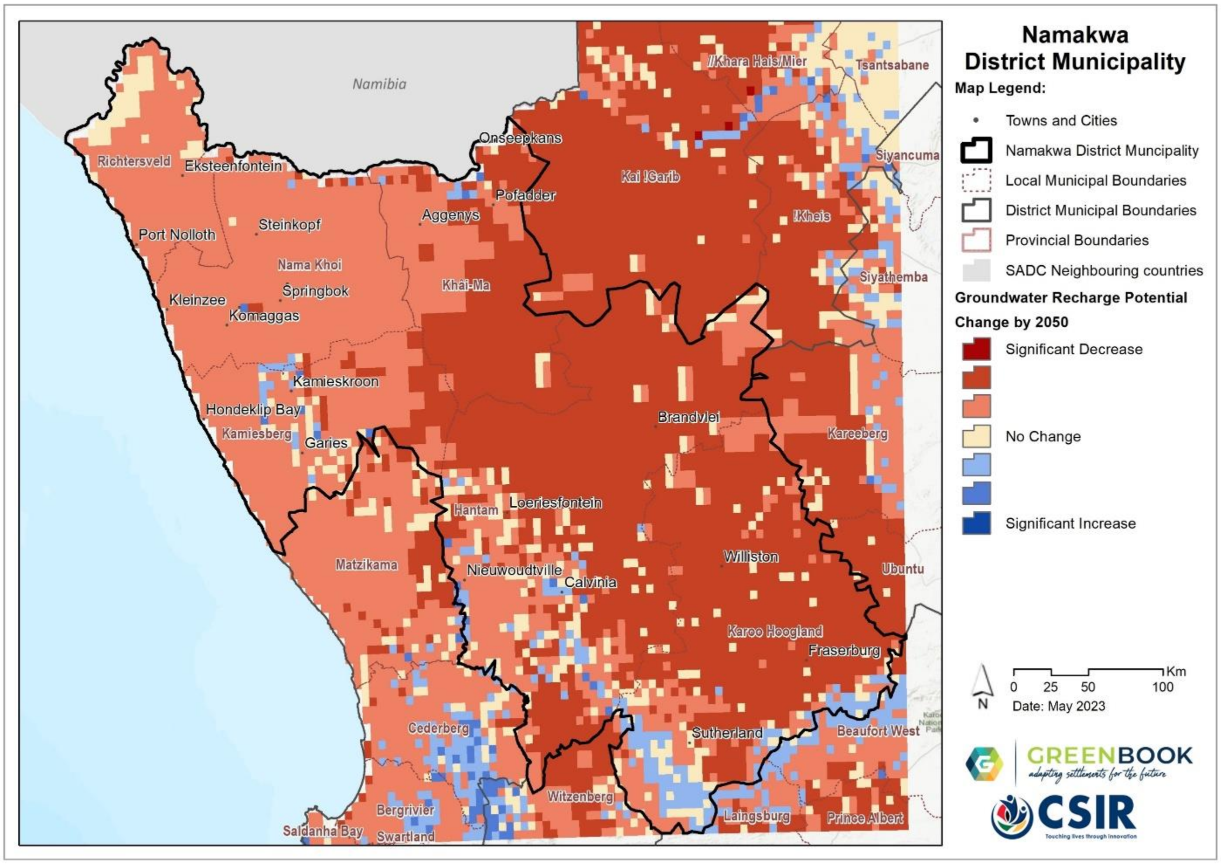

Figure 25: Projected changes in groundwater recharge potential from baseline climatic conditions to the future across Namakwa District Municipality

Most settlements in the District have a low to medium risk of groundwater depletion as most of the Local Municipalities face a downward trend in population growth. Fraserburg and Williston are projected to have a medium risk of groundwater depletion due to a decrease in recharge potential, whereas Port Nolloth also faces a medium groundwater depletion risk due to some population growth pressure.

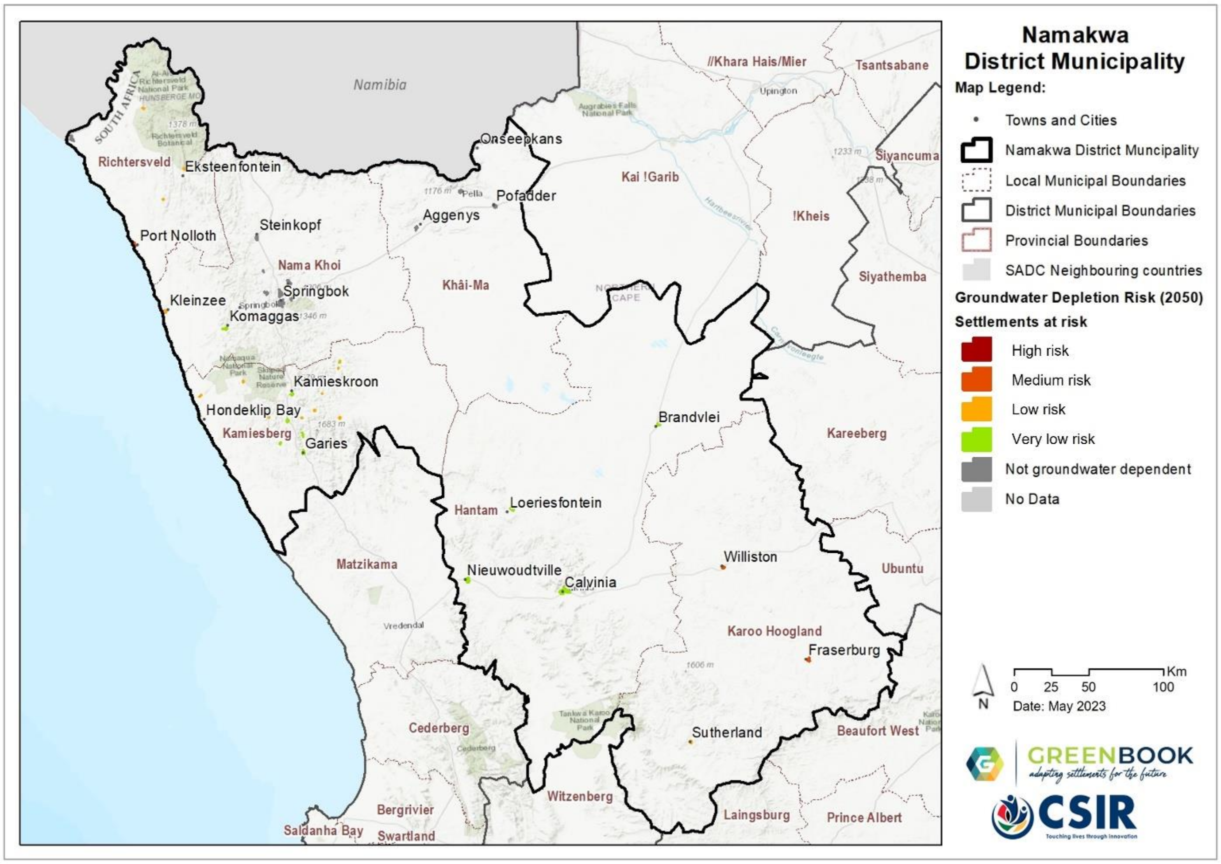

Figure 26: Groundwater depletion risk at settlement level across Namakwa District Municipality

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

Local Municipality	Water Demand per Capita (l/p/d)	Water Supply per Capita (l/p/d)	Current Water Supply Vulnerability
Richtersveld	164.42	182.94	0.90
Nama Khoi	680.81	926.15	0.74
Khai-Ma	925.17	1353.79	0.68
Kamiesberg	56.04	N/a	N/a
Hantam	84.63	95.85	0.88
Karoo Hoogland	88.29	93.66	0.94

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.

Richtersveld

The Richtersveld LM's water demand is currently lower than supply, and water supply vulnerability is low. Future population growth will increase marginally, while rainfall will decrease, which may increase future water supply vulnerability.

Nama Khoi

Water supply vulnerability is currently relatively low in this Local Municipality. Although the Municipality is projected to experience a decline in mean annual runoff, it will also undergo a population decline, and water supply vulnerability is expected to further decrease in the future.

Khai-Ma

Water supply vulnerability is currently low due to water supply far exceeding water demand. Future water supply will, however, decline as temperatures increase and runoff decreases. The Municipality will experience a population decline which may mediate the water supply vulnerability.

Kamiesberg

There is currently no statistics on Kamiesberg's per capita water supply and demand. This Local Municipality is, however, projected to experience a significant decline in rainfall, coupled with increased evapotranspiration. Population growth is anticipated to decline by almost 52 % in future, which will decrease water supply vulnerability.

Hantam

Water supply vulnerability is currently relatively low and is expected to further decline by 2050. Although climate projections are for a decrease in average annual rainfall, significant expected population decline will decrease pressure on water supply.

Karoo Hoogland

Water supply vulnerability is currently relatively low in the Municipality and is expected to increase to a level where demand would outstrip supply. This is the result of a projected decrease in average annual rainfall, increased evaporation, a resultant decrease in mean annual runoff and increase in population growth.

2.4.2. Agriculture, forestry, and fisheries

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

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

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

The AFF sector contributes 10.20 % to the local GVA of the District (CoGTA, 2020). The potential impact of climate change and climate hazards on agriculture is notable considering its importance in supplying employment and being an important livelihood strategy for local communities.

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

Richtersveld

In the Richtersveld LM the AFF sector contributes 2.50 % to the local GVA, which is a contribution of 0.04 % to the national GVA for the AFF sector. Of the total employment, 8.80 % is within the AFF sector. The main farming enterprise in this Local Municipality is extensive sheep farming for meat production. There is also intensive irrigation along the fertile banks of the Orange River, which supports the production of quality agricultural products such as table grapes. Climate projections show a generally hotter and drier climate which could significantly reduce the regeneration of the veld and make farmers more reliant on feeding their flocks. It could also reduce growth and reproductive efficiency due to heat and nutrition stress. Irrigation requirements would increase as evapotranspiration increases.

Nama Khoi

In Nama Khoi LM, the AFF sector contributes 1.70 % to the local GVA, which is a contribution of 0.11 % to the national GVA for the AFF sector. Of the total employment, 7.19 % is within the AFF sector. The main agricultural commodities are sheep and deciduous fruits. Climate projections show a generally hotter and drier climate, becoming drier towards the end of the century. Drier conditions will lead to deteriorating veld conditions and reduced availability of forage. Small-scale sheep farmers will be especially vulnerable due to their low capacity provide additional feeding in times of drought. Increased heat stress on livestock can also lead to reduced growth and reproductive efficiency. For deciduous fruit farming, the increase in evapotranspiration and heat stress could increase irrigation requirements. The reduction in available winter chill may alter the suitability for some deciduous fruit cultivars.

Khai-Ma

In Khai-Ma LM, the AFF sector contributes 18.22 % to the local GVA, which is a contribution of 0.17 % to the national GVA for the AFF sector. Employment in the agricultural sector is very low due to extensive sheep farming in the Municipality, with this generally requiring a minimal workforce. The main agricultural commodities are sheep farming and irrigated fruit such as table grapes, dates and citrus. Drier conditions will lead to deteriorating veld conditions and reduced availability of forage. Small-scale sheep farmers will be especially vulnerable due to their low capacity to provide additional feeding in times of drought. Increased heat stress on livestock can also lead to reduced growth and reproductive efficiency. This will increase water requirements for irrigated crops.

Kamiesberg

In Kamiesberg LM, the AFF sector contributes 11.89% to the local GVA, which is a contribution of 0.08% to the national GVA for the AFF sector. Of the total employment, 24.93 % is within the AFF sector. The main agricultural commodities are sheep and deciduous fruit. Climate projections show a generally warmer and drier climate. Drier conditions will lead to reduced availability and quality of pastures due to decline in rainfall. This will reduce the regeneration of the veld and make farmers more reliant on feeding their flocks. A hotter and drier climate will increase water demand for irrigated crops.

Hantam

In the Hantam LM, the AFF sector contributes 21.26% to the local GVA, which is a contribution of 0.27% to the national GVA for the AFF sector. Of the total employment, 31.45% is within the AFF sector. The main agricultural commodities are sheep, rooibos tea and wheat. Climate projections show a generally warmer and drier climate. Drier conditions will lead to reduced availability and quality of pastures due to decline in rainfall. This will reduce the regeneration of the veld and make farmers more reliant on feeding their flocks.

Karoo Hoogland

In the Karoo Hoogland LM, the AFF sector contributes 30.8% to the local GVA, which is a contribution of 0.19% to the national GVA for the AFF sector. Of the total employment, 42.52% is within the AFF sector. Owing to the lack of surface water, low rainfall and low vegetation cover, sheep farming is the only major agricultural farming enterprise. Climate projections show hotter and somewhat more arid conditions towards the end of the century. Some increases in rainfall in the near future would be advantageous to the veld quality, with positive impacts on sheep production.

3. Recommendations

The greatest risks faced across the Namakwa District are drought and increased temperatures, with the risk of extreme heat stress projected for the far northern parts of the District, into the future (2050). Population growth in the District is projected to decline in the future for the period up to 2050. Although the declining population would reduce vulnerability and pressure on natural resources, it may also leave settlements more vulnerable to economic change. With Namakwa being a rural District Municipality with settlements in remote locations, the negative impacts of population decline include the loss of labour, changes in household age and gender structure and off-farm income. Owing to the large distances between settlements in Namakwa, this District Municipality is also extremely vulnerable in terms of regional connectivity and access to services. People have to commute large distances to access basic services such as healthcare and education, which further contribute to economic and socio-economic vulnerability.

The Namakwa District has unique biodiversity and is characterized by vast tracts of land that is largely no longer under pristine natural environments. The Nama-Karoo biome, covering most of the District, is the second most threatened biome in South Africa. Future hotter and drier conditions, together with further overgrazing of the veld, will lead to a loss of the Nama-Karoo and Fynbos biomes, as well as an increase of the Desert biome (NDM, 2018).

The main projected coastal impacts of climate change in the Northern Cape are accelerated sea level rise, increased storminess and increases in ocean temperatures. Sea level rise and coastal storms will have an impact on the fisheries industry and could threaten existing coastal settlements and other coastal infrastructure in the province (NDM, 2018).

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

1. To ensure water security and quality for human consumption and agriculture under a changing climate: Given the water scarcity challenges in the country, developing comprehensive strategies for water resource management is crucial. Namakwa District, in particular, is projected to experience significant increases in temperatures, with parts of the District facing extreme risk of heat and drought tendencies into the future (at least up to 2050). Such changes in temperatures and precipitation typically lead to increased evapotranspiration, which could further reduce runoff and increase water losses in dams, and other surface water bodies, thus threatening potable water supply. Moreover, increasing temperatures coupled with heat extremes often result in increased water demand for irrigation, as well as domestic and industrial use, and in cases whereby existing water supply systems are not able to meet such increases in demand, water security is reduced. NDM 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 manage the physical isolation of communities and potential increased migration to urban and peri-urban areas: Considering that most of Namakwa's settlements are sparsely located across the District and poorly connected, it is essential to manage the isolation of communities residing in these settlements by reducing their vulnerabilities and increasing their capacity to cope with unexpected shocks, should they arise. Moreover, increased migration to urban centres often results in increased pressure on, and competition for, resources and services, and ultimately increases the exposure of growing populations to climate hazards, which are projected to occur in some of these well-serviced urban and peri-urban areas. Therefore, to manage this isolation, as well as the potential increases in migration to nearby urban and peri-urban areas, NDM could consider improving the connectivity and accessibility of remote settlements, which can be achieved by developing rural infrastructure and promoting sustainable urban growth. This will help accommodate newcomers and attract investment, and ultimately stimulate the local economy, which will give residents a reason to stay put, and reduce growth pressure on urban and peri-urban areas.

3. To manage the impacts of heat stress on humans and livestock: Increasing temperatures, as well as increases in the frequency and intensity of heat extremes, pose serious risks to people and animals. Increases in the risk of heat-related illnesses among vulnerable people and animals, as well as the spread of water- and vector-borne diseases emanating from the deteriorating water quality, are some of the primary impacts of heat-related weather events. The District could therefore mitigate such impacts by implementing measures that minimize the adverse effects of extreme heat on people and animals such as promoting the use of cooling technologies, providing public health guidance during heatwaves, advocating for livestock management practices that protect animals from heat stress, and ensuring access to climate-sensitive health services (such as heat illness prevention or disease surveillance).

4. To increase the resilience of the agricultural sector by supporting commercial and small-scale farmers across industries: Agriculture is one the sectors that are most likely to be adversely affected by climate change. Moreover, considering its role in terms of food security and job creation, especially for unskilled and semi-skilled workers, developing an agricultural policy that takes climate change impacts into consideration will be necessary. Such a policy, as well as accompanying interventions, could involve providing farmers with (i) access to resilient crop varieties, (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, market fluctuations, and pests.

5. To protect natural resources and manage the loss of high-priority biomes: As noted earlier, NDM's unique natural resources and ecosystems are already under threat from the impacts of climate change, with desertification identified as one of the leading processes altering some the District's biomes. The replacement of the District's Nama-Karoo and Fynbos biomes with the Desert biome is likely to result in biodiversity loss. Therefore, protecting and restoring natural ecosystems such as high priority biomes, wetlands, river ecosystems and riparian areas, to perform critical ecosystem services, enhance (or at least maintain) 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.

6. 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 therefore 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.

These goals are not exhaustive and could be complemented by other strategies tailored to the specific context and needs of the NDM. The key to success lies in integrating the programmes and actions that will be identified under each goal, into all aspects of municipal decision-making and operations, as well as engaging communities in these efforts.

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