REVISION OF THE BERGRIVIER MUNICIPAL CLIMATE CHANGE ADAPTATION PLAN

CLIMATE CHANGE RESPONSE STRATEGY

2024

BERGRIVIER MUNICIPALITY

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ACRONYMS

AR5	IPCC 5th Assessment Report
AR6	IPCC 6th Assessment Report
ARC	Agricultural Research Council
BM	Bergrivier Municipality
BSP	Biodiversity Spatial Plan
CH4	Methane
CRVA	Climate Risk and Vulnerability Assessment
CO_2	Carbon dioxide
DALRRD	Department of Agriculture Land Reform and Rural Development
DEA	Department of Environmental Affairs
DEA&DP	Department of Environmental Affairs and Development Planning
DFFE	Department of Forestry, Fisheries and the Environment
DJF	December, January, and February season
DOA	Department of Agriculture
DWS	Department of Water and Sanitation
FRA	The Global Forest Resources Assessments
GHG	Greenhouse gas
IDP	Integrated Development Plan
IPCC	Intergovernmental Panel on Climate Change
ISCW	Institute for Soil, Climate and Water
MAM	March, April, and May season
N_2O	Nitrous oxide
NEES	National Energy Efficiency Strategy
NCCRP	National Climate Change Response Plan
RCP	Representative Concentration Pathway
RDP	Reconstruction and Development Programme
SANLC	South African National Land Cover
SDF	Spatial Development Framework
SON	September, October, and November season
SWH	Solar Water Heating systems
UNFCCC	United Nations Framework Convention on Climate Change
WCDoA	Western Cape Department of Agriculture
WCDM	West Coast District Municipality
WCG	Western Cape Government
WTW	Water Treatment Works
WWTW	Wastewater Treatment Works

1 INTRODUCTION

Climate change (CC) is a global phenomenon that largely has localised impacts. Scientific research suggests that when the world reaches a global warming level of 1.5°C, we need to be prepared for increasingly severe, interconnected and often irreversible impacts of climate change on ecosystems, biodiversity, and human systems. Climate change encompasses alterations in the Earth's climatic conditions induced by the release of greenhouse gases (GHGs)—mainly carbon dioxide (CO_2), methane (CH_4), and nitrous oxides (N_2O)—into the atmosphere resulting from anthropogenic activities such as:

- *the burning of fossil fuels like coal, oil, and natural gas—this includes combustion in power plants, industries, transportation, and the residential sector,*
- *agricultural activities (e.g. fertiliser additions to soils, raising livestock, manure management, burning or residues),*
- *land use and land use change,*
- *industrial emissions from product production (e.g. cement production, metal production) and*
- *waste treatment (landfills, wastewater treatment, burning of waste).*

These activities have the potential to disrupt and transform various aspects of our natural environment, societies, and economies. Without significant reductions in emissions and appropriate measures to adapt to the anticipated impacts, the stability and sustainability of our ecosystems, social structures, and economic systems could be severely compromised, rendering the maintenance of the well-being and livelihood of society increasingly unsustainable.

As a continent, Africa is one of the lowest contributors to GHG emissions, yet it is the one with the most vulnerabilities and lowest adaptive capabilities. Key development sectors have already experienced widespread losses and damages attributable to human-induced climate change; including biodiversity loss, water shortages, reduced food production, loss of lives and reduced economic development. The latest scientific evidence-based report (AR6)—compiled by the Intergovernmental Panel on Climate Change (IPCC)—indicates with high confidence that, due to changes in the rainfall patterns and extreme weather events, there is likely to be increased floods and droughts in Southern Africa (IPCC, 2022). According to the IPCC, limiting global warming to 1.5°C is expected to substantially reduce damage to African economies, agriculture, human health, and ecosystems. Reducing climate change associated risks and vulnerabilities requires a coordinated approach to the identification and implementation of actions necessary to respond to differing impacts across regions, communities, and societies.

All spheres of government have a varying number of roles to play in the implementation of the NCCR White Paper (DEA, 2012). In addition, the Climate Change Bill (DFFE, 2022)—which will eventually become the Climate Change Act[1]—defines responsibilities for different national government departments, as well as for provincial and local government, including municipalities. The Climate Change Bill intends to ensure that South Africa is empowered to respond adequately to climate change and its risks and impacts. Both the NCCR White Paper and the Climate Change Bill indicate that local government plays a crucial role in building climate resilience through planning human settlements and urban development, the provision of municipal infrastructure and services, water and energy demand management, and local disaster response, amongst others. Given this responsibility and the fact that climate change impacts are felt most directly at the local level, there is a great need for proactive efforts to build climate resilience in all municipalities in the country.

In response to these national policies, the Bergrivier Municipality developed their first Climate Change Adaptation Plan in 2014 (BM, 2014) and have subsequently appointed Gondwana Environmental Solutions to review this document and develop a Climate Change Adaptation and Mitigation Response Plan. This plan will assist the Bergrivier Municipality in identifying risks and developing and implementing actions to respond to both current and future climate change risks. The objective of this project is to develop a Climate Change Adaptation and Mitigation Response Plan that will cover broad themes which include:

- *Climate Risk and Vulnerability Assessment (CRVA),*
- *Climate resilience and adaptive capacity,*
- *Best practice for climate change management, adaptation, and mitigation,*
- *Stakeholder consultation and empowerment,*
- *Research and development, and*
- *Implementation plan.*

The Implementation Plan will be developed in two steps, namely, (a) a status quo report and (b) an implementation plan. This report serves as the status quo report and includes:

- *a comprehensive background analysis of the location, socio-economic standing, and biophysical environment of the Bergrivier Municipality,*
- *an analysis of the climate and climate projections in the municipality, and*
- *a risk and vulnerability assessment which will assess the potential climate impacts and the vulnerabilities—in terms of communities, infrastructure, water,*

[1] The Climate Change Bill is currently going through a stakeholder consultation and review process before being finalised.

services, environment, etc.—in the Bergrivier Municipality, so that areas of greatest risk to climate change can be identified.

Once the climate risks have been identified, then the next phase (development of the implementation plan) can begin, where the actions that are needed to reduce these risks and increase resilience will be established. An assessment of the previous adaptation actions and the progress will also be completed as part of this process. These actions will enable the municipality and its inhabitants to adapt to the changing climate conditions effectively. The project timelines are provided in Table 1.

Table 1: Project Plan.

	Output	Deliverable Dates
1	22/23FY - Inception Report	2023/02/07
2	22/23FY - Draft Stakeholder Consultation Report	2023/04/01
3	22/23FY - Draft Literature Review Report (Adaptation plan)	2023/06/01
4	Stakeholder Engagements	2023/09/11 to 2023/09/15
5	23/24FY - Draft Climate Change Plan	2023/11/30
6	Stakeholder Engagements	Tentative (2024/02/12 – 2024/02/13
7	23/24FY - Final Climate Change Plan	2024/05/31

2 POLICY FRAMEWORK FOR CLIMATE CHANGE ADAPTATION AND MITIGATION

2.1 National Climate Change Policy Framework

South Africa (SA) has often been at the forefront of international efforts to address climate change. To this end, SA acceded to the United Nations Framework Convention on Climate Change (UNFCCC) in 1997, ratified the Kyoto Protocol in 2002 and became a party to the United Nations Paris Agreement on Climate Change as part of its efforts to combat climate change by keeping global temperature increases well below 2 degrees Celsius. As a signatory to the UNFCCC, it (SA) became a global leader in the establishment of a new treaty to limit carbon emissions when it hosted the 17th Conference of the Parties (COP 17) of the UNFCCC.

National climate change governance in SA is the product of more than two decades of policy evolution (Table 2) and has been shaped by an elaborate landscape of executive policies, strategies, regulations, and institutions. The 2004 National Climate Change Response Strategy (DEAT, 2004), followed by the National Climate Change Response White Paper (NCCRWP)—approved in 2011 (DFFE, 2011)—form the foundation of SA's national climate policy. Furthermore, in 2012, climate change became a key element of the National Development Plan (NPC, 2012).

Polices on adaptation and resilience have had little focus to date, however some progress has been made with the National Climate Change Adaptation Strategy being approved in 2020 (DEA, 2020). This document outlines 4 main objectives and describes 9 interventions of the policy (Table 3).

Table 2: Timeline of key climate-related policy at the national level (Adapted from Averchenkova et al., 2019).

Year	Cross-cutting	Energy	Transport	Industry	Agriculture	Waste	Water	Adaptation/ Resilience
2004	National Climate Change Response Strategy						National Water Resource Strategy I	
2005								
2006								
2007			Biofuels Regulatory Framework					
2008		National Energy Act						
2009		Non-renewable electricity levy		Section 12K of Income Tax Act		National Environment Management: Waste Act		
2010			Environmental Levy for CO_2 on motor vehicles	Industrial Policy Action Plan (IPAP) 2010/11-2012/13				
2011	National Climate Change Response White Paper	SANS 204: Energy Efficiency in buildings. Integrated Resource Plan for Energy (2010-30)						
2012	National Development Plan			IPAP 2011/12-2013/14				
2013		Section 12L of Income Tax Act		IPAP 2012/13-2014/15			National Water Resource Strategy II	

2014				IPAP 2013/14-2015/16				National long-term Adaptation Strategies
2015	Nationally Determined Contribution			IPAP 2014/15-2016/17	Climate Change Sector Plan			Disaster Management Amendment Bill
2016				IPAP 2015/16-2017/18				
2017				IPAP 2016/17-2018/19 National GHG Emission Reporting Regulation. National Pollution Prevention Plans			Water and Sanitation Sector Policy on Climate Change	Draft National Climate Change Adaptation Strategy
2018	National Climate Change Bill	Integrated Resource Plan for Energy (2019)		IPAP 2017/18-2019/20	National Climate Smart Agriculture Strategic Framework		National Water and Sanitation Master Plan	
2019	Carbon Tax Bill		Carbon Tax fuel levy. Green Transport Strategy for SA (2018-2050)	IPAP 20118/19-2020/21				
2020	Low Emission Development Strategy 2050			Updated National GHG Emission Reporting Regulation		National Waste Management Strategy 2020	National Water Security Framework	National Climate Change Adaptation Strategy
2021	Updated Nationally Determined Contribution. AQMP							
2022	Just Transition Framework							

Table 3: Strategies, interventions and outcomes outlined in the National Adaptation Strategy for South Africa (Source: DFFE, 2020).

OBJECTIVE	INTERVENTION	OUTCOME
OBJECTIVE 1: Build climate resilience and adaptive capacity to respond to climate change risk and vulnerability.	**INTERVENTION 1:** Reduce human, economic, environment, physical and ecological infrastructure vulnerability and build adaptive capacity.	**Outcome 1.1:** Increased resilience and adaptive capacity achieved in human, economic, environment, physical and ecological infrastructure vulnerability.
	INTERVENTION 2: Develop a risk, early warning, vulnerability and adaptation monitoring system for key climate vulnerable sectors and geographic areas.	**Outcome 2.1:** An early warning and monitoring system for key climate vulnerable sectors and geographic areas developed and implemented.
OBJECTIVE 2: Promote the integration of climate change adaptation response into development objectives, policy, planning and implementation.	**INTERVENTION 3:** Develop vulnerability and resilience methodology framework that integrates biophysical and socio-economic aspects of vulnerability and resilience.	**Outcome 3.1:** An adaptation vulnerability and resilience framework developed and implemented across 100% of key adaptation sectors
	INTERVENTION 4: Facilitate mainstreaming of adaptation responses into sectoral planning and implementation.	**Outcome 4.1:** An effective adaptation planning that covers at least 80% of the South African sectors identified in the NCCAS.
		Outcome 4.2: Achieve a 100% coverage of climate change considerations in sectoral operational plans.
OBJECTIVE 3: Improve understanding of climate change impacts and capacity to respond to these impacts.	**INTERVENTION 5:** Promote research application, technology development, transfer and adoption to support planning and implementation.	**Outcome 5.1:** Increased research output and technology uptake to support planning and implementation.
	INTERVENTION 6: Build the necessary capacity and awareness for climate change response.	**Outcome 6.1:** Capacity building and awareness for climate change response enhanced.
OBJECTIVE 4: Ensure resources and systems are in place to enable implementation of climate changes responses.	**INTERVENTION 7:** Establish effective governance and legislative processes to integrate climate change in development planning.	**Outcome 7.1:** Adaptation governance defined and legislated through the Climate Change Act once approved by parliament.
		Outcome 7.2: Institutional support structures for climate change adaptation strengthened.
		Outcome 7.3: Enhanced public-private-civil society collaboration and stewardship.
	INTERVENTION 8: Enable substantial flows of climate change adaptation finance from various sources.	**Outcome 8.1:** Adequate financial resources of national adaptation priorities from national fiscus and international sources.
	INTERVENTION 9: Develop and implement an M&E system that tracks implementation of adaptation actions and their effectiveness.	**Outcome 9.1:** A national M&E system developed and implemented.

South Africa's climate priorities span both climate adaptation and mitigation. The Climate Change Bill (DFFE, 2022) is aimed at:

- *Regulating climate change mitigation, for example, reduce Greenhouse Gas (GHG) emissions to slow down and stop climate change,*
- *Manage climate change adaptation – the government must assess all the risks and expected impacts, and create response plans at the national, provincial, and local level, and*
- *Defining responsibilities for different national government departments, as well as for provincial and local government (including municipalities) to ensure all relevant role-players are mandated to do their part in responding to climate change.*

2.2 Provincial Climate Change Policy Framework

The Western Cape has a very well-developed climate change policy environment with the key elements being outlined in the timeline in Figure 1.

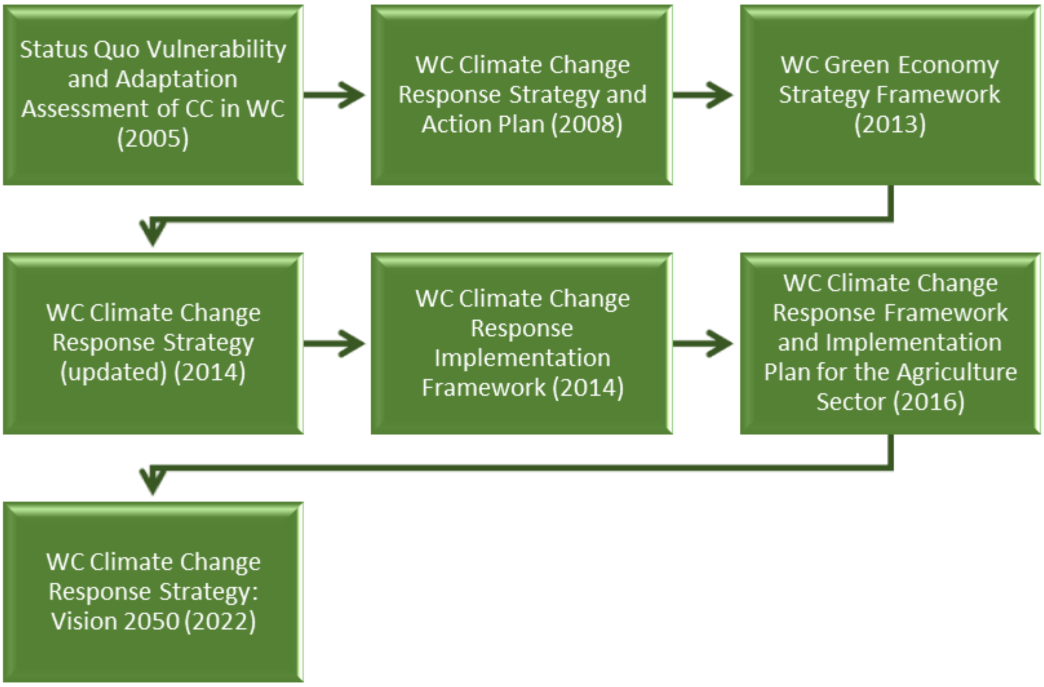


Figure 1: Climate change policy development in the Western Cape.

The WC Climate Change Response Strategy (WCCCRS) (DEA&DP, 2022) has four guiding objectives:

- *Responding to the climate emergency,*
- *Transitioning in an equitable and inclusive manner to net zero emissions by 2050,*
- *Reducing climate risks and increasing resilience, and*
- *Enabling a Just Transition through public sector, private sector, and civil society collaboration.*

Actions that need to be carried out by 2025 and by 2030 to achieve these objectives are clearly outlined in this strategy. The WCCCRS Implementation Plan (DEA&DP, 2023) provides the details of the proposed institutional framework for co-ordination of climate change matters in the Western Cape (Figure 2).

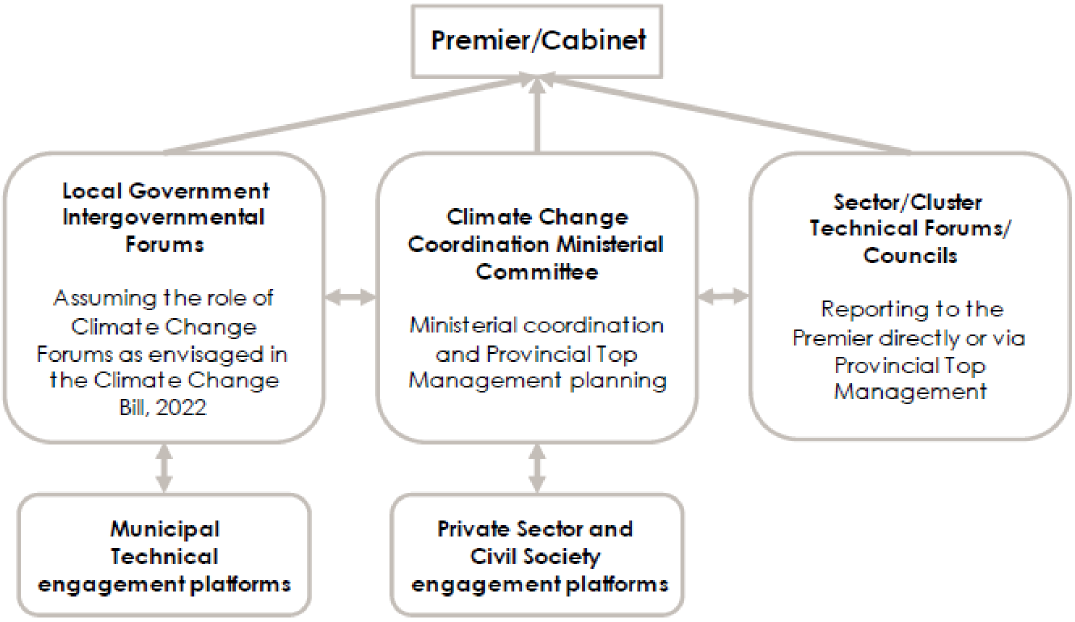


Figure 2: Proposed Climate Change Response Implementation Institutional Framework in the Western Cape (Source: DEA&DP, 2023).

In addition to these climate change policies there are several other related strategies and policies that will be considered during this project:

- *Integrated Second Generation of The West Coast District Municipality, inclusive of Five Local Municipalities Air Quality Management Plan 2019-2024,*
- *City of Cape Town Climate Change Action Plan (2021),*
- *Ecological Infrastructure Investment Framework (2021),*
- *Growth for Jobs Strategic Framework and Strategy (Final, 2023-2035),*

- *Municipal Energy Resilience Initiative (2022),*
- *Western Cape Provincial Coastal Management Programme (2022-2027),*
- *Western Cape Integrated Drought and Water Response Plan (Draft, 2022),*
- *Sustainable Water Management Plan (2018),*
- *Environmental Risk and Vulnerability (Phase 2) (Draft, 2023),*
- *Provincial Strategic Plan (2014-2019),*
- *Western Cape Spatial Development Plan (2014), and*
- *SmartAgri: Updated Climate Change Trends and Projections for the Western Cape (2022).*

2.3 District policies and strategies

The district level documents to be considered in the development of the Bergrivier Adaptation Implementation Plan are:

- *West Coast District Municipality IDP,*
- *West Coast District Municipality SDF 2014, and*
- *West Coast District Municipality Climate Change Plan 2019.*

2.4 Municipal Policy Framework and strategic direction

Bergrivier Municipality was established in 2000 as a local municipality through the amalgamation of Velddrif Municipality, Porterville Municipality and Piketberg Municipality. Bergrivier Municipality has a Mayoral Executive System combined with a Ward Participatory System in terms of Section 12 of the Municipal Structures Act, Act 117 of 1998.

The municipality's mandate is to:

- *provide democratic and accountable government to the community,*
- *ensure the sustainable provision of services to the community,*
- *promote social and economic development,*
- *promote a safe and healthy environment, and*
- *encourage communities and community organisations to get involved in local government matters.*

The functions of the municipality—as set out in Schedules 4B and 5B of the Constitution and Section 84 of the Municipal Structures Act—do not specifically include climate change responses. However, as stated in the Bergrivier Adaptation Plan (BM, 2014), climate change is an integrating factor that needs to be mainstreamed into all activities and functions in the municipality. The Bergrivier Municipality takes its strategic direction from its Integrated Development plan and, in relation to responding to climate change, Strategic

Goal 5—create a sustainable, inclusive, and integrated living environment—it is of upmost importance, specifically as one of the objectives highlighted here is to conserve and manage the natural environment and mitigate the impacts of climate change. The aim is to develop Bergrivier as the first municipality that has a zero-carbon footprint. In support of this goal, the Bergrivier Municipality has developed several strategies and plans that will guide in dealing with the impacts of climate change (Table 4). All these plans and strategies were considered in the development of this status quo report and will also be used to help formulate the development of the Climate Change Response Implementation Plan.

Table 4: LM documents to be considered in the development of the Bergrivier Municipality Adaptation Implementation Plan.

	Plan or strategy
Bergrivier Municipality Plans and Strategies	Bergrivier Municipality Climate Change Adaptation Plan (2014)
	Bergrivier Municipality Integrated Development Plan (2022)
	Bergrivier Municipality Spatial Development Framework 2019-2024 (2019)
	Revised Disaster Management Plan and Risk Preparedness Plans (2013)
	Water Services Development Plan (2022)
	Integrated Waste Management Plan (2019)
	LED Strategy (2015)
	Bergrivier Municipality Biodiversity Report (2010)
	Local Biodiversity Strategic and Action Plan (LBSAP) (2011)
	Integrated Second Generation of the West Coast District Municipality inclusive of Five Local Municipalities Air Quality Management Plan 2019-2024
	Bergrivier Municipal Second-generation Coastal Management Programme 2019-2024 (2019)
	Groot Berg River Estuary Draft Estuarine Management Plan (Draft, August 2021)
	Integrated Transport Plan (2019)
	Municipal Infrastructure Plan
	The Bergrivier Municipality Invasive species monitoring, control, and eradication plan (2020)

2.4.1 Bergrivier Adaptation Plan (2014)

The first Bergrivier Adaptation Plan was completed in 2014 in which four climate impacts (high temperature, floods, erratic rainfall, and heavy winds) were identified and assessed. Two stakeholder workshops were held as part of the development of this plan; the first stakeholder workshop was used to identify the level of impact of the climate hazards on various sectors (Table 5) whilst the second was used to identify adaptation options. The following high-risk areas and interventions were identified and incorporated into the Adaptation Plan:

- *Mainstreaming of climate change adaptation into municipal governance:*
    - *Capacity building and awareness, and*
    - *Environmental sector engagement.*
- *Climate resilient low-cost housing:*
    - *Assess the potential for new low-cost housing developments to be more resilient,*
    - *Greening Reconstruction and Development Programme RDP housing design, and*
    - *'Green building' retrofitting of existing low-cost housing.*
- *Stormwater management:*
    - *Improved management of stormwater,*
    - *Investigate alternative use of storm water, and*
    - *Regulation of storm water drainage (by-law).*
- *Conservation of natural resources:*
    - *Expand and participate in existing alien clearing programmes, and*
    - *Expand existing working on fire programmes.*
- *Agriculture interventions:*
    - *Targeted participatory planning process for agriculture sector in IDP,*
    - *Mainstream agriculture sector into municipal planning, and*
    - *Municipality should have representation on Agriculture Union.*

Table 5: Key climate impacts per activity area (Source: BM, 2014).

Key sectors / activities	Climate hazards			
	High temp	Flood	Erratic rainfall	Heavy winds
Infrastructure - Roads	L	M	L	L
Infrastructure -Structures / buildings	M	L	L	M
Infrastructure - Low income housing	M	H	L	M
Infrastructure - Storm water	L	H	H	M
Service delivery - Water	M	M	L	L
Service delivery - Electricity	M	M	L	M
Natural Resources - veld / soil / land	H	M	M	L
Natural Resources - water quality / quantity	M	M	M	L
Residents' health	L	M	L	M
Seasonal work (employment)	M	M	L	L
Agriculture - wheat	M	L	H	M
Agriculture - potatoes	M	M	M	M
Agriculture - table grapes & wine grapes	M	L	M	L
Agriculture - fruit (Bo-berg)	M	L	L	M
Fishing	M	L	L	H
Tourism	M	M	M	M
Manufacture and trade	M	L	L	L

3 BERGRIVIER MUNICIPALITY SITUATIONAL ANALYSIS

3.1 Geographical Overview

The Bergrivier Municipality falls within the administrative boundaries of the West Coast District Municipality in the Western Cape Province (Figure 3) and is named after the Berg River that runs through the area. It is surrounded by the Cederberg to the north, Swartland and Cape Winelands District to the south, Cape Winelands District to the east, and Saldanha Bay and the Atlantic Ocean to the west. The municipality is known for its diverse landscape ranging from captivating rural landscapes and agricultural lands to picturesque mountain ranges and coastal areas along the Atlantic Ocean.

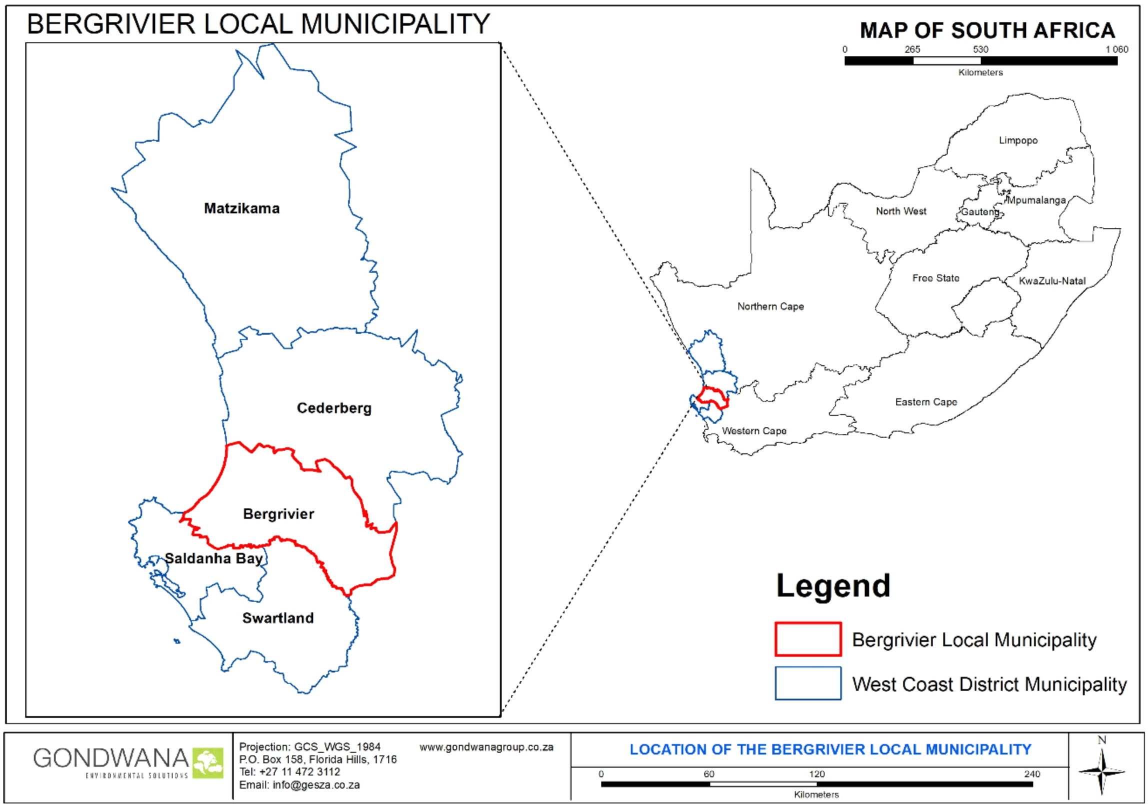


Figure 3: Locality Map of Bergrivier Municipality.

The municipality covers a geographical area of 4,407.04 km^2 and includes 8 proclaimed towns, approximately 40 kilometres of coastline and an expansive rural area. It encompasses a series of coastal towns and resorts; namely Velddrif, Laaiplek, and Dwarskersbos, main urban settlements including Piketberg, Porterville, Eendekuil, Aurora and Redelinghuis, and rural settlements under the ownership of the Moravian Church, specifically Goedverwacht and Wittewater. Another notable settlement within the region is De Hoek, which is privately owned and features an interconnected industrial and administrative complex (BM, 2019).

3.2 Ward delimitation

The ward demarcation of Bergrivier Municipality was changed for the 2016 municipal election in accordance with the Local Government Municipal Demarcation Act 1998 (Act 27 of 1998) (Demarcation Act), and was demarcated into 7 (seven) wards (Figure 4):

- *Ward 1: Porterville Town, Voorberg and the rural area to the north of Porterville,*
- *Ward 2: Remainder of Porterville (Monte Bertha) and the rural areas to the south of Porterville,*
- *Ward 3: Western and Southern portion of Piketberg Town, De Hoek, Wittewater, and Goedverwacht,*
- *Ward 4: is predominantly urban and comprises the North-eastern portion of Piketberg Town,*
- *Ward 5: western and southern portion of Eendekuil, Redelinghuis and Genadenberg,*
- *Ward 6: is predominantly rural and comprises the towns of Aurora, Noordhoek and Dwarskersbos and the rural areas between these settlements, and*
- *Ward 7: a predominantly urban coastal settlement which comprises Velddrif and includes Port Owen and Laaiplek.*

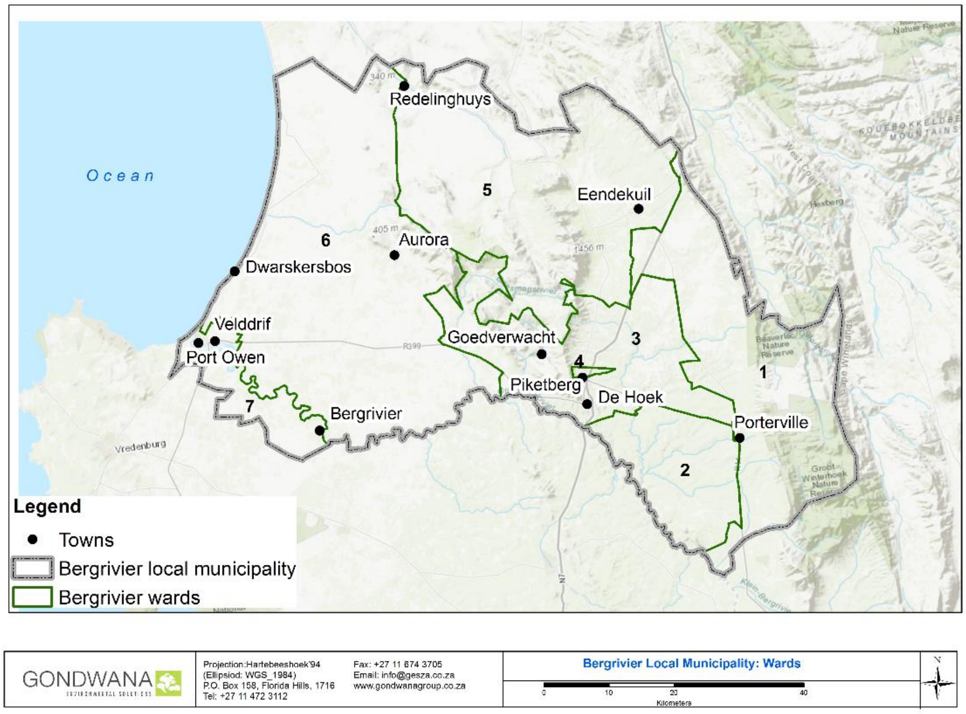


Figure 4: Map of the wards in the Bergrivier Municipality (Source: BM, 2022).

3.3 Settlements

A description of the settlements in Bergrivier Municipality is given in Table 6.

Table 6: Overview of settlements in the Bergrivier Municipality (Source: BM, 2022b).

Settlement	Overview
Aurora	Aurora is also classified as an isolated village. The town has a rural character against a picturesque topographical setting. This town has no autonomous economic base other than the accommodation of farm workers involved in the nearby farms and basic provision associated with this use.
Dwarskersbos	Dwarskersbos is a coastal town characterized by its property market, holiday accommodation and tourism. The sea and coastal area are the most important natural resources. The main function of the town is to provide holiday accommodation. Tourism, retirees and second home residents provide a solid base for the local economy.
Eendekuil	Eendekuil is also classified as an isolated village. It functions as a low-order agricultural service centre that is dependent on Porterville for higher-order municipal services. Mainly a dormitory town for farm workers and retired people. This town has no autonomous economic base other than the accommodation of farm workers involved in the nearby farms and basic service provision associated with this use.
Piketberg (Including Piket Bo Berg)	Piketberg is classified as a central place and is the administrative seat of the Bergrivier Municipality. It is also the service and commercial centre of the surrounding agricultural area. The primary economic base of Piketberg is agriculture. Public-sector activities related to the municipal head office, district offices, provincial government offices and other public functions also provide a solid base for the local economy.
Porterville (Including Dasklip Pass)	Porterville is also classified as a central place and sound infrastructure has contributed towards the establishment of a Regional Kaap Agri Office as well as the Voorberg prison. The economic base of Porterville is primarily agriculture, which is supplemented by some recreational and tourism activities.
Redelinghuis	Redelinghuis is classified as an isolated village. The town mainly functions as a residential area for the surrounding agricultural sector and retired people. Redelinghuis is dependent on Porterville for higherorder municipal services. There is some recreational and tourism potential in the Verlorenvlei area which is a Ramsar Site which falls partially within Bergrivier's area of jurisdiction. This town has no autonomous economic base other than the accommodation of farm workers involved in the nearby farms and basic service provision associated with this use.
Velddrif (Including Laaiplek, Port Owen and Noordhoek)	Velddrif is a coastal town, which functions as a focal point for the fishing industry along the West Coast. The most important resources are the sea, the coastal environment, salt pans and the Bergrivier Estuary. Tourism, retirees and second home residents provide a solid base for the local economy
Goedverwacht and Wittewater	Goedverwacht and Wittewater are also classified as isolated villages. These towns are located on private land, within a predominantly agricultural area. They are Mission Stations run by the Moravian Church of South Africa and have little direct investment to stimulate economic activities. Inhabitants work mainly on the surrounding farms, but the villages do boast some very good builders. The scenic mountains and the missionary culture offer some tourism potential, but this can only be realized within the context of the larger tourism plan for the region.

3.4 Biophysical environment

3.4.1 Topography

The topography of the Bergrivier Municipality is a blend of mountains, valleys, plains, and coastal areas, contributing to its scenic beauty, diverse ecosystems, and agricultural productivity. There are several mountain ranges, including the Piketberg Mountains, Olifantsberg Mountains, Winterhoek Mountains, and Groot Winterhoek Mountains, within the municipality. The mountainous areas are located centrally and within the north-eastern regions as depicted in Figure 5. Alongside the mountains and valleys, there are also extensive plains and plateaus, with 80% of Bergrivier Municipality being flat, lowland areas. These flat or gently rolling areas are often used for agricultural purposes, particularly for the cultivation of crops such as wheat, barley, and citrus fruits. The Bergrivier Municipality also includes a stretch of the South African coastline along the Atlantic Ocean. The coastal areas are characterised by sandy beaches, rocky cliffs, and estuaries formed by the rivers meeting the sea.

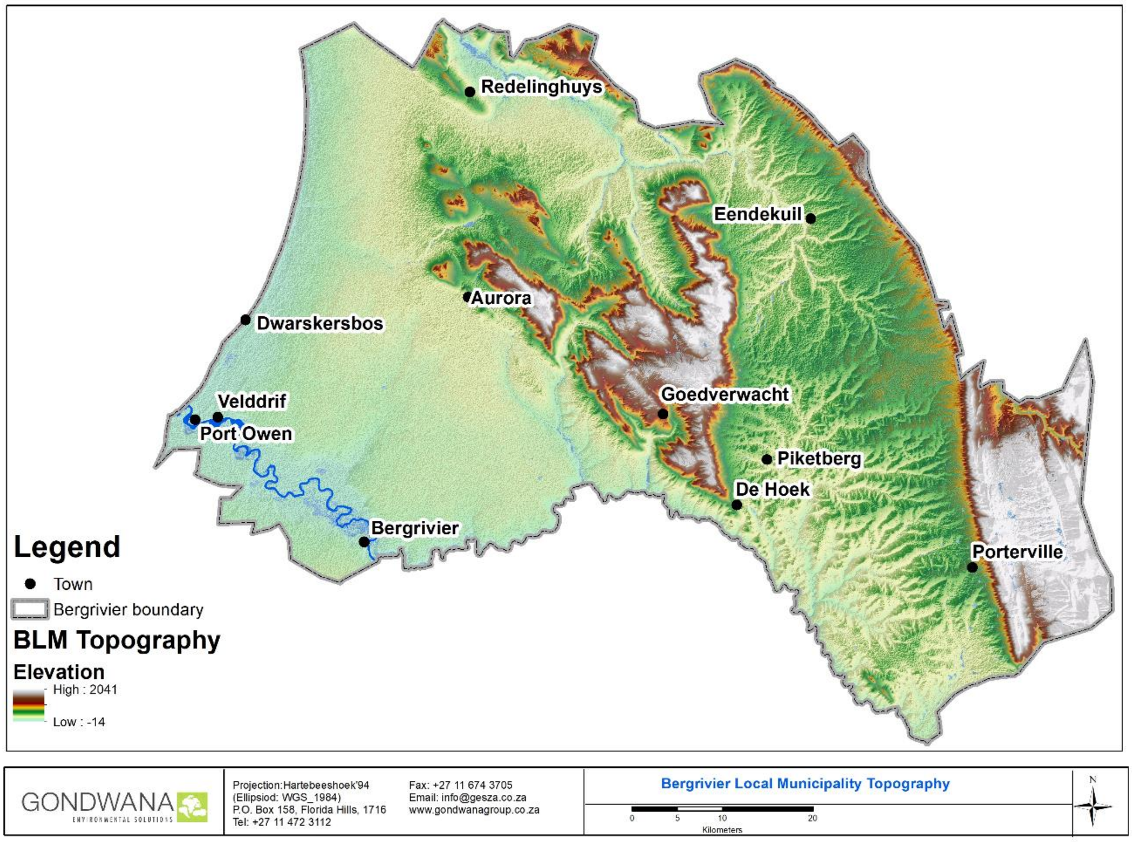


Figure 5: Bergrivier Municipality topography.

3.4.2 *Geology and soils*

The Bergrivier Municipality is characterised by a variety of soil types, altitude slopes and rainfall patterns. The underlying structure of the Bergrivier Municipality consists of two distinct groups of geological formation, which are overlaid by a layer of shallow sandy deposits in the coastal plain region. Firstly, there are the Malmesbury Group (42.4% of the area) and Table Mountain Group (22.4% of the area), followed by Quaternary deposits (35.2% of the area) (Figure 6)

This geology leads to three main types of soils in Bergrivier (Figure 7):

- *Well-structured soils*
- *Well-drained, but poorly structured soils and*
- *Unstructured sand and shallow soils*

The municipality also has a variety of faults and fold formations. The De Hoek Fault, which extends along the western boundary of the Piketberg in the northwest and southeast orientation, is the larger of the two faults.

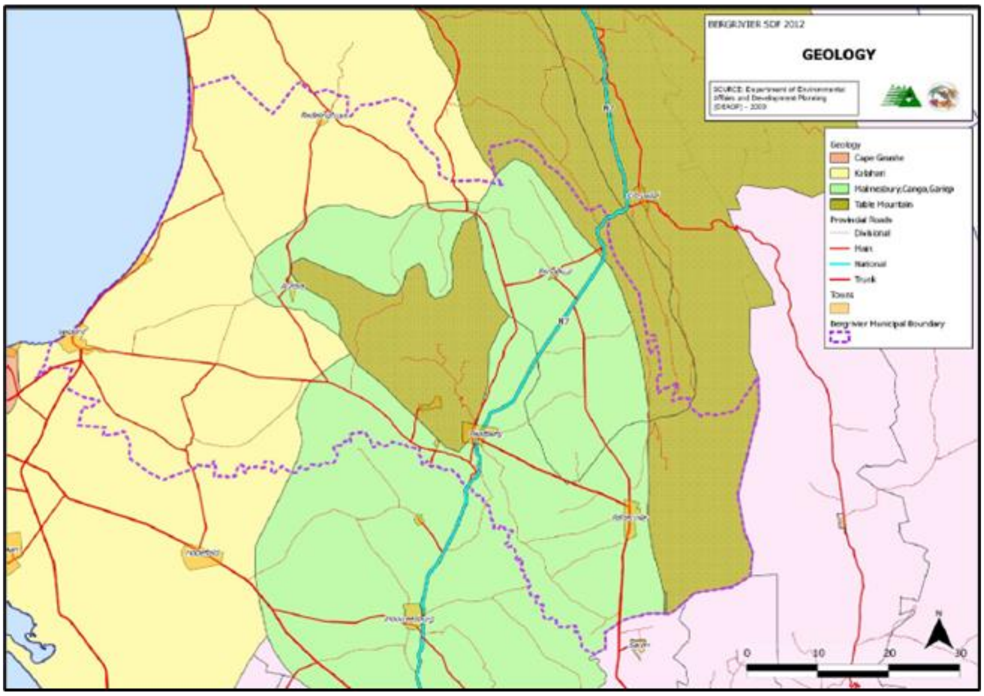


Figure 6: Bergrivier Municipality geology (Source: BM, 2013).

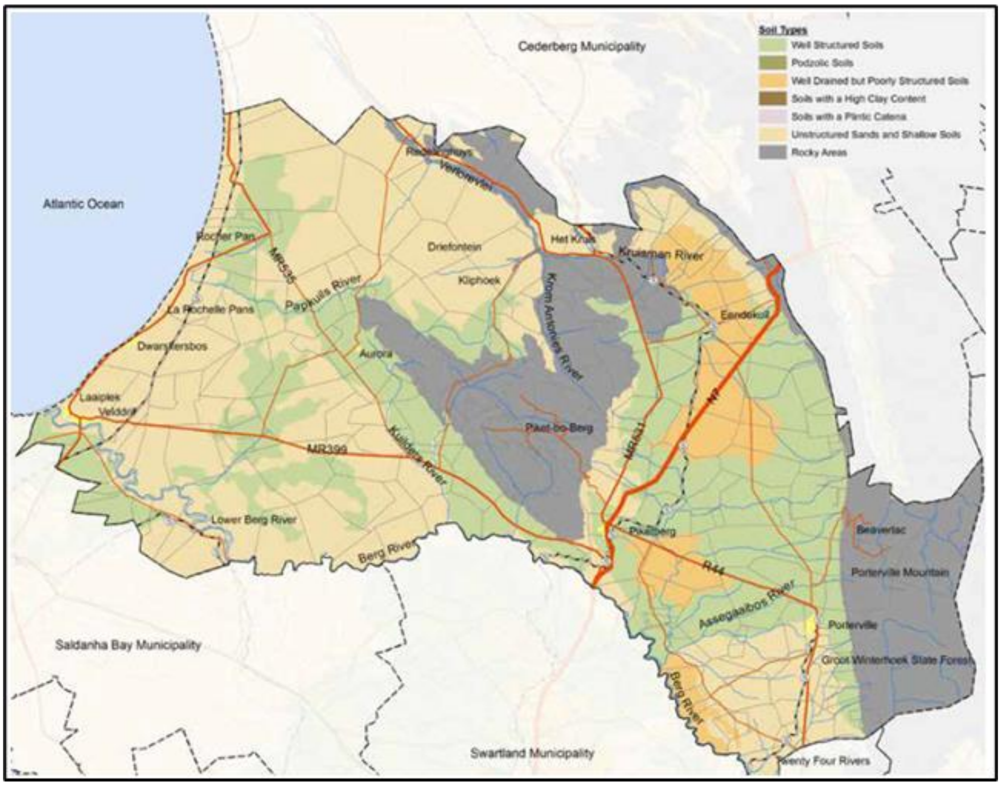


Figure 7: Map showing the soil types in the Bergrivier Municipality (Source: BM, 2019).

3.4.3 Climate

The Bergrivier area experiences a Mediterranean climate, characterised by dry summers and wet winters. The climate in the Bergrivier region is influenced by its proximity to the Atlantic Ocean, which moderates temperature and rainfall. During the winter months, the Bergrivier area experiences cooler temperatures, with average daily highs ranging from 15°C to 20°C. Nights can be cold, with temperatures dropping to 5- and 10°C. The average annual rainfall across the Berg Rivier catchment area ranges from over 1,000 mm in the mountain regions in the east, to around 200 mm towards the western coastal areas (Cullis, et al., 2019).

In the summer months the Bergrivier area is warm and dry, with average daytime temperatures ranging from 25°C to 30°C. Heatwaves are not uncommon during this time, with temperatures occasionally reaching the mid-30s°C. The nights are generally cool and pleasant, with temperatures ranging from 15°C to 20°C. Rainfall is scarce during the summer months, and the region experiences dry conditions.

Spring and Autumn in the Bergrivier area bring transitional weather patterns. Spring is characterised by mild temperatures and occasional rainfall as the region transitions from winter to summer. Autumn replicates a similar pattern, with gradually cooling temperatures and occasional rainfall, as the region transitions from summer to winter. Overall, the

Bergrivier area enjoys a moderate climate, with relatively mild temperatures throughout the year. Figure 8 shows some temperature, rainfall, and evapotranspiration trends across the region.

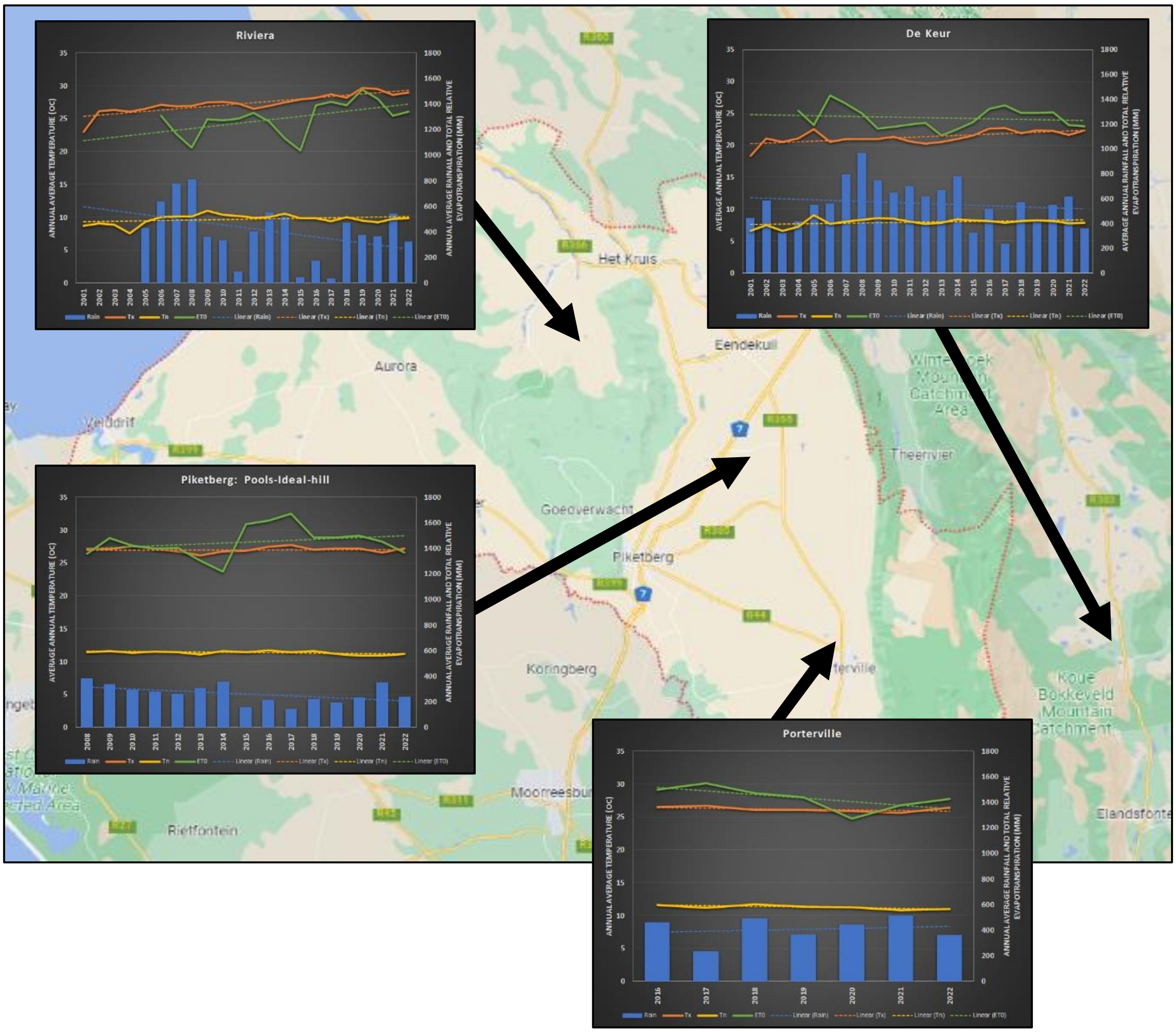


Figure 8: Trends in annual average minimum (yellow) and maximum (orange) temperature, annual average rainfall (blue bars) and total relative evapotranspiration (green) at four stations across the region (Source: ARC-ISCW).

3.4.4 Water resources

Bergrivier Municipality is rich in both above and below ground water resources (Figure 9). However, much of it relies on water storage and this may become less reliant as conditions become drier. The Berg River is the most important surface water source. Most of the water from the Berg River contains a fair number of dissolved salts, however it can still be used for irrigation. The Kruismans River flows from Eendekuil to the Verlorenvlei and is a source for agricultural irrigation. Some of the fountains provide fresh water, but as one moves away from the mountainous areas, the borehole water is brackish and not suitable for irrigation, although it can be used for livestock. Farmers from

Velddrif have reported that the estuary contains saline water, and this has led to them purchasing water from the municipality.

Bergrivier Municipality is situated within the newly established Berg-Olifants Water Management Area. Bergrivier is the Water Services Authority (WSA) for the entire municipal management area and its Water Services functions are managed by its Engineering Services Department. In addition to being the WSA, Bergrivier Municipality is also the Water Services Provider (WSP) and supplies bulk water to other towns and settlements. The West Coast District Municipality supplies bulk potable water to Velddrif and Dwarskersbos whereas Bergrivier Municipality provides bulk potable water to all the other towns and settlements.

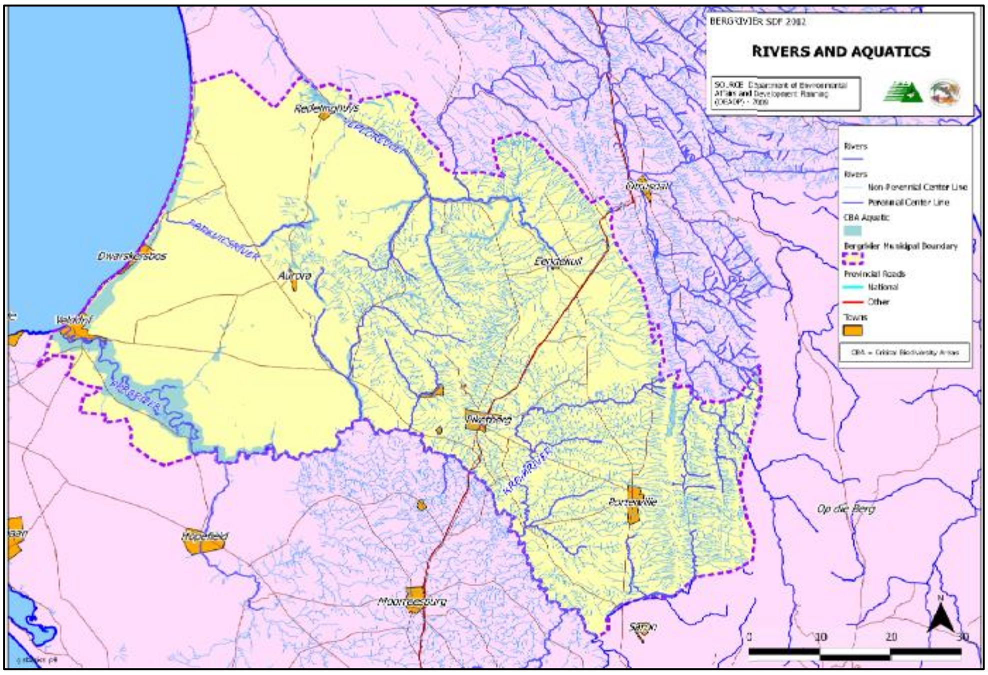


Figure 9: Rivers and aquatic areas in the Bergrivier Municipality (Source: BM, 2013).

3.4.5 Land cover and biodiversity

The Bergrivier Municipality is situated within the Cape Floral Region, recognised as the world's significant non-tropical biodiversity hotspot for its diversity of flora and fauna (UNESCO, 2023). The Cape Floral region is an exceptional floral realm with World Heritage status and the Berg River Estuary, which holds significant conservation value for birdlife. This region is remarkable for its unique biodiversity and dense population of endemic plant species. Furthermore, it has a distinctive and intricate terrain characterised by notable levels of species diversity, a wide range of ecosystem types, and localised plants and animal species (MSDF, 2019).

The ecosystems found in the Bergrivier Municipality (Figure 10) are:

- *Fynbos,*
- *Strandveld (succulent karoo),*
- *Renosterveld,*
- *Shrubland and*
- *Aquatic (including wetlands, rivers, floodplains, and estuaries) vegetation.*

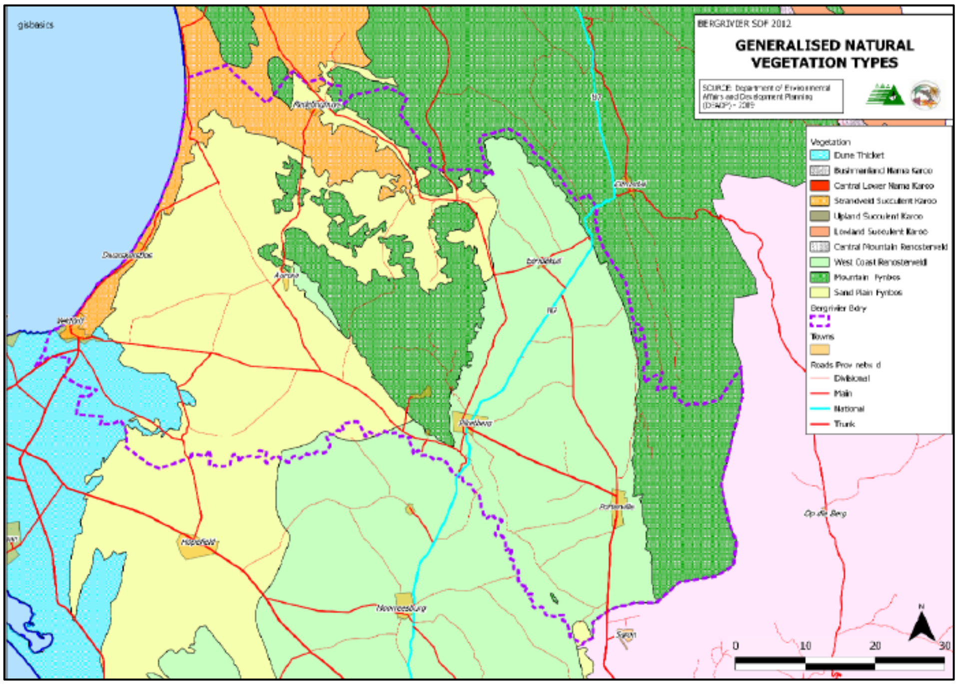


Figure 10: Natural vegetation types in the Bergrivier Municipality (Source: BM, 2013).

The Berg River estuary is a functional estuary and is one of 4 permanently open estuaries on the west coast (Whitfield, 2000). It is also one of the largest estuaries in the country, with a total area of 61 km^{2}. Additionally, it is one of the most important in the country in terms of its conservation value (DEA&DP, 2021). A total of 35 fish species from 30 families have been recorded in the Berg River estuary, of which 48% can be regarded as either partially or completely dependent on the estuary for their survival. These include some highly valuable species such as White Steenbras and Elf, as well as lower value species such as Harders. The Berg River is home to the Berg River Red Fin (Pseudobarbus burgi), which is endemic to the ecosystem and presently considered a critically endangered species.

The Berg River supports the highest recorded density of shorebirds on the West Coast of Africa and is one of two places in South Africa where approximately 30 000 wading birds migrate to annually. The Berg River Estuary is one of the 290 estuaries in South Africa that has attained recognition as a Ramsar Site—the 28th to be precise—under the Convention on Wetlands of International Importance, making it the second wetland of international significance. This declaration underscores its critical role in supporting biodiversity, as well as cultural and economic activities (DFFE, 2022).

In addition to its ecological significance, the Berg River estuary is important for local communities and economic activities. It supports commercial and recreational fishing, with species like Mullet, White Stumpnose, and various types of Breams being caught in these estuaries. Estuaries also attract visitors for boating, canoeing, and other water-based recreational activities.

Efforts are made to conserve and manage the Bergrivier estuaries to protect their ecological values. These include measures to control pollution, manage fishing activities sustainably, and maintain the estuarine ecosystems' overall health. Conservation organisations, government agencies, and local communities work together to ensure the long-term preservation of these estuaries and their associated habitats.

The Berg River estuary largely falls within the jurisdiction of the Cederberg Local Municipality and holds significant importance within the Bergrivier Municipality as the primary critical estuary. The Bergrivier Municipality retains the responsibility for managing the catchment of the Verlorevlei within its own municipal area (LAB, 2010). The municipality is also home to conservation areas like the Rocherpan Nature Reserve, the Groot Winterhoek Wilderness Area and Winterhoek Mountain catchment areas managed by CapeNature. Moreover, the Verlorenvlei Wetland, situated downstream of Redelinghuis, constitutes another notable conservation area.

3.4.6 Coasts and coastal zones

Bergrivier Municipality has 46 kilometres of coastline with Velddrif, Dwarskersbos and Laaiplek being the main coastal towns. The public launch site at Rooibaai is currently operational, and the municipality is in the process of incorporating two additional sites—namely Southern Dwarskersbos and Port Owen—through the provincial public launch site procedure. Figure 11 shows the critical biodiversity areas along the Bergrivier Municipality coastline.

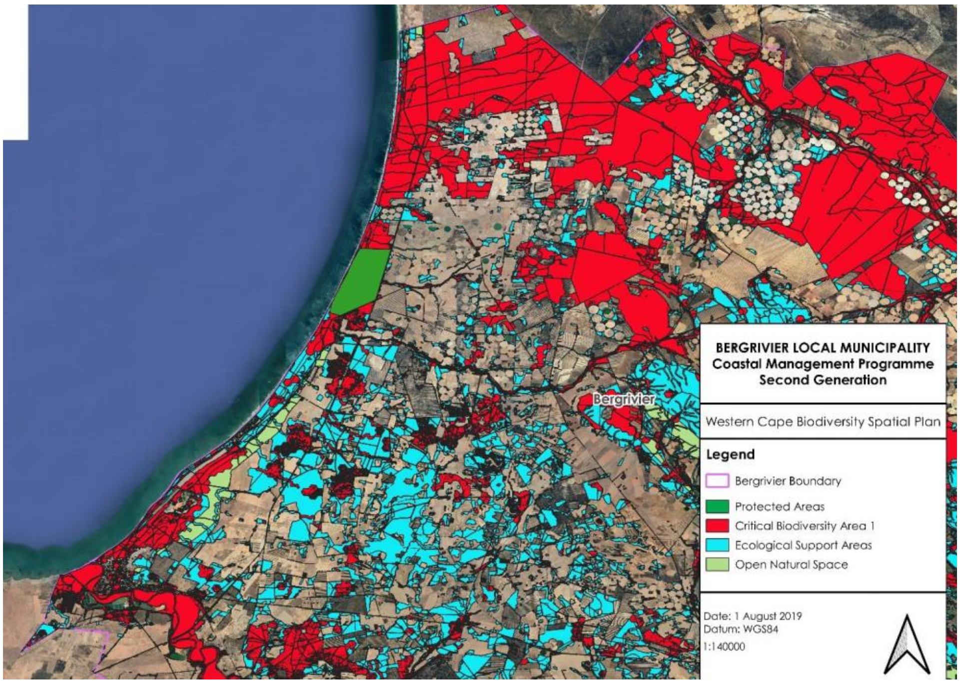


Figure 11: Critical biodiversity areas around the coast in the Bergrivier Municipality (Source: BM, 2019b).

The coastal protected regions encompass the Rocherpan Marine Reserve and the Lower Berg River Conservancy as detailed in the Bergrivier Coastal Management Plan (BM, 2019). Rocherpan, a coastal natural sanctuary situated approximately 25 kilometres north of Velddrif within the municipality, is abundant in bird species and vibrant indigenous wildflowers. The primary feature of the reserve is a seasonal vlei, which is typically arid from March to June. In 1966, Rocherpan was officially designated as a nature reserve, covering an area of 930 hectares and, in 1988, the adjacent portion of the Atlantic Ocean was designated as a marine reserve, covering 150 hectares in size.

The coastal and estuarine areas in the municipality experience dynamic processes of erosion and deposition. Development in high-risk and sensitive areas has been limited, apart from Laaiplek and Velddrif. However, the storm damage reported in Laaiplek by the local restaurants and the municipal resort is indicative of land erosion and points to possible displacement risk (BM, 2019).

3.4.7 Land use change

Economic development has significantly impacted the Bergrivier Municipality with slightly more than 58% of the total area having undergone transformation, primarily as a result of farming activities and human settlements, inter alia (BM, 2019). Another threat is alien plant invasion, for example where alien vegetation occupies 13% of the total Berg River catchment area with natural vegetation only occupying 2% (DEA&DP, 2021). A variety of mining operations including granite and heavy mineral quarrying and diamond dredging are also found within the region (Petersen, 2013).

3.5 Demographic overview

The Bergrivier Municipal area had a population of 70 276 in 2022 (20 412 households), making it one of the municipalities with a comparatively lower population within the West Coast District Municipality. It is projected that the population will increase to 77 713 by 2025 with an average annual growth rate of 1.2% during that period. Females constitute 51.7% of the population and 69.1% of the population are of working age with a dependency ratio of 44.7. The average age is 29 (Statistics SA, 2022).

3.6 Socio-economic context

3.6.1 Human development

The Census Survey 2022 (Statistics SA, 2022) indicates that 30.4% of the population completed matric and 10.3% obtained higher education. School attendance is around 61.8% (Statistics SA, 2022). There are 20 schools in the municipality and the matric outcomes dropped from 85.7% in 2018 to 77.6% in 2019 and remained unchanged in 2020. This is the lowest rate in the district.

In terms of health, child health has improved since 2014 although the immunisation rate remains relatively low. The number of malnourished children has deteriorated since 2019 and the neo-natal mortality rate worsened over this period. The number of patients receiving antiretroviral treatment increased between 2019 and 2021 but the number of new patients has decreased. All clinics and ambulances that fall under Bergrivier Municipality are managed by the Western Cape Government's Department of Health and Wellness. In the Bergrivier Municipal Area, there are 3 primary healthcare facilities, which comprise of 3 fixed clinics with 7 mobile/satellite clinics (WCG, 2021), along with 2 district hospitals. Emergency medical services, including 5 ambulances, are provided by the Western Cape government known as Medical Emergency Transportation and Rescue Operations (METRO), offering various rescue options (land, air, and sea) to the public.

The average annual household income is R57 300, which is about double that of the West Coast (Statistics SA, 2011). On the other hand, the average annual income is R30 000 which is about the same as the West Coast. Fifty six percent of the population is employed with 83% being employed in the formal sector. The GDP per capita in Bergrivier was R54 210 in 2014 and this increased to R66 770 in 2020. The Gini coefficient which indicates income inequality—in Bergrivier, has steadily increased from 0.55 in 2014 to 0.6 in 2020 (WCG, 2021).

Overall, the Human Development Index for Bergrivier, which is a composite indicator reflecting education levels, health, and income, has increased from 0.67 in 2014 to 0.74 in 2020. This indicates that human development in the municipality has improved.

3.6.2 Service delivery

The majority of households in the Bergrivier Municipality reside in formal dwellings (91.6%), whilst 8.4% of the households reside in either informal, traditional, and other dwellings (Statistics SA, 2022). The number of formal dwellings in Bergrivier increased between 2011 and 2016 at an average annual rate of 2.9% which translates into approximately 459 additional formal dwellings per year. Key challenges relate to the scarcity of suitable land for housing and high cost of bulk and services infrastructure (BM, 2019). The percentages shown in Figure 12 indicate the water and electricity service access levels in the Bergrivier Municipality were higher or at the same level as access to formal dwellings.

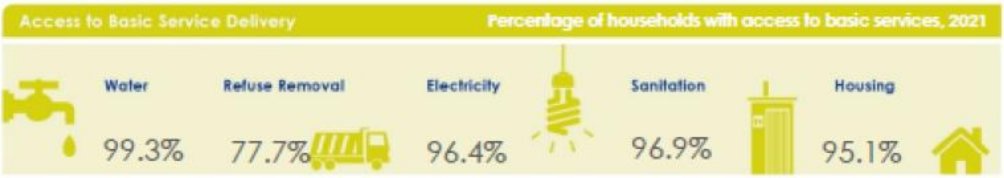


Figure 12: Water and electricity service access levels in the Bergrivier Municipality.

Access to a flush toilet was at 96.9% and the removal of refuse at least weekly by the local municipality stood at 77.7% of households (Statistics SA, 2022). Due to the exacerbated economic pressures on household income levels, the Bergrivier Municipality provides a package of free basic services to households that are financially vulnerable (DEA&DP, 2021).

3.6.3 Transport sector

The primary road network in the Bergrivier Municipality is made up of a National Road (N7) which runs in a north-south direction through the municipality, and this carries approximately 4000 vehicles daily. Additionally, there are provincial roads such as the R44, R27, R399, R365 and MR527 which link different towns within the municipality to one another. The number of vehicles on these roads is between 500 and 1500 vehicles per day (Figure 13). Mini-bus taxis are the dominant mode of public transport in the Bergrivier

Municipal area, primarily due to the flexibility of the mini-bus taxi industry to adapt to the various passenger demands in each town.

There are several stations in Bergrivier (De Hoek, Piketberg, Burgers, Pools, Eendekuil, Droeryskloof, Het Kruis) that form part of the Transnet Freight Rail line which runs from Bellville via Kalbaskraal to Bitterfontein in the north. Velddrif is the only town in the Bergrivier municipal area that has a small port, which is mostly used for fishing and recreational purposes. There are no commercial airports (BM, 2019).

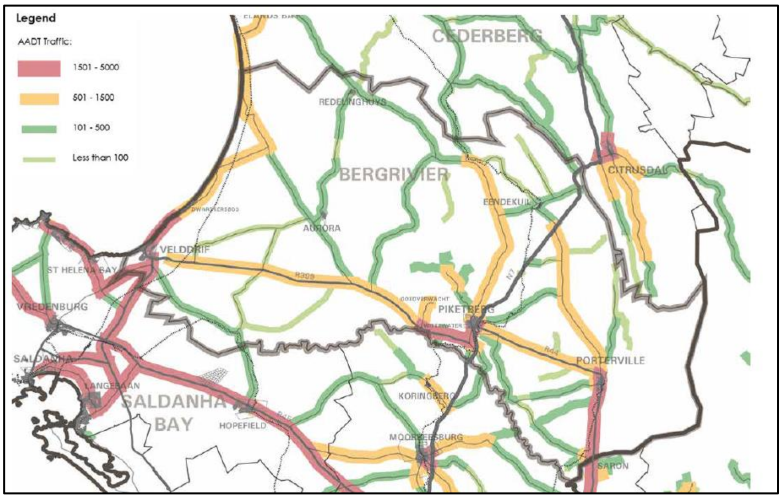


Figure 13: Annual average daily traffic on key roads in the Bergrivier Municipality (Source: BM, 2019).

3.6.4 Agriculture, Forestry and Fishing sector

The agricultural sector forms a large part of the economic makeup and contributes not only to the primary sector, but also to the secondary (through processing and manufacturing) and tertiary (through the value chain) sectors. This sector contributes 23.2% to the GDPR (WCG, 2021). Agriculture is recognised as the largest employment sector within the Bergrivier Municipality, providing employment for more than half the total labour force (53%).

3.6.4.1 Crops and livestock

Agriculture is the largest of the land uses in Bergrivier Municipality, covering approximately 85% of the land area. Primary agricultural activities include livestock farming (sheep, cattle, and pig), winter grain and fruit farming, with cultivated crops like grapes, watermelons, proteas, waterblommetjies, assorted vegetables and Rooibos as depicted in Figure 14.

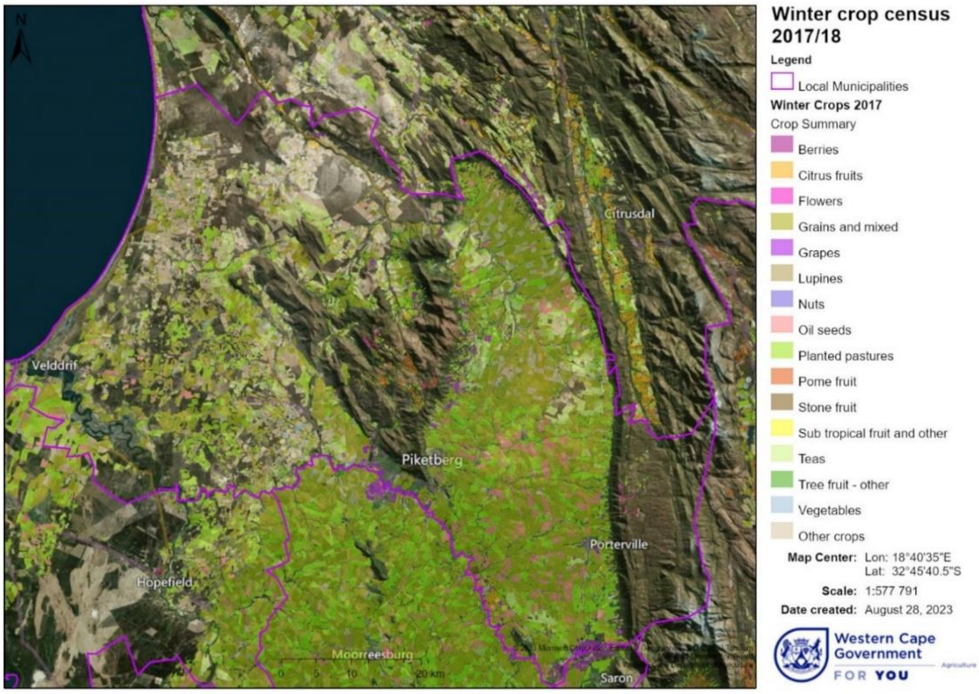


Figure 14: Crop distribution in Bergrivier Municipality based on the winter crop census for 2017/18 (Source: CapeFarmMapper[2]).

In an area like Bergrivier, which experiences low rainfall levels (<500mm per annum), the agricultural potential is largely dependent on the availability of irrigation water (BM, 2019). Dryland agricultural potential is greatest south of Porterville and Piketberg and in the Kliphoek-Redelinghuis area and decreases as one moves towards the coast. The total agricultural area of the Bergrivier Municipality is constituted of 51.2% dryland and 8.7% irrigated (BM, 2019).

There are three main types of agriculture, namely:

- *Large-scale extensive farming:*
    - *Dominant winter grain producing area (between Piketberg and Porterville),*
    - *Farming practices often include a combination of small stock and/or large stock production, and*
    - *Farm sizes are generally large (±1000ha) to counteract climate risk.*
- *Small-scale intensive irrigation enterprises:*
    - *These are found in more mountainous areas (Porterville Mountains, Piket-bo-Berg) and along the Berg River, and*
    - *Production in these areas includes mainly fruit, floriculture (Protea), viticulture and vegetable production.*

[2] *Downloaded from CapeFarmMapper (https://gis.elsenburg.com/apps/cfm/#) on 28 August 2023).*

- *Large-scale irrigation enterprises:*
    - *Sandveld and the Aurora coastal belt*
    - *Mixed farming, with a combination of small stock, strip grain cultivation and centre pivot potato production*
    - *Centre pivot farming is also practiced in the Kliphoek-Driefontein-Redelinghuis area and along the Berg River.*

In the Status Quo Review of Climate Change and Agriculture in the Western Cape Province (DEA&DP, 2016), agro-climatic zones were identified through the aggregation of Relatively Homogeneous Farming Areas (RHFAs)[3] based on climatic, vegetative, and productive attributes. Seven of these agro-climate zones fall within the Bergrivier Municipality (Figure 15). The summary of the broad biophysical features and crop/livestock commodities for each of these 7 agro-climatic zones are provided in Table 7.

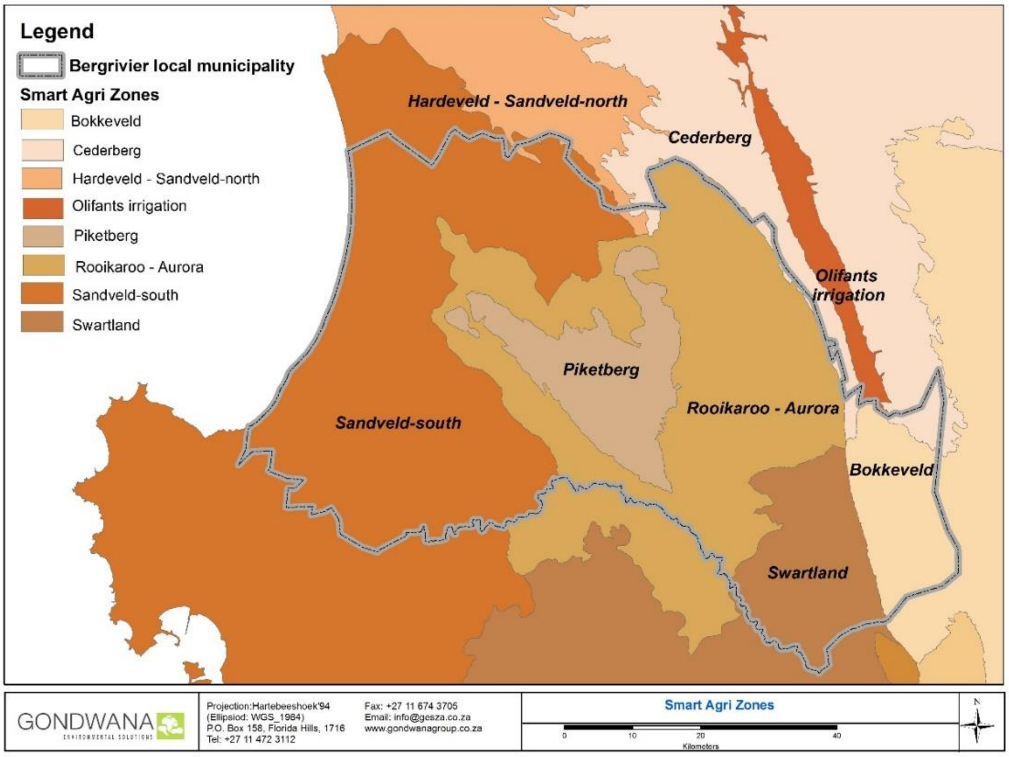


Figure 15: Map of Agro-climatic zones in Bergrivier (Source: picture from BM, 2019, original data from DEA&DP, 2016).

[3] *RHFA are defined as 'Homogeneous Farming Areas' and demarcate areas where the main agricultural activities practiced, or which realistically could be practiced, are common to most farm enterprises; within which the pertinent climate factors do not vary sufficiently to influence production practices and potential. These agri-ecological zones provide an excellent spatial unit for representing the specific agricultural character, current enterprises, and climatic potential of a locality.*

Table 7: Broad biophysical features and crop/livestock commodities for the agro-climate zones found in the Bergrivier Municipality.

Agro-climate zone	Main biophysical features	Main crops	Livestock
Bokkeveld	High altitude plains between mountain ridges	Pome fruit, wheat, stone fruit, onions, potatoes	Cattle
Cederberg	High elevation mountains with valleys	Rooibos, wheat, citrus, wine grapes, stone fruit, vegetables, potatoes, flowers	Cattle
Hardeveld/Sandveld-north	Coastal plains	Wheat, wine grapes, rooibos, potatoes, vegetables	Cattle, sheep
Piketberg	'Island mountain', fertile shale soils	Pears, fynbos flowers, stone fruit, wheat, citrus, herbs/essential oils, wine grapes, Cape rush, rooibos	Cattle, sheep
Rooikaroo-Aurora	Flat dry plains	Wheat, canola, rooibos, table and wine grapes, potatoes, olives, flowers	Cattle, sheep
Sandveld-south	Coastal, sandy infertile soils	Wheat, potatoes, rooibos, canola, citrus, flowers	Cattle, sheep
Swartland	Fertile, and bordered by mountains to the east	Wheat, wine and table grapes, canola, olives, citrus, vegetables, stone fruit, berries, flowers	Cattle, dairy, pigs, sheep

3.6.4.2 Fishing

The Bergrivier Municipality fishing sector, specifically at Laaiplek Harbor, has a diverse range of fresh fish which is readily accessible to both individuals and the local market. This includes not only direct purchases at the harbour but also at local fish shops and markets in the surrounding areas. Moreover, Laaiplek features local factories that engage in fish processing and canning, with a specific focus on fishmeal production. The predominant fish species in this region include mullet, pilchards, round herring, and various types of line fish. Fishing activities in this harbour primary focus on small pelagic fish such as anchovies, pilchards, and round herring. While West Coast Rock Lobster is also landed at the harbour, it is not as prevalent as in other west coast harbours. A notable presence in this sector is Eigevis, a family-owned business that operates two pelagic fishing vessels, docked at the main quay.

The region experiences an abundance of snoek, a popular fish, during the snoek season. Additionally, Bokkom Laan, situated near Laaiplek Harbor in Velddrif, serves as the hub for traditional small-scale net-fishing operations. In response to the prohibition of gillnetting in the estuary in 2003, fishermen now place their nets in the open sea just off Laaiplek, primarily catching mullet/harders. This catch is then dried to produce the renowned local delicacy known as Bokkoms. The largest fishing processing factory in Laaiplek is Marine Products, established in the 1950s (now referred as the Amawandle Pelagic Fish factory). The factory plays a pivotal role in the local economy, employing about 490 seasonal workers and 80 permanent employees.

3.6.5 Mining and Manufacturing

The manufacturing sector contributed 24.8% to the GDPR in 2019 (WCG, 2021). Salt, limestone for cement and sand for building purposes are the three commodities that are currently mined in the Bergrivier Municipality (Bergrivier SDF, 2012-2017). Many of the mines in Bergrivier are not operational (Figure 16).

The following registered mining activities are located within the coastal zone and estuaries in the Bergrivier Municipality (Figure 17):

- *Kliphoek salt works on Farm Kliphoek No 59, an opencast mine, mining salt on the southern bank of the Berg River,*
- *Velddrif Salt Company (Pty) Ltd on Portion 69 of Farm 110, an opencast mine, mining salt, on the southern bank of the Berg River at the southern entrance to Velddrif,*
- *Berg River Salt Works (Cape Salts Pty Ltd) on Farms Kliphoek, Uitkomst and Vlaminke Vlei; an opencast mine mining salt located on the southern bank of the Berg River.*

There is a cement manufacturing company (PPC De Hoek) located near Piketberg, a fishmeal production company, and an incinerator at Voorberg Correctional Facility (BM, 2019b).

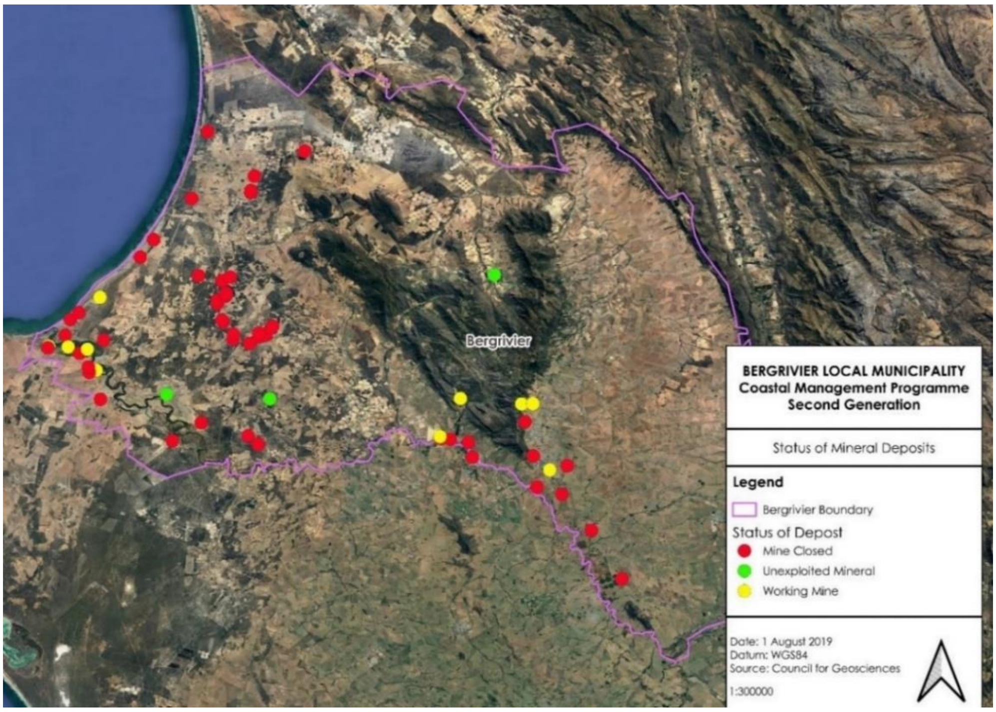


Figure 16: Map of mining activities in Bergrivier (Source: picture from BM, 2019).

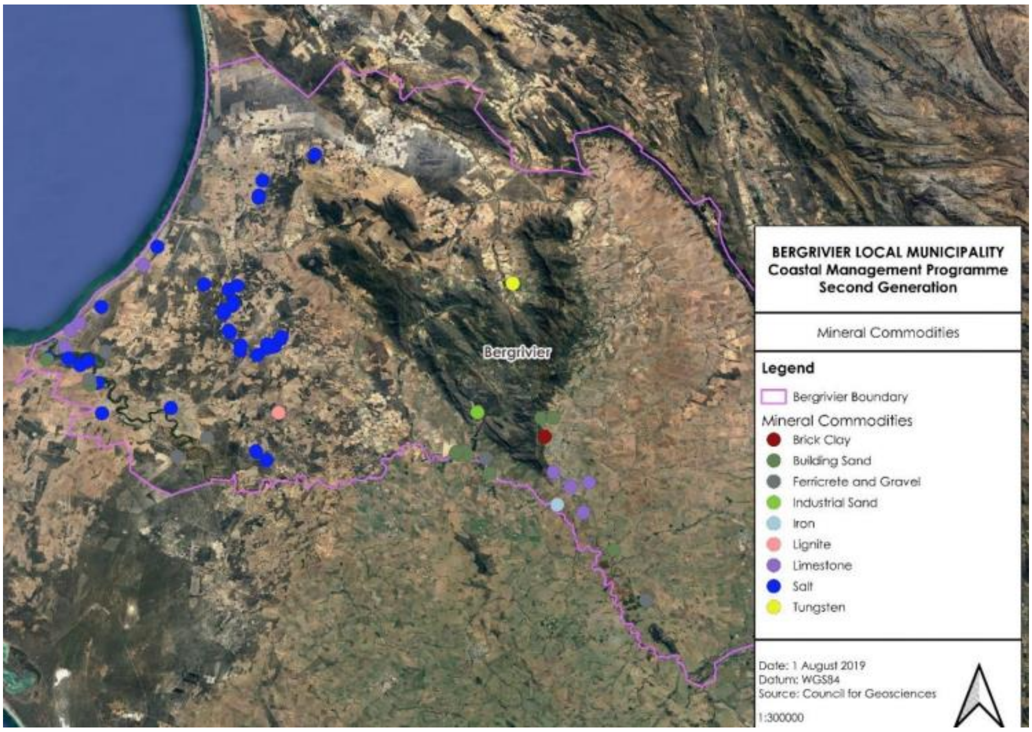


Figure 17: Different mineral commodities or mines located within the Bergrivier Municipality (Source: picture from BM, 2019).

3.6.6 Tourism

The tourism sector in the Bergrivier Municipality possesses distinctive features due to its diverse landscape and environment. It has been identified as a promising economic sector, making it a priority for tourism development in the region. Tourism activities are expected to drive local investment, create employment opportunities, and promote economic growth. However, since the area only attracts tourists seasonally, the prevalence of seasonal, temporary, or part-time jobs and activities has a detrimental effect on the overall potential of an economic boom in the area. This issue is also relevant to seasonal employment in agriculture and fishing.

Several tourism attractions have been identified in the region, including unique floral locations such as Sandvlakte fynbos, West Coast Renosterveld, and Berg-fynbos. Tourism attractions for fauna include the wetland birdlife in the two RAMSAR territories in and around Velddrif. The region also boasts archaeological and paleontological sites, culturally rich historic sites, and well-preserved conservation areas. Velddrif/Laaiplek, which includes Port Owen and Noordhoek—situated along the coast—have seen a significant shift in their economic profile. These towns have transitioned from primarily serving as centres for processing fishing and agricultural products to becoming more service-oriented tourism destinations (MSDF, 2019). Port Owen offers a diverse array of tourist attractions. Known for its picturesque canals and water-based activities, visitors can partake in water sports, boat trips, and even birdwatching, thanks to the region's abundant wetland birdlife.

There are various tourism routes in the Bergrivier towns, including the flower route between Velddrif and Piketberg, which also serves as the culture route. The adventure route covers all minor and dirt roads, with destinations in Aurora, Redelinghuis, Dwarskersbos (R27), Eendekuil, and Porterville. Additionally, the bird route runs along the coast (R27). It is anticipated that most of the future tourism growth in the Bergrivier municipal area will focus on Velddrif, Laaiplek, and Dwarskersbos (Bergrivier SDF, 2012-2017).

3.6.7 Waste

Bergrivier has wastewater treatment works (WWTW) at Dwarskersbos, Eendekuil, Piketberg, Porterville and Velddrif (BM, 2022b)—those at Velddrif and Dwarskersbos are within the coastal zone (WCDM, 2019).

The primary refuse removal service involves billing the residents monthly for waste collection. All residences within urban areas receive weekly refuse removal services, except for Goedverwacht and Wittewater, who have their own refusal removal. Businesses have separate days for their waste removal and miscellaneous waste is collected upon request. The collected refuse is then taken to the refuse transfer centres located in Piketberg, Eendekuil, Redelinghuis, Porterville and Aurora from where it is transported to the Highlands landfill near Malmesbury (BM, 2022). Waste from the Velddrif Transfer Station is disposed of at the Vredenburg landfill site.

According to the Integrated Development plan of Bergrivier Municipality (Review 2023/24), the Department of Environmental Affairs and Development Planning (DEA&DP) granted closure permits for previously used landfill sites, with support from the Department of Forestry, Fisheries, and the Environment. Rehabilitating old landfill sites in Aurora, Redelinghuis, Piketberg, and Porterville is a substantial challenge due to an estimated cost of approximately R85 million. Unfortunately, the municipality lacks the financial reserves for this undertaking but considers it a top priority and is seeking external funding. The closure and rehabilitation of the Velddrif site is part of a land exchange where the new owner will cover the rehabilitation expenses. Additionally, the municipality requires funding to establish drop-off points in Dwarskersbos, Redelinghuis, and Eendekuil for the community to safely dispose of excess household waste. However, securing funding for both initiatives, especially the old landfill site rehabilitation, remains problematic due to the high associated costs.

4 HISTORICAL AND PROJECTED CLIMATE TRENDS

4.1 Historical Climate Trends

4.1.1 Western Cape

Historical climate trends for the Western Cape Province were assessed in a report by Jack (2022) which provided updated climate data for the SmartAgri Status Quo Review (DEA&DP, 2016). In this study the outputs from a variety of climate models (CRU TS-4.05, CHIRPS, GPCC, and ECMWF ERA5-Land) were analysed and the main findings are presented here. The data assessed is made up of the SmartAgri zones that are described in section 3.5.4 above as these zones show differences in terms of climatic, vegetative, and productive attributes (Figure 18).

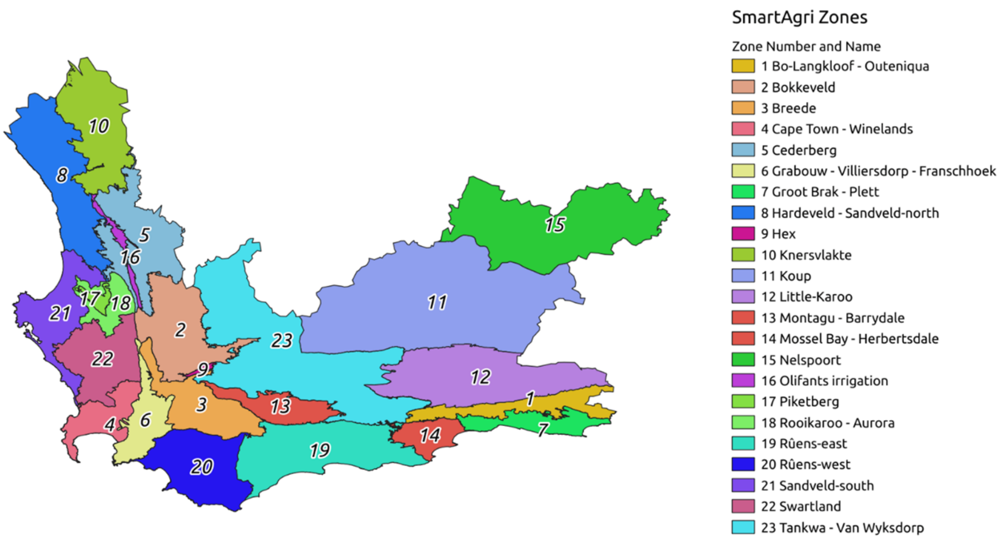


Figure 18: The 23 primary SmartAgri zones used for the climate analysis (Source: DEA&DP, 2016).

4.1.1.1 Temperature

Spatial patterns in historical (1902-2020) mean seasonal daily minimum and maximum temperatures show the coastal-to-inland gradient with minimum temperatures being lower inland than at the coast, but with maximum temperatures being higher inland than at the coast (Figure 19). When considering the century scale temperature trends (^{o}C/decade), it is evident that temperatures have consistently increased over the past century at around 0.1^{o}C/decade (close to the global mean). The trends in daily maximum temperatures are highest during autumn (MAM[4]) and spring (SON[5]). An assessment of the seasonal trend in the average number of frost days—where minimum temperature is less than 0^{o}C—

[4] March-April-May
[5] September-October-November

shows that there is a reduction in the number of frost days; a reduction which can be as high as 30% (3 days per season).

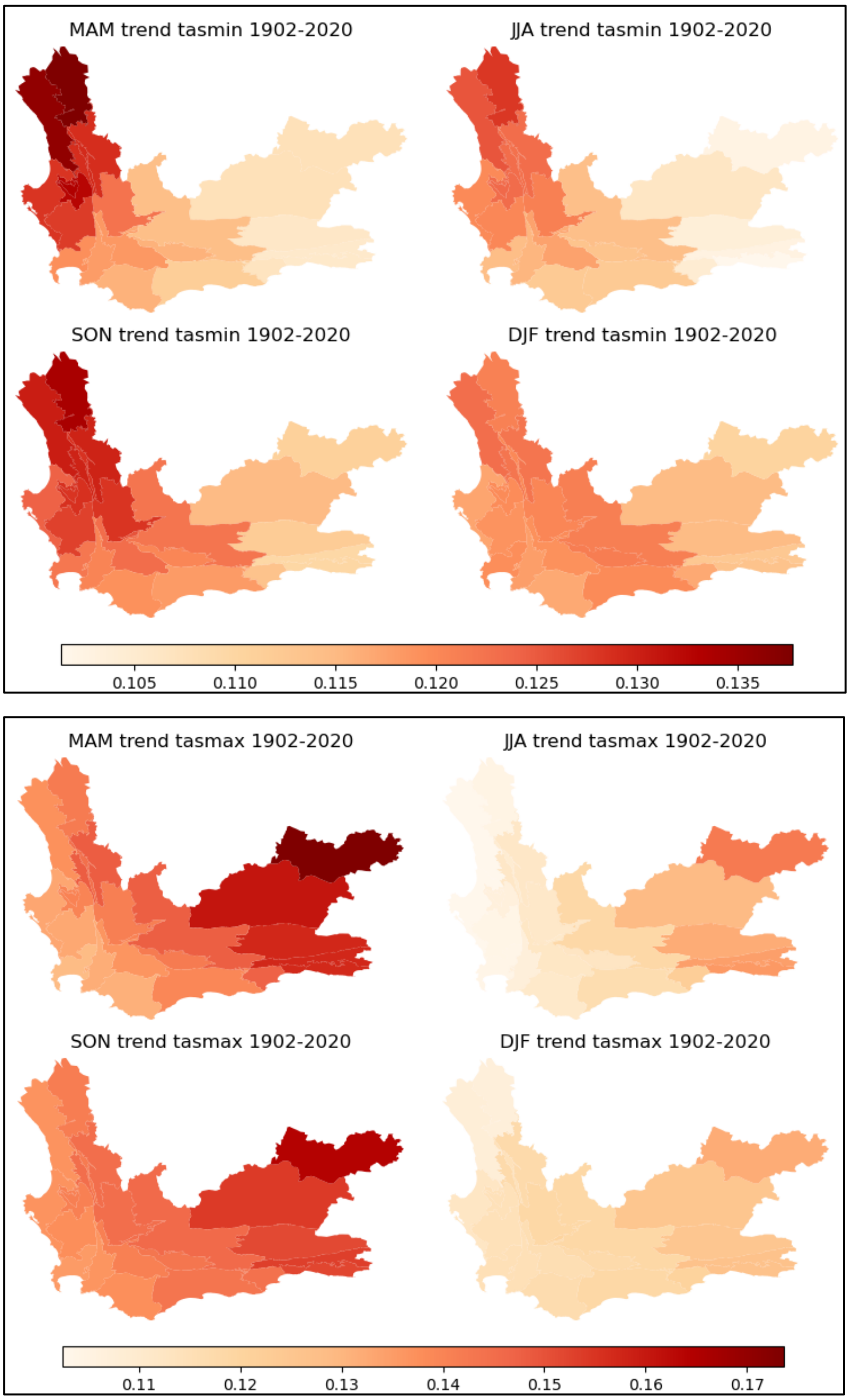


Figure 19: Mean seasonal daily minimum (top) and maximum (bottom) temperature trends (ºC/decade) across the Western Cape Province based on CRU TS4.05 dataset from 1902-2020 (Source: Jack, 2022).

4.1.1.2 Rainfall

An analysis of the historical rainfall data clearly shows that the Western Cape predominantly experiences winter rainfall, with some summer rainfall occurring in the far north-eastern zones (Figure 20). Trends in seasonal rainfall (mm/decade) are strongest during autumn and show a drying trend with rainfall decreasing by up to 18mm/decade in the central regions. The trends in intense rainfall events very closely follows the mean precipitation, i.e., high rainfall intensity generally occurs in wetter areas. Trends in consecutive dry days are largely insignificant, except for a negative trend during the SON period.

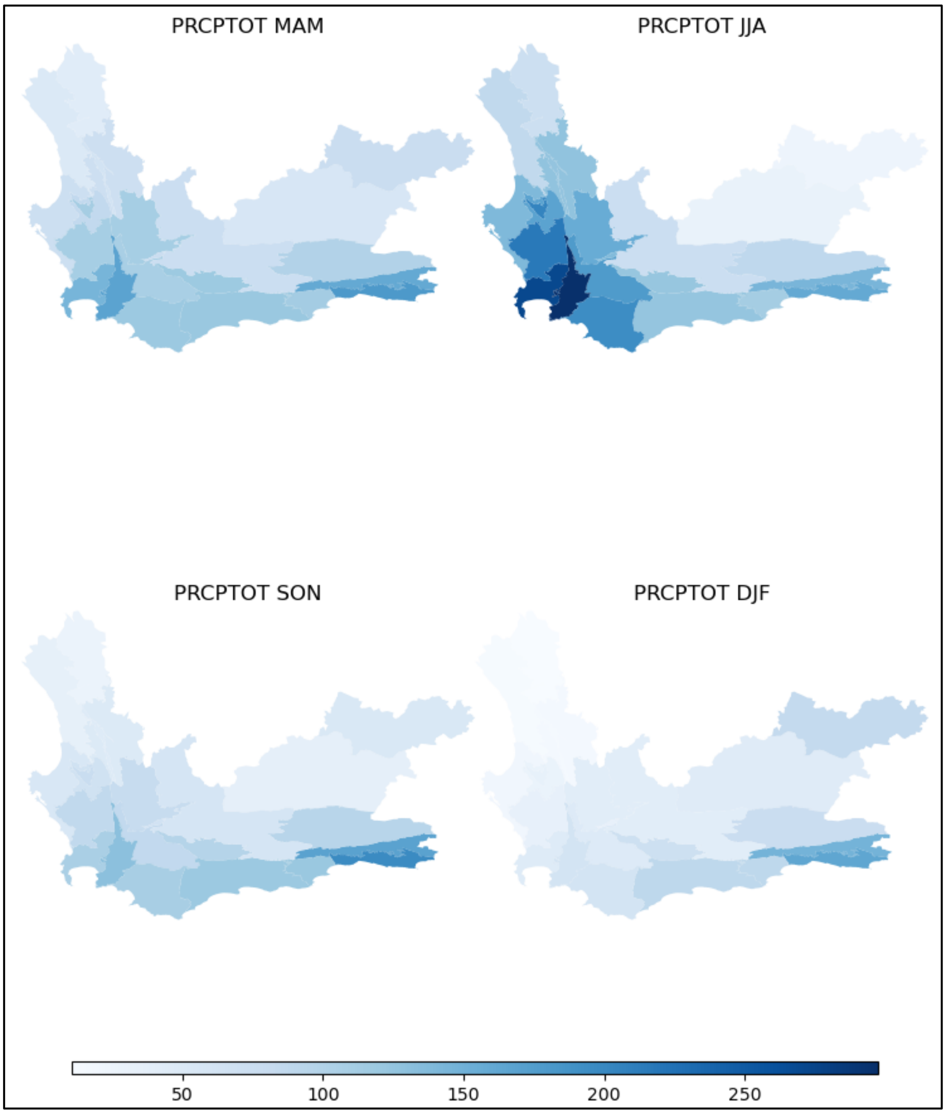


Figure 20: The seasonal total rainfall (mm) across the Western Cape based on CHG CHIRPS merged rainfall product over the period 1983-2020 (Source: Jack, 2022).

4.1.1.3 Evapotranspiration trends

Potential evapotranspiration (PET), which assumes unlimited moisture availability, is clearly strongest during the core summer months (DJF[6]). In many areas evapotranspiration would be limited by soil moisture and therefore actual evaporation is likely higher during spring than mid-summer. Positive trends in PET are mainly driven by significant temperature increases and are shown to be highest in the most southern and the most western zones, while being strongest in spring (SON) and summer (DJF).

4.1.2 Bergrivier Municipality

The figures below (Figure 21 to Figure 27) highlight some historical trends in the climate of the Bergrivier Municipality. A summary of historical climate in Bergrivier Municipality is provided in Table 8.

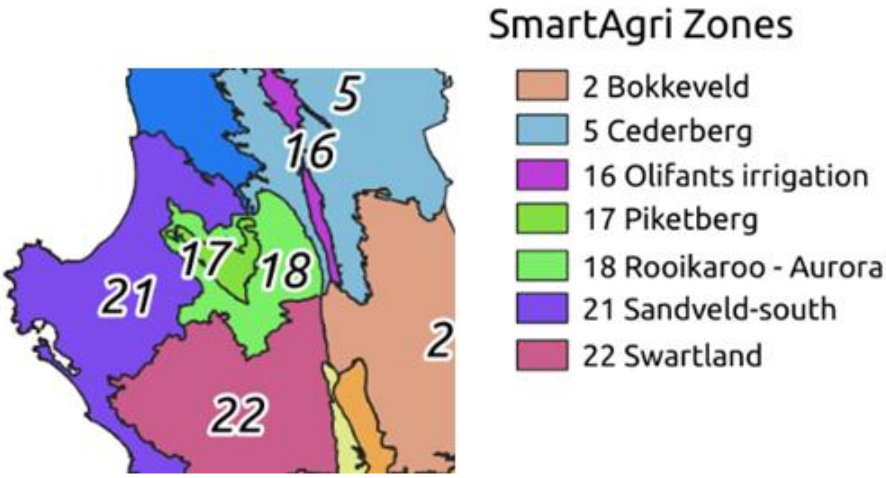


Figure 21: SmartAgri zones found in the Bergrivier Municipality region and on which the analysis below is based (Source: modified from DEA&DP, 2016).

[6] December-January-February

4.1.2.1 Temperature

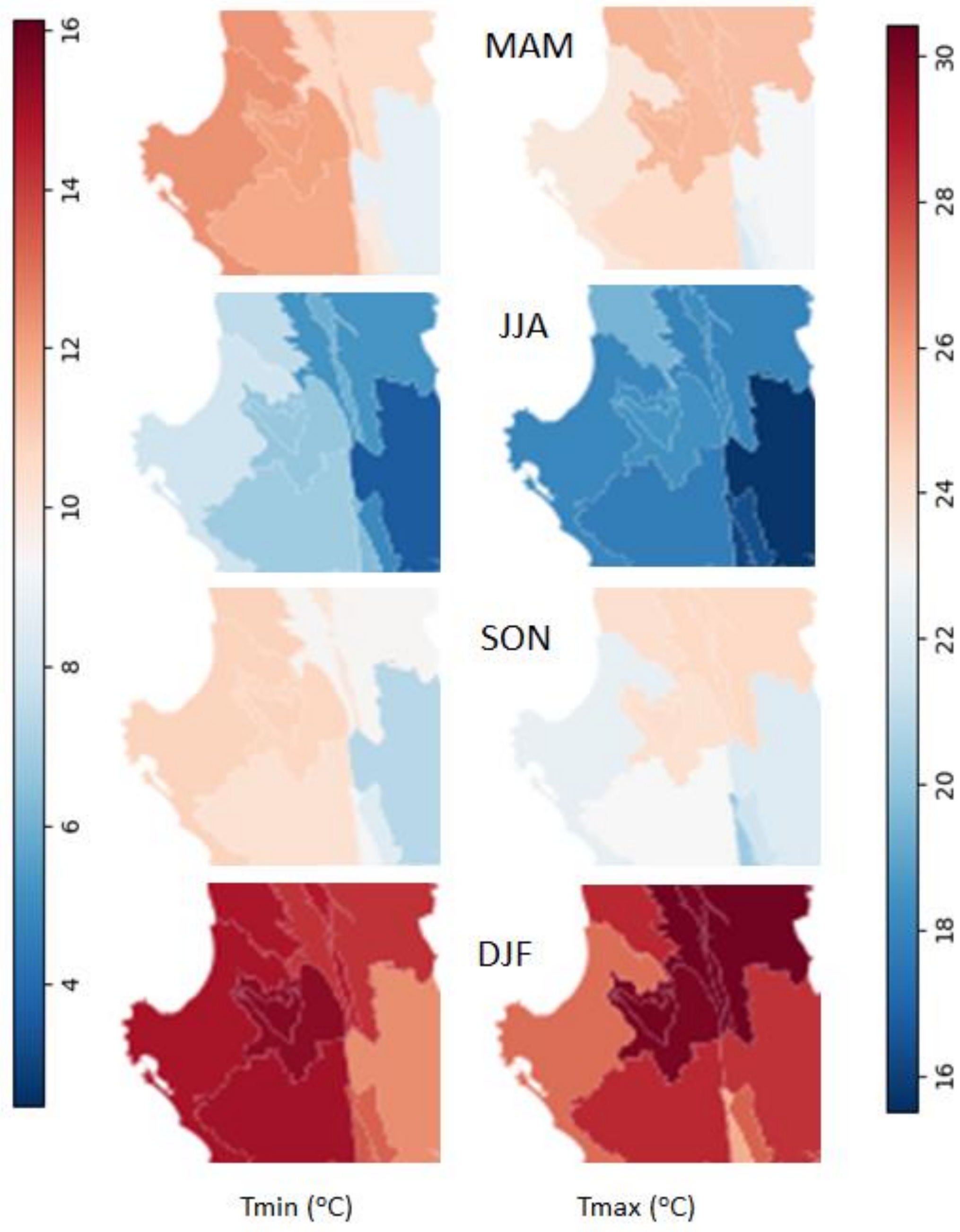


Figure 22: Mean seasonal daily temperatures across the Bergrivier Municipality region based on the CRU TS4.05 dataset from 1902-2020 (Source: Jack, 2022).

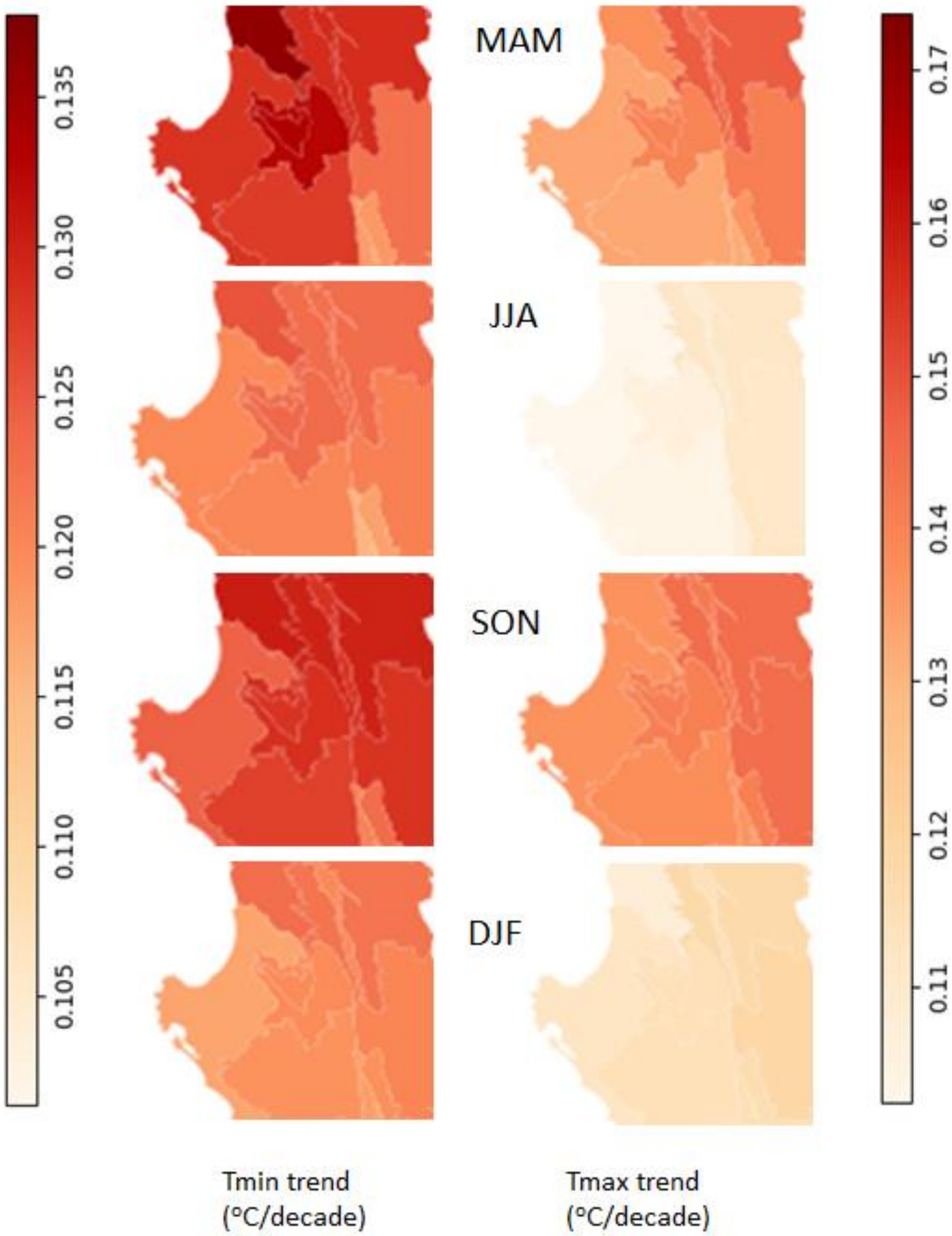


Figure 23: Mean seasonal daily maximum trends (°C/decade) across the Bergrivier Municipality region based on the CRU TS4.05 dataset from 1902-2020 (Source: Jack, 2022).

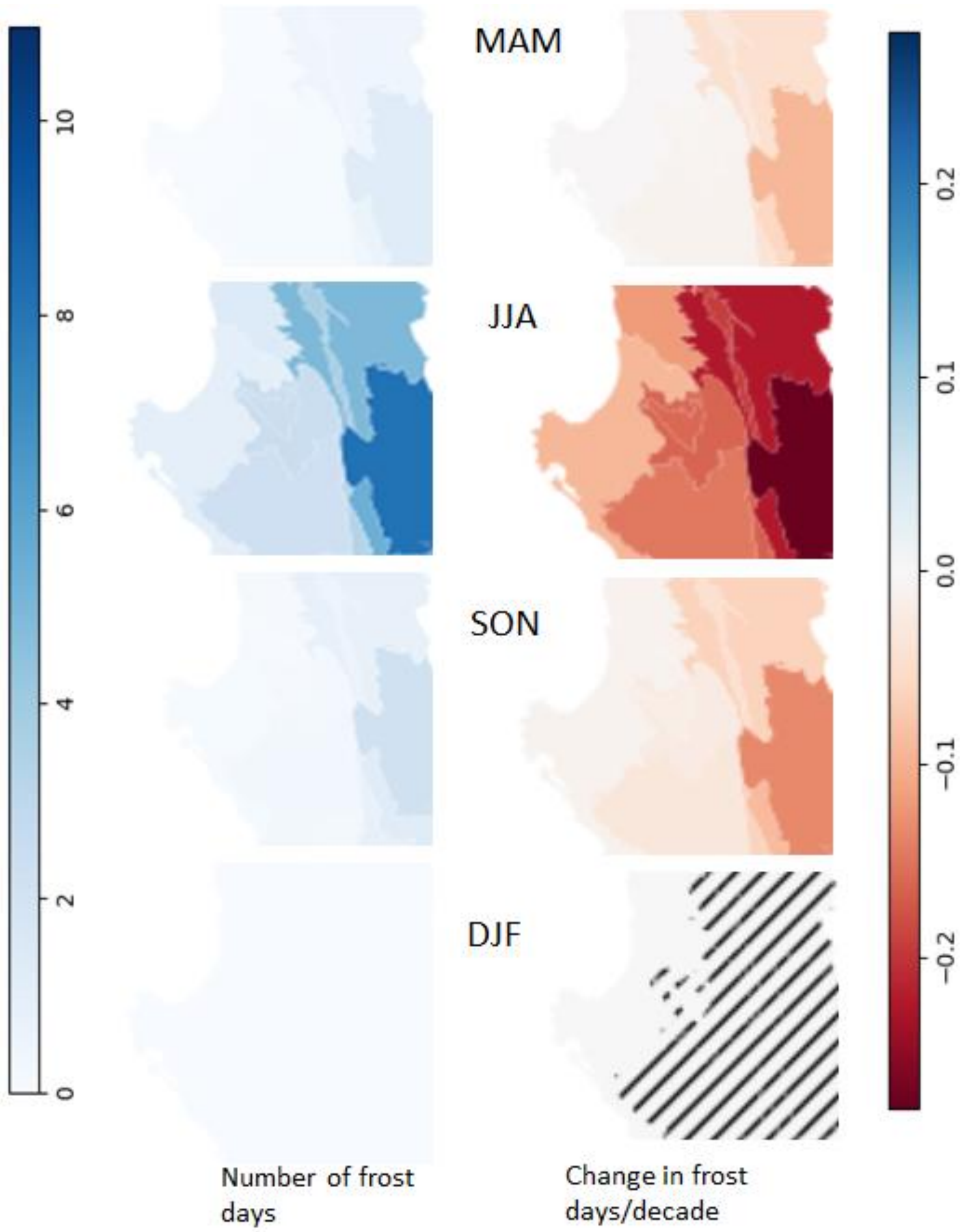


Figure 24: Number of frost days and the trends in frost days in the Bergrivier Municipality region based on CRU TS4.05 observations over the period 1902-2020 (Source: Jack, 2022). Diagonal hashing indicates no significant difference with a p-value threshold of 0.05.

4.1.2.2 Rainfall

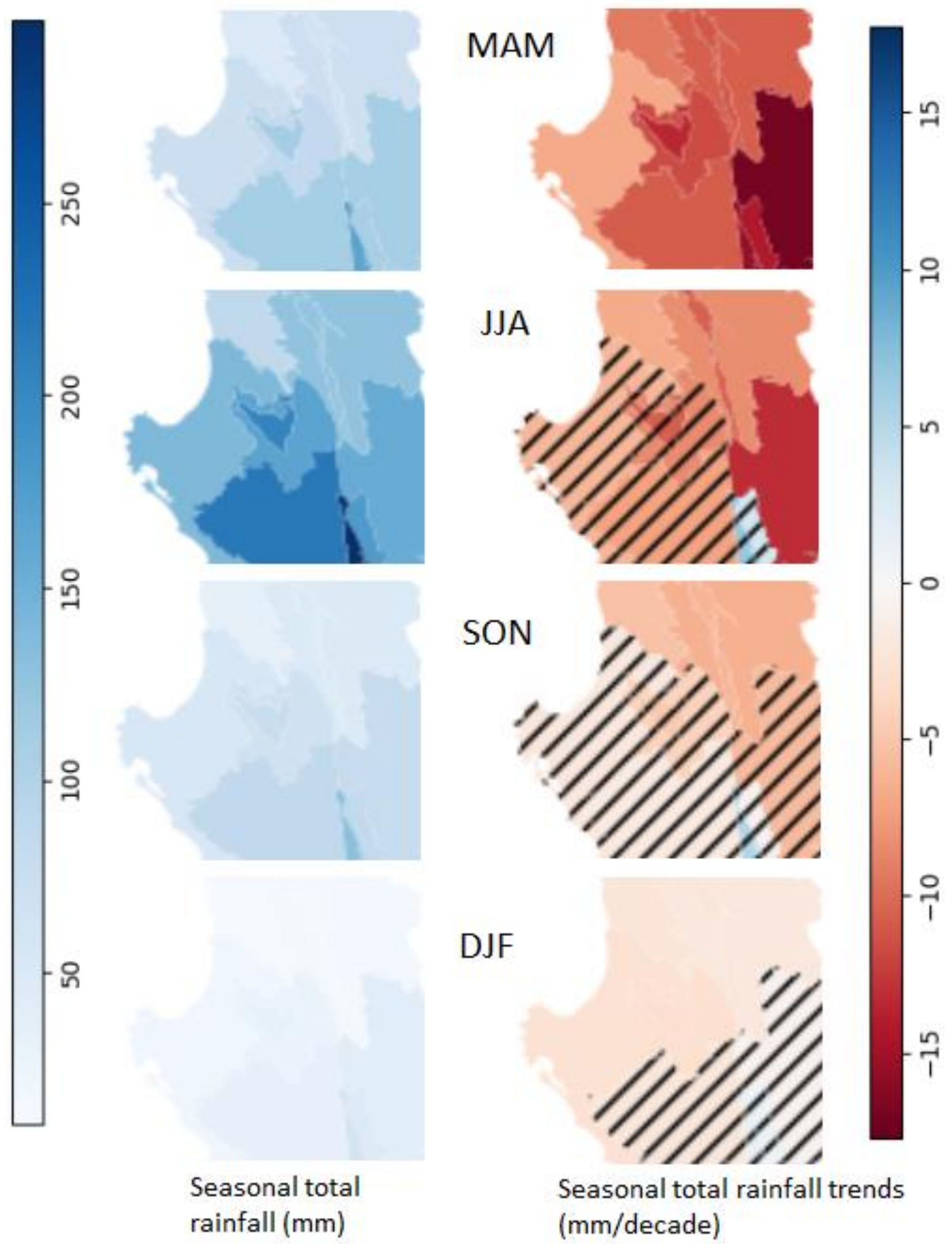


Figure 25: Seasonal total rainfall and trends in seasonal rainfall based on CHG CHIRPS merged rainfall product over the period 1982-2020 (Source: Jack, 2022). Diagonal hashing indicates no significant difference with a p-value threshold of 0.05.

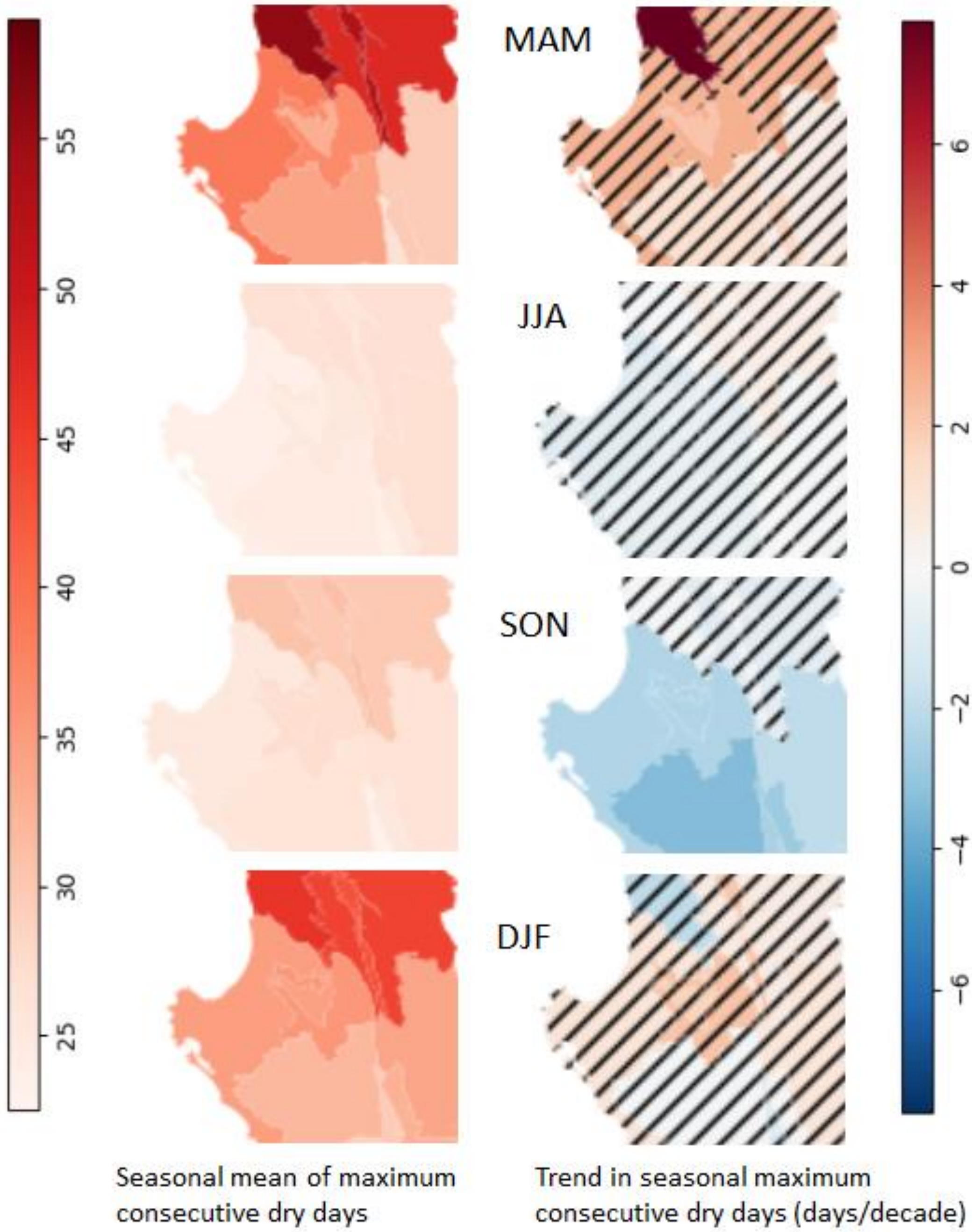


Figure 26: Seasonal maximum consecutive dry days and the trends per decade across the Bergrivier municipal region based on the CHG CHIRPS merged rainfall product over the period 1983-2020 (Source: Jack, 2022). Diagonal hashing indicates no significant difference with a p-value threshold of 0.05.

4.1.2.3 *Evapotranspiration*

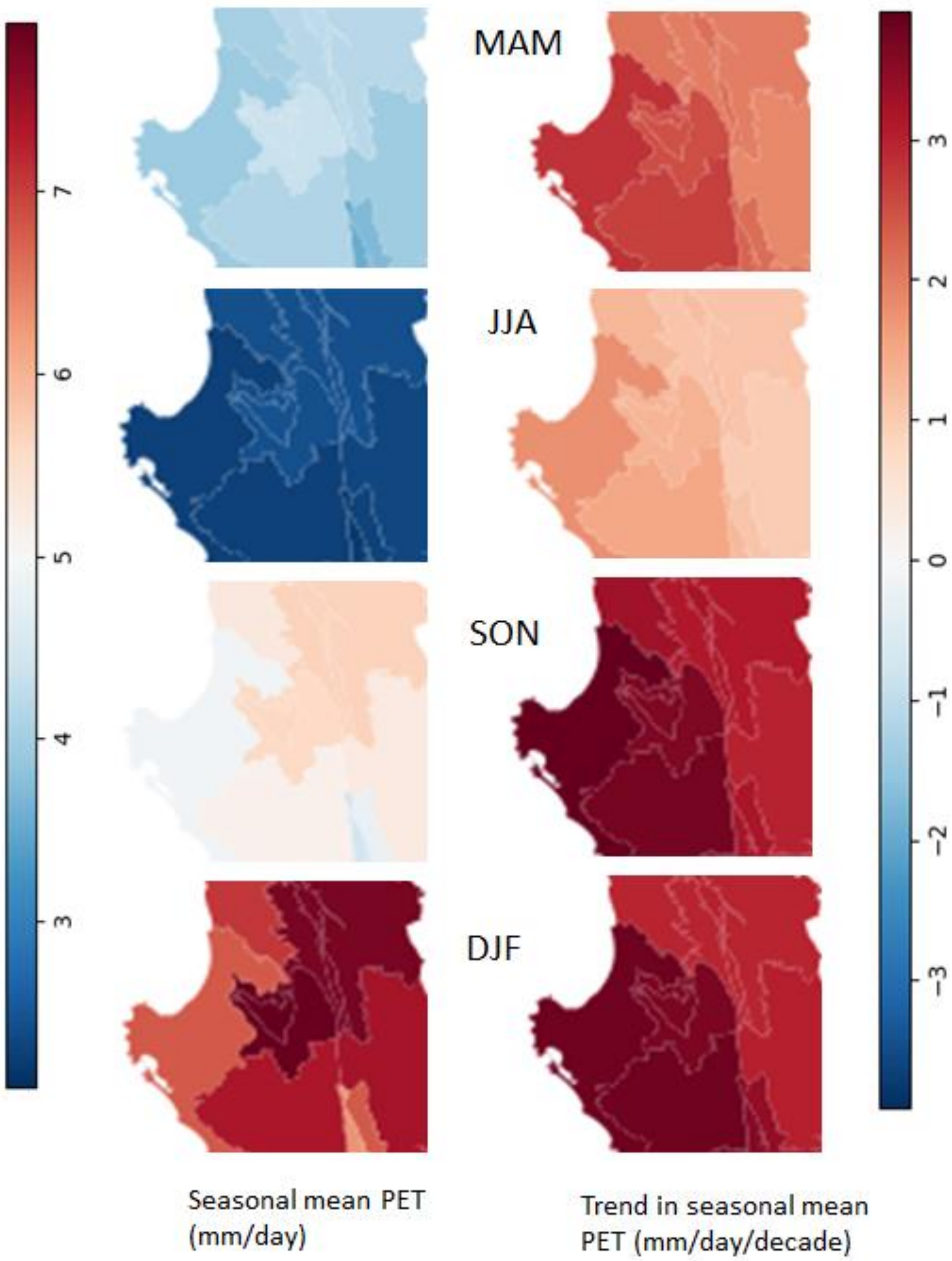


Figure 27: Seasonal mean potential evapotranspiration (PET) and the trends in PET per decade across the Bergrivier municipal region based on the CRU TS4.05 dataset over the period 1902-2020 (Source: Jack, 2022).

Table 8: Summary of historical climate in Bergrivier Municipality

<table>
<tr><th>Factor</th><th>Seasonal results</th><th>Decadal seasonal trend results</th></tr>
<tr><td>Minimum temperature</td><td>• Temperatures generally higher at the coast and decline towards the eastern interior regions of Bergrivier Municipality, except in DJF where minimum temperatures are higher in the inland regions</td><td rowspan="2">• Increased more during spring and autumn than in core summer and winter seasons.
• The regions around Piketberg (AgriSmart zones 17/18) appear to have the highest increases of all regions in Bergrivier Municipality</td></tr>
<tr><td>Maximum temperature</td><td>• Generally lower at the coast, but also lower in the Bokkeveld region around Porterville.
• The regions around Piketberg (AgriSmart zones 17/18) are always (in all seasons) warmer than the surrounding regions</td></tr>
<tr><td>Number of frost days</td><td>• Minimal in Bergrivier Municipality except in JJA where there are around 2 days at the coast; this increases to around 8 days in the Bokkeveld region around Porterville</td><td>• Decreased across the region with highest decreases in JJA.
• Largest declines (up to 25% in JJA), in the Bokkeveld region around Porterville</td></tr>
<tr><td>Rainfall</td><td>• Bergrivier Municipality receives around 140mm – 205 mm in JJA and almost no rain in summer.
• The Piketberg region has the highest rainfall</td><td>• The region shows a decline in seasonal rainfall in all seasons.
• A significant decline (10-15mm per decade) is seen in winter in the Bokkeveld region.
• Biggest declines across the entire Bergrivier Municipality are seen in MAM with the decline increasing from the coastal areas to the Bokkeveld region.
• Declines of 5-10 mm/decade are seen in DJF</td></tr>
<tr><td>Consecutive dry days</td><td>• Maximum consecutive dry days occur in MAM, followed by DJF</td><td>• Over the decades the number of consecutive dry days has been decreasing by 2-4 days/decade in the Piketberg region in MAM
• No significant changes in JJA and DJF
• Number of consecutive dry days has been declining across Bergrivier Municipality in SON</td></tr>
<tr><td>Potential evapotranspiration</td><td>• Lowest in JJA and highest in DJF
• Seasonal mean PET always highest in the Piketberg (AgriSmart zones 17/18) region</td><td>• PET has been increasing in all seasons with the highest increases in SON and DJF.
• The increases show a gradient across Bergrivier Municipality with the highest increases at the coastal area and declining towards the inland regions.</td></tr>
</table>

4.2 Climate Projections

There are many different scenarios for future projections on climate change. In this report data is taken from Jack (2022) in which the CMIP6 SSP scenarios were investigated. The Shared Socioeconomic Pathways (SSP) narratives are descriptions of how the future might unfold in terms of broad societal trends. By describing major socioeconomic, demographic, technological, lifestyle, policy, institutional and other trends, the narratives add important context for a broad user community to better understand the foundation and meaning of the quantitative SSP projections (Riahi et al., 2017). The various SSP narratives are given in Table 9. The data discussed in this report utilises the SSP2 4.5 (middle of the road) and SSP5 8.5 scenarios, as shown in Table 9 and Figure 28.

Table 9: Summary of the SSP narratives (Source: Riaha et al., 2016).

Name	Scenario type	Narrative
SSP1	Sustainability	The world shifts gradually, but pervasively, toward a more sustainable path, emphasising more inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader emphasis on human well-being. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Consumption is oriented toward low material growth and lower resource and energy intensity.
SSP2	Middle of the road	The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceeds unevenly, with some countries making relatively good progress while others fall short of expectations. Global and national institutions work toward, but make slow progress in, achieving sustainable development goals. Environmental systems experience degradation, although there are some improvements, and overall, the intensity of resource and energy use declines. Global population growth is moderate and levels off in the second half of the century. Income inequality persists or improves only slowly and challenges to reducing vulnerability to societal and environmental changes remain.
SSP3	Regional rivalry	A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. Policies shift over time to become increasingly oriented toward national and regional security issues. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Investments in education and technological development decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time. Population growth is low in industrialised and high in developing countries. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions.
SSP4	Inequality	Highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both across and within countries. Over time, a gap widens between an internationally connected society that contributes to knowledge- and capital-intensive sectors of the global economy, and a fragmented collection of lower-income, poorly educated societies that work in a labour intensive, low-tech economy. Social cohesion degrades and conflict and unrest become increasingly common. Technology development is high in the high-tech economy and sectors. The globally connected energy sector diversifies, with investments in both carbon-intensive fuels like coal and unconventional oil, but also low-carbon energy sources. Environmental policies focus on local issues around middle- and high-income areas.
SSP5	Fossil-fuel development	This world places increasing faith in competitive markets, innovation, and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. Global markets are increasingly integrated. There are also strong investments in health, education, and institutions to enhance human and social capital. At the same time, the push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy, while global population peaks and declines in the 21st century. Local environmental problems like air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including geo-engineering, if necessary.

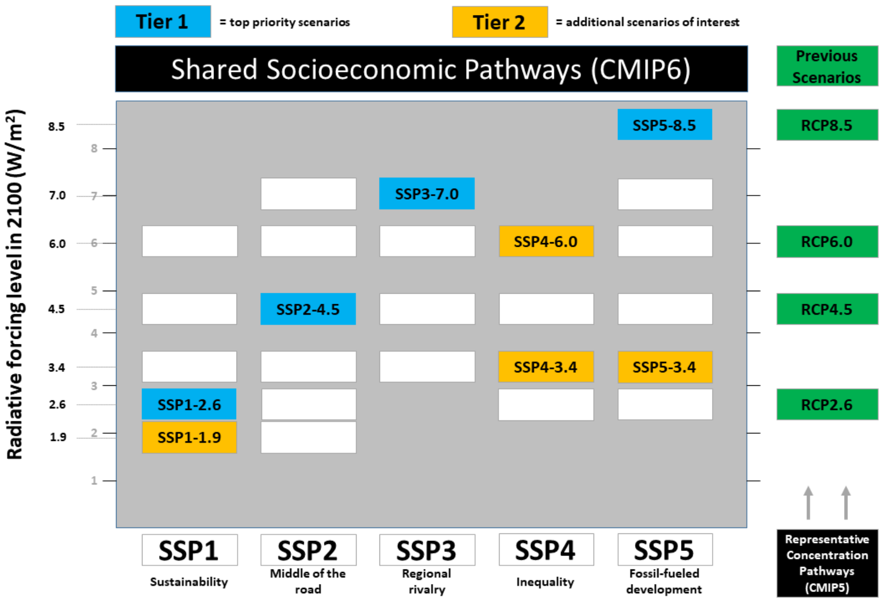


Figure 28: SSP-RCP scenario matrix illustrating scenario simulations (Source: Government of Canada website[7] which was an adaptation of O'Neill et al., 2016).

4.2.1 Western Cape

The SSP2 4.5 pathway (based on shared socioeconomics) represents a moderate global response to climate change. Based on this scenario the key findings from Jack (2022) for the Western Cape are:

Temperature indices:

- *Temperatures are expected to significantly rise over the next few decades and beyond in all SmartAgri zones. By 2060, mean temperature increases of 1°C to 1.8°C are projected compared to the recent past (1981-2010).*
- *Some SmartAgri zones, especially those farther from the coast, may experience even higher increases, with projections reaching up to 2°C.*
- *Mean daily minimum temperatures (night-time temperatures), are also expected to increase, particularly in inland zones like Nelspoort, where increases may reach as high as 2.7°C.*
- *These temperature increases lead to more hot days, with the number of days exceeding 30°C expected to increase, ranging from as few as five to as many as 30 more days per year in inland zones.*

[7] https://climate-scenarios.canada.ca/?page=cmip6-overview-notes

Rainfall indices:

- *Projections related to rainfall changes exhibit uncertainty. Some models foresee minimal reductions in rainfall, while others project up to a 20% reduction in annual rainfall averaged over the province.*
- *Most SmartAgri zones show projections of decreased summer rainfall, but these changes may not always be statistically significant. Natural variability plays a role in these projections.*
- *Some zones and seasons may experience statistically significant rainfall reductions of up to 40%.*
- *Certain zones, like Nelspoort and adjacent Koup zones, exhibit high uncertainty due to their transitional location between different rainfall dynamics.*

Evaporation and drought indices:

- *Projected potential evapotranspiration (PET) increases consistently across all zones, driven by rising temperatures.*
- *The frequency of drought events, determined by indices like SPI and SPEI, is expected to increase, with SPEI-based droughts showing more rapid increases due to temperature-driven evaporation.*
- *In some clustered zones, a 1-in-10 drought event under current conditions is projected to become a 1-in-2 event by mid-century, influenced by increased evaporation.*

4.2.2 ***Bergrivier Municipality region***

In Jack (2022), several projection models were used with a variety of outputs. To simplify, four "archetype" models were identified (Table 10), which broadly represent the range of projected temperature and rainfall. The climate projections in this section discuss the climate predictions for the Bergrivier region in terms of these four archetypes.

Table 10: Archetype models and their provincial scale projection description (Source: Jack, 2022).

Archetype model name	Provincial scale projection
MPI-ESM1-2-LR	Almost no rainfall change, low magnitude temperature increase (~1.2°C)
TaiESM1	High temperature increases (~2.4°C), large rainfall reduction
GFDL-CM4	Moderate temperature increases (~1.7°C), large rainfall reduction
EC-Earth3	Moderate temperature increases (~1.7°C), mixed spatial pattern of rainfall change (increases in Nelspoort region, decreases elsewhere)

4.2.2.1 Temperature

Projected mean annual maximum daily temperature from three of the archetypes[8] shows that temperatures across the region are expected to increase, with this increase possibly being between 1.18ºC and 1.56ºC. These projected changes, even at the seasonal level, are significant for the SSP2 8.5 scenario (Figure 29). The mean annual minimum daily temperature is also expected to increase, with the three models showing increases of 0.93ºC to 1.41ºC. The mean annual daily temperature shows an increase of between 1.03ºC and 1.43ºC. Generally, the increase is slightly lower in the Sandveld-south region which is closer to the coast. Mean annual consecutive dry days are shown in three models to increase by 0.26 to 2.6 days, whilst one model shows a decline of 0.4 days in the central regions. Generally, the increase in consecutive dry days is highest in DJF, followed by MAM. These changes are, however, not shown to be significant.

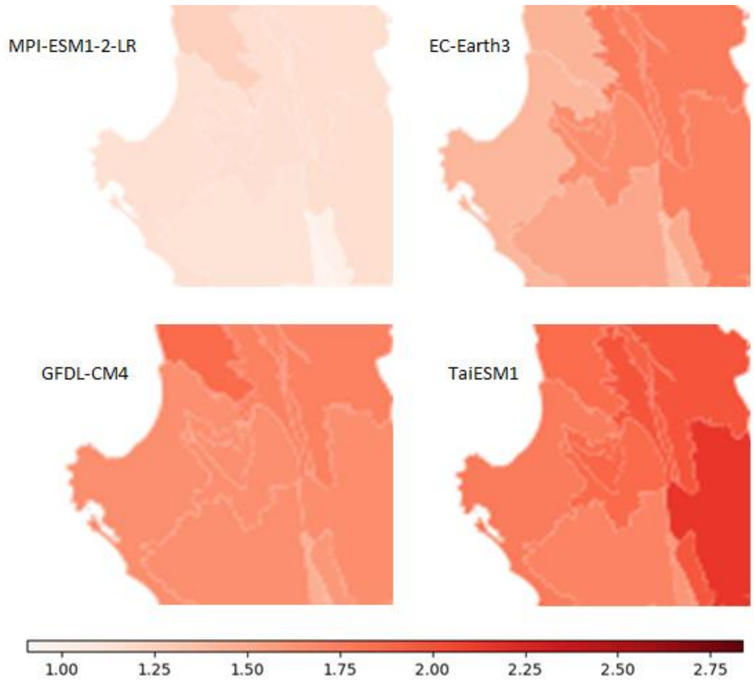


Figure 29: Projected changes in annual mean temperature (ºC) across Bergrivier Municipality derived from the CMIP6 model ensemble SSP5 8.5 pathway for the period 2030-2060 for the four archetype models.

4.2.2.2 Rainfall

Projected annual total rainfall (mm) is estimated across the 4 archetype models to decline by between 4.6mm and 21.99mm. Again, these changes are not shown to be significant (Figure 30).

[8] TaiESM1 model did not give changes in minimum and maximum temperatures.

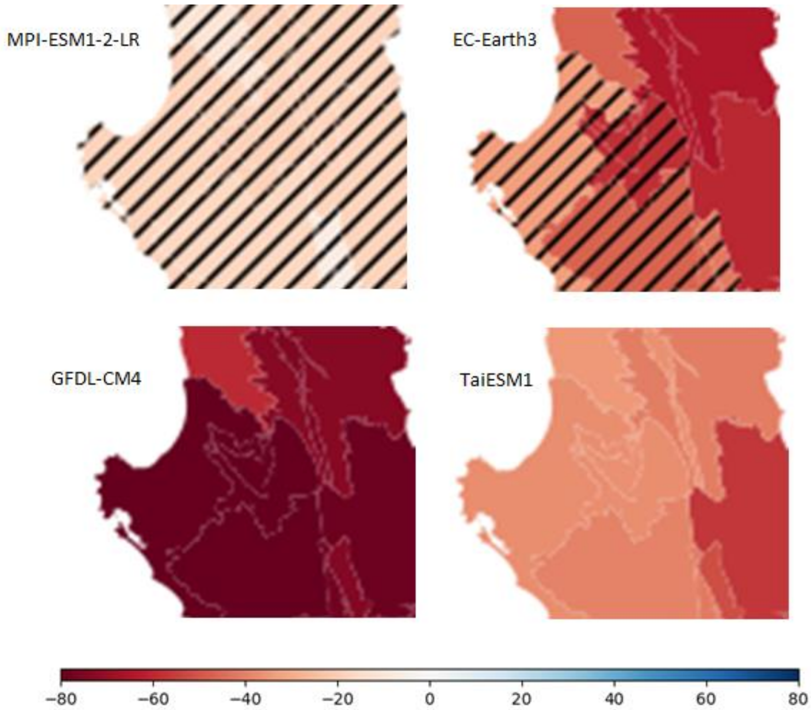


Figure 30: Projected changes in the annual total rainfall (mm) across the Bergrivier municipal region derived from the CMIP6 model ensemble SSP5.85 pathway for the period 2030-2060 for the 4 archetype models. Diagonal hashing indicates trends that are not statistically different with a p-value threshold of 0.05 (Source: Jack, 2022).

4.2.2.3 Evapotranspiration

Potential evapotranspiration data was provided in Jack (2022), but this was for the whole region of Cape Town to Bokkeveld (which includes some parts of Bergrivier Municipality). This data (Figure 31) shows that PET is expected to increase in the future as conditions get warmer.

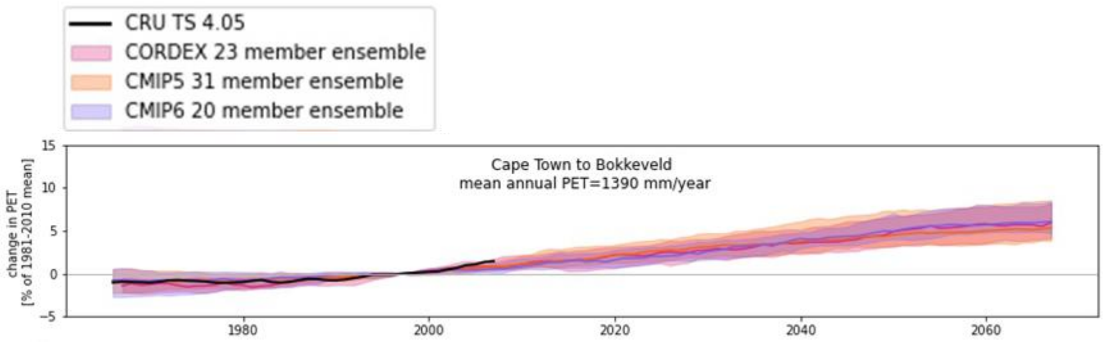


Figure 31: Changes in mean annual potential evapotranspiration derived from CMIP5, CMIP6 and CORDEX model ensembles, and observed data from the CRU TS4.05 dataset (Source: Jack, 2022).

4.2.2.4 Drought

Drought is a complex phenomenon and is often understood using different framings. Meteorological drought is focused on deficits in rainfall whereas hydrological drought is focused on deficits in soil moisture and runoff. Socio-economic drought refers to the more complex aspects of drought as they impact the broadly-understood socio-economic system. The Standardised Precipitation Index (SPI) is a drought index based only on rainfall deficit, whereas the Standardised Precipitation Evaporation Index (SPEI) calculates a moisture budget (precipitation minus potential evapotranspiration) and is closer to identifying hydrological drought. The data projections suggest that drought conditions are likely to be far more common in the future (Figure 32 and Figure 33).

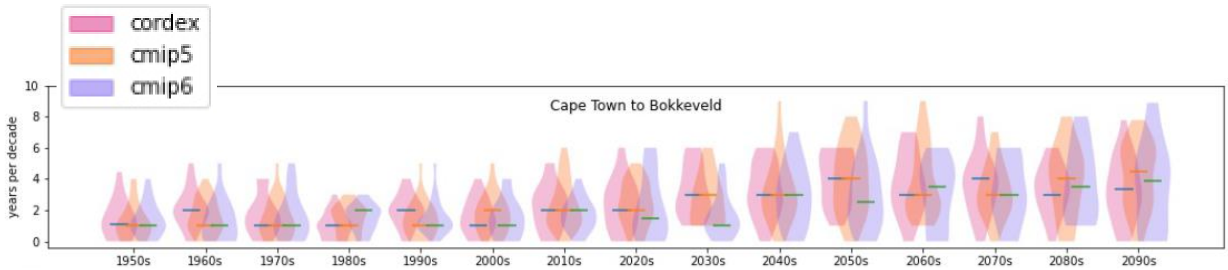


Figure 32: Plots of changes in drought years/decade with SPI< -1.0. Each plot represents the ensemble distribution of projected changes for a particular ensemble for that particular 10-year period. Horizontal bars mark the median of the ensemble (Source: Jack, 2022).

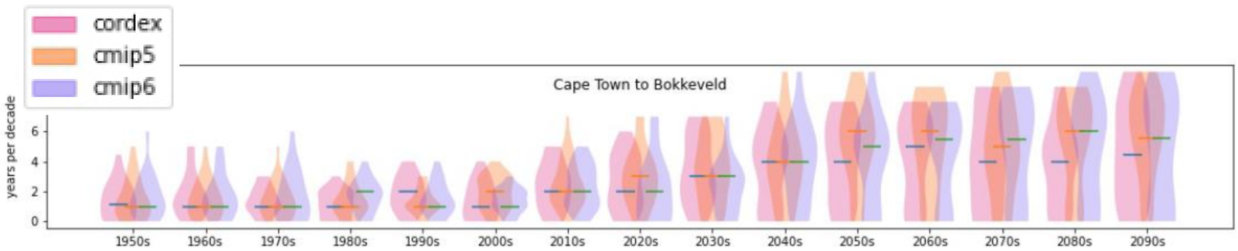


Figure 33: Plots of changes in drought years/decade with SPEI< -1.0. Each plot represents the ensemble distribution of projected changes for a particular ensemble for that particular 10-year period. Horizontal bars mark the median of the ensemble (Source: Jack, 2022).

5 CLIMATE RISK AND VULNERABILITY ASSESSMENT

The impacts of droughts, floods, and heatwaves are often the most widely reported. Gradual changes in temperature and rainfall that affect patterns of food production, diseases, and species populations, amongst others, are also being observed and pose significant threats to the functioning of society. To design and implement effective adaptation interventions to reduce risks and vulnerabilities it is necessary to assess where, to what extent, and by whom these climate impacts are being felt. In addition, why the patterns are as they are, and how this might change in the future. A better understanding of climate risks and vulnerabilities is also critical in advancing the climate change mitigation agenda.

The key step in understanding risk is identifying who and what is exposed to the climate hazards and might therefore be potentially impacted or harmed. This includes all groups that could be adversely affected—people, animal, and plant species, built infrastructure and ecological infrastructure. Climate vulnerability is a component of climate risk and explains why some, when equally exposed to a climate hazard, like a drought or coastal inundation, are impacted worse than others. A climate change risk and vulnerability assessment, which is an analysis of the expected impacts, risks, and adaptive capacity of a region to climate change, enables a better understanding of current and future risks. It allows for the identification of hot spots where adaptation measures are needed the most and assists the municipality to prioritise the actions and focus resource accordingly.

5.1 General methodology

5.1.1 Spatial assessment

As per the project's Terms of References, a spatial approach was considered for the identification of vulnerable and high-risk areas in the Bergrivier Municipality. Whilst there are a number of advantages to a spatial assessment, there are also limitations to a spatial assessment at a municipal level, for example:

- *Lack of spatially explicit data:*
    - *At a municipal level this means that data is required at ward or town level and there are not a lot of statistics on all the variables at this level. If data is at the ward level, then the whole ward gets the same score, so hot spots within a ward become difficult to identify. Wards may also contain both rural and urban areas, so averaging over the ward would be incorrect for both situations.*

- *Data sets from various time periods:*
    - *Although the assessment tries to use recent data and data from the same period, not all spatial data sources have the required level of detail. This results in a variety of data being used. It is one of the reasons why, for example, the older 2011 census data may be used instead of more recent census data as the data is available at town level.*
- *Differing spatial scales:*
    - *Spatial data is obtained from a variety of sources and may have differing spatial scales. Outputs are based on a combining of these data sets and so these differing spatial scales can influence the outputs. This should be considered when interpreting the data.*

In considering these limitations, the hazards and exposure regions were identified using spatial techniques, whilst the adaptive capacity, sensitivity and vulnerabilities incorporated information from literature and stakeholders to provide a more comprehensive output.

5.1.2 Assessment methodology

The climate risk and vulnerability assessment were conducted following the IPCC AR5 approach (Figure 34). The first step was to assess climate hazards and exposure areas, where these variables are defined as:

- ***HAZARD*** *is the potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources (IPCC, 2022), and*
- ***EXPOSURE*** *is the risk these hazards pose to people (and livelihoods), species or ecosystems, environmental functions, services, and resources, infrastructure, and economic, social, or cultural assets, within a given place or setting (IPCC, 2022).*

The next step in the process was to conduct a vulnerability assessment, where vulnerability is determined by combining information on exposure with sensitivity and adaptive capacity information. The higher the exposure and sensitivity and the lower the adaptive capacity, the more vulnerable an area or system is.

These variables are defined as:

- ***SENSITIVITY** refers to the factors that directly affect the consequences of a hazard, and can include physical attributes (e.g., soil type, building material) of a system and socio-economic attributes (e.g., age structure, income structure).*
- ***ADAPTIVE CAPACITY** is the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences; and*
- ***VULNERABILITY** is the propensity for or predisposition towards adverse effects. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and a commensurate lack of capacity to cope and adapt (IPCC, 2022).*

The sensitivity and adaptive capacity information was obtained from stakeholder engagements and information from literature. Vulnerability was determined using the following equation (Figure 34):

- *Vulnerability = (exposure + sensitivity) - adaptive capacity*

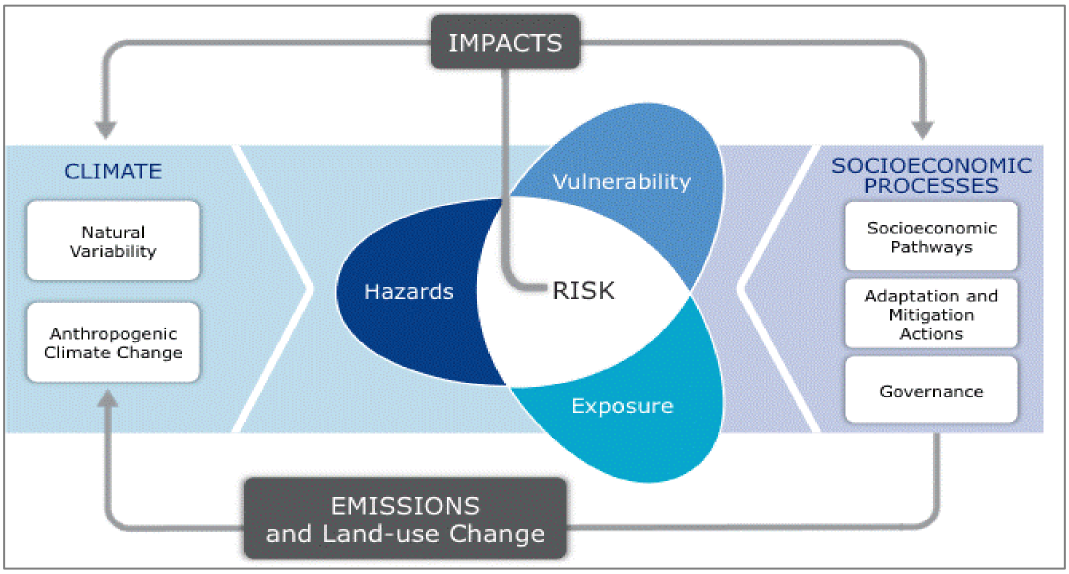


Figure 34: Risk assessment as presented in WGII AR5 Report (IPCC, 2014).

5.2 Focus areas

The list of potential impacts, vulnerabilities and risks to climate change are quite extensive (IPCC, 2022). In this study, therefore, focus areas were selected by considering the issues that were presented in the previous adaptation plan as well as those that were highlighted by stakeholders[9]. This also considered the activities highlighted in the West Coast District Municipality Climate Change Plan (WCDM, 2019) which emphasised Agriculture, Biodiversity and Environment, Coastal and Marine, Human Settlements, Infrastructure and

[9] See the Stakeholder Engagement Report (RN_2303567).

Disaster Management and Water. The following areas or sectors were selected for assessing the impacts, vulnerabilities and risks associated with climate change:

- *Water resources (ground and surface water),*
- *Agriculture,*
- *Coastal areas (flooding and erosion),*
- *Infrastructure,*
- *Settlements and communities, and*
- *Environment.*

These areas were also selected so that the information drawn out could be used to develop specific actions for the affected directorates within the municipality.

5.3 Climate trends and hazards

A more detailed assessment of projected climate changes for the Bergrivier Municipality was undertaken to determine seasonal variations and impacts, and the identification of specific climate hazards. The data from the four archetypes (Table 10) were assessed and the maps show the GFDL-CM4 and EC-Earth3 models only, as these are more middle of the road scenarios (Figure 35). The SSP2 4.5 scenario, which is the shared socio-economic pathway representing a "middle of the road" pathway, is used as this is indicated by Jack (2022) to be a reasonable scenario to explore. The SSP2 8.5 scenarios (shown in section 4.2.2), will be mentioned in relation to some of the variables to indicate possible variation.

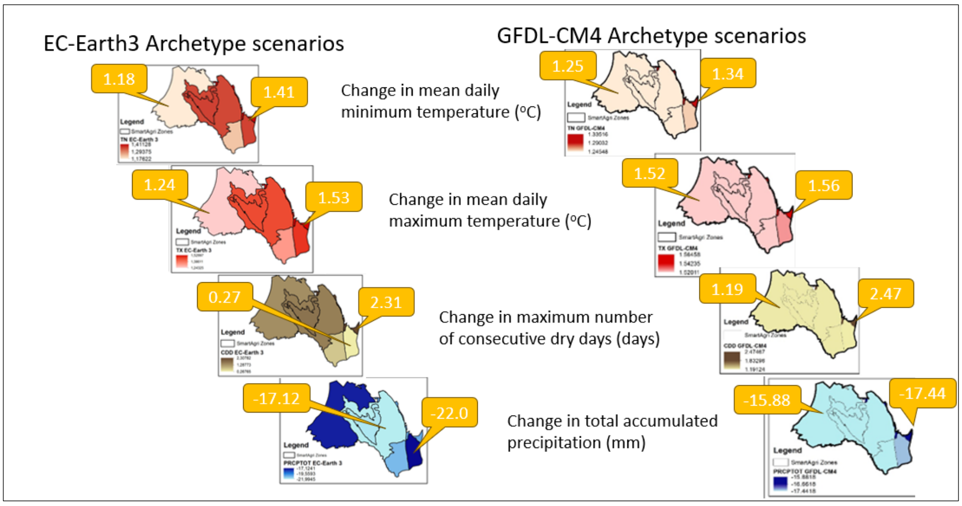


Figure 35: GFDL-CM4 and EC-Earth3 climate scenarios for the Bergrivier Municipality SmartAgri Zones showing change between current and 2030-2060 projections (WC DOA, 2023).

The data (Table 11) shows that temperatures, both daily maximum and minimum, are expected to increase in the future. These increases are higher under the SSP2 8.5

scenario and are, in all cases, indicated to be significant. The greatest increases are expected in the December, January, and February (DJF) season. Precipitation on the other hand, shows a decline across the area, whereas the precipitation estimates are highly uncertain, show greater variability and are therefore shown as not significant, at least in most cases. Even though the changes may be indicated to be insignificant, it doesn't mean this is not likely to happen. The data therefore still gives some insights into what might be expected.

Precipitation declines are shown to be greatest in the June, July, August (JJA) season. March, April, May (MAM) season shows the highest increase in dry days, whilst JJA and September, October, November (SON) season show the greatest decline in the number of consecutive wet days. Unfortunately, the indices for drought were not provided so are not included in the dataset.

With precipitation declining and there not being any increase in the frequency of rainfall events over 20mm, it is taken that the occurrence of floods is minimal in the Bergrivier Municipality. This is supported by historical data (Figure 36), as well as by the flood hazard map developed by the DEA&DP (DEA&DP, 2023).

Table 11: Seasonal projected changes in climate across the Bergrivier Municipality based on GFDL-CM4 and EC-Earth3 climate scenarios (Source: WCG DoA, AgriSmart Project). Orange cells represent the month with the largest increases and the blue are the largest declines.

Variable	Description of changes expected in Bergrivier Municipality by 2060 relative to the 1981-2010 period									
	MAM		JJA		SON		DJF		Annual mean	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Mean daily temperature (ºC)	1.04	1.14	1.22	1.43	1.20	1.47	1.29	1.42	1.19	1.42
Mean daily minimum temperatures (ºC)	1.02	1.14	1.05	1.25	1.16	1.40	1.29	1.44	1.18	1.34
Mean daily maximum temperature (ºC)	1.09	1.20	1.22	1.51	1.31	1.67	1.35	1.51	1.24	1.53
Frequency of daily maximum temperature above 30ºC	4.06	4.78	0.00	0.03	2.27	2.99	8.03	9.12	3.68	4.23
Frequency of daily minimum temperatures above 20ºC	3.29	3.51	0.00	0.00	0.19	0.46	5.03	5.98	2.13	2.49
Frequency of daily minimum temperatures below 0ºC	0.00	-0.06	-0.52	-4.28	-0.03	-0.12	0.00	0.00	-0.14	-1.11
Total accumulated precipitation (mm)	-14.98	-21.01	-36.85	-41.28	-17.56	-27.84	-4.07	-11.84	-17.12	-21.99
Number of days with precipitation >20mm (days)	-0.19	-0.43	-0.21	-0.52	0.02	-0.17	0.00	-0.38	-0.15	-0.32
Maximum number of consecutive dry days (days)	-1.43	4.16	-0.65	-0.30	1.00	2.16	-0.38	2.52	0.27	2.47
Maximum number of consecutive wet days (days)	-0.28	-0.49	-0.77	-1.03	-0.62	-0.84	-0.19	-0.45	-0.49	-0.63

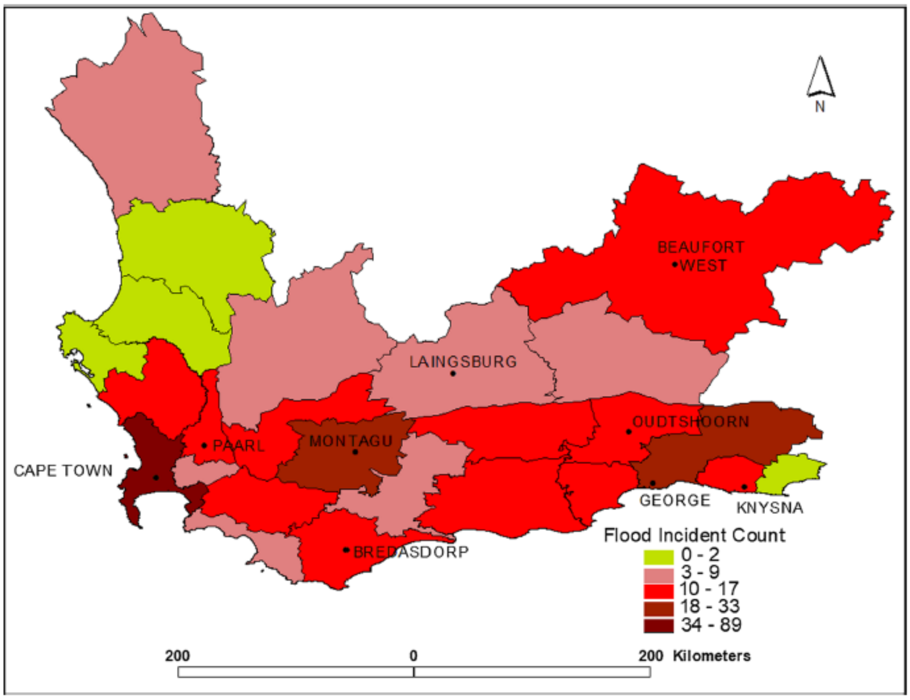


Figure 36: Flood count and risk analysis map for the Western Cape between 1900 and 2018 (Source: Dube et al., 2022).

Drought and evapotranspiration are expected to increase across the region (see section 4.2.2). Daily maximum near surface temperatures (Tx) are an indication of heat stress (Schwingshackl et al., 2021), and so with increasing temperatures an increase in heat stress is expected. Increases in temperature result in an increase in the number of hot days. The number of days in which the daily maximum temperatures are over 30°C are expected to increase by about 5 days/year and the number of days where the daily minimum temperatures are over 20°C are indicated to increase by 4 to 6 days/year. On the other hand, the number of days in which daily minimum temperature are below zero are indicated to decline by 1 day/year in the future.

Higher air temperatures and drier conditions can lead to an increased availability of dry fuels, especially during summer and autumn months. This results in an increased risk of runaway, large fires, and thus presents increased risk to people, animals, and assets due to uncontrollable fires. Fire was not identified as a hazard in the previous adaptation plan (BM, 2014), and in the Greenbook (CSIR, 2019), the Bergrivier Municipality is shown to have a low to medium risk of increased fires. The Greenbook is an older dataset, but the information does to correlate with what is shown in the Western Cape Veld Fire Plan 2019-20 (WCG, 2019). On the other hand, the WC Environmental Risk and Vulnerability Assessment (DEA&DP, 2023) indicates the Bergrivier Municipality to have a medium wildfire hazard, although the risk is shown to be low.

5.3.1 *Climate hazard scores*

The major climate hazards were assessed and ranked in terms of their current and historical frequency and likelihood (section 4.1.2), their projected likelihood and significance (section 4.2.2 and above), and their relative magnitude based on the projected data (see above). In terms of magnitude the data in Bergrivier Municipality was considered relative to the projected changed across the Western Cape region. Stakeholder comments were incorporated into the scoring process. The ranks were 3 for high, 2 for medium and 1 for low. These scores were then averaged to obtain an average ranking for each hazard (Table 12). Details on the scoring approach applied for the Climate Risk and Vulnerability assessment for hazards and sectors under climate change impacts, exposure and sensitivity are on APPENDIX A 1.

Table 12: Hazard ranking.

Rank	Increase CDD[10]	Increase hot days[11]	Decreased rainfall	Dryness[12]	Inland Floods	Coastal floods	Fire
	High	High	Medium high	High	Medium low	Medium high	Medium high

[10] CDD – Consecutive dry days
[11] Increase in the number of days where $T_{mean}>30^oC$.
[12] Dryness is a weighted average of increased consecutive dry days, increased days with $T_{mean}>30^oC$ and decrease in precipitation.

5.4 Climate change impacts, exposures, and sensitivities

5.4.1 Water resources

5.4.1.1 Impacts

The effects of climate change, including increased reduction in rainfall, more consecutive dry days, and rising average temperatures, can have significant implications for water resources in the region (Table 13).

Table 13: Climate impacts on water resources.

Water source	Potential impacts
Ground water	• **Total precipitation:** Reduction in rainfall (-15.88 mm to -21.99 mm) within the municipality can directly lead to a decline in groundwater recharge. With less precipitation infiltrating the ground, aquifers may not be replenished as efficiently as before. This can result in a gradual decline in groundwater levels over time. • **Consecutive days of extreme weather**: A record of >2 days of increased consecutive days is projected over the municipal region. Prolonged periods of dry weather can exacerbate the reduction in groundwater recharge. Without regular rain to replenish aquifers, the available groundwater resources may become scarcer. This can affect the reliability of groundwater as a water source for local communities. • **Mean daily temperature**: The models project temperature change for the municipal change to increase by between 1.18 °C and 1.41 °C. Higher temperatures can intensify evaporation rates, leading to further loss of groundwater. The available groundwater may be more susceptible to depletion during drought periods as temperature change increases. Additionally, warmer temperatures can alter the dynamics of groundwater flow, potentially affecting its quality and availability. • **Sea level rise:** Sea level rise and increased abstraction in coastal aquifers will increase the risk of sea water intrusion and significantly impact on the water quality from these boreholes.
Surface water	• **Total precipitation**: Bergrivier will experience variations in total precipitation due to climate change. Reduced precipitation levels can lead to a decreased recharge of surface water sources, making them more vulnerable. This can result in lower water availability for both residential and agricultural use. Areas with low projected changes in precipitation, characterised by high sensitivity, are notable for having a high number of consecutive dry days. • **Consecutive days of extreme weather**: Increasingly frequent and prolonged periods of extreme weather, such as droughts, can impact the vulnerability of surface water. Extended droughts can reduce the replenishment of surface water, while intense rainfall events can lead to surface water contamination and flooding, affecting the quality and availability of water resources. This is true of Bergrivier, where places that lack surface water are projected to have more consecutive dry days. • **Mean daily temperature**: Rising mean daily temperatures can increase the vulnerability of surface water. Higher temperatures can contribute to increased evaporation rates, reducing water levels in reservoirs and rivers. Additionally, elevated temperatures can affect water quality, promoting the growth of harmful algae and bacteria. • **Sea level rise:** The rising of sea levels leads to an increased risk of sea water intrusion and reduced water quality from the boreholes. The demand on other water sources will therefore increase.

5.4.1.2 *Exposure and sensitivities*

Bergrivier Municipality is home to several rivers, dams and springs which feed into the municipal water supply. The municipality comprises 9 urban settlements—Piketberg, Porterville, Velddrif (which includes Port Owen, Laaiplek and Noordhoek), Dwarskersbos, Eendekuil, Aurora, Redelinghuis. Goedverwacht and Wittewater are private property/farms and are not serviced by Bergrivier Municipality. There is another settlement called De Hoek, but this is not serviced in respect of water by the municipality (BM, 2022b). Bulk potable water is provided to Velddrif and Dwarskersbos by the West Coast District Municipality. Velddrif has the largest water distribution network, followed by Piketberg.

High population density areas may stress surface water bodies, potentially leading to over-extraction. This can deplete surface water resources and indirectly impact groundwater levels as interconnected systems respond to changes in surface water availability. Population in the Bergrivier settlements has been increasing at an annual population growth rate of 1.2% (WCG, 2021). According to the water audit (BM, 2022b), Velddrif has the highest expected population growth of 5% per annum, followed by Dwarskersbos (3.5%) and Eendekuil, and Goedverwacht at 2.0%. Velddrif has the largest population (17 946), whilst Dwarskersbos only has 945 people. Increased pressure on surface water will lead to increased reliance on ground water.

Piketberg, with over 1967 households, is the main town of Bergrivier and provides primary agricultural services to the surrounding town. Water sources in the town may be strained due to the growing population, particularly if extraction is not controlled. Velddrif has additional pressures as, with the expanding growth and progress in the Saldanha Bay/Vredenburg Regional Economic Hub, Velddrif/Laaiplek has emerged as a preferred coastal destination for residents who commute, local business owners, as well as domestic and international tourists. Increasing tourism will further pressure water demand.

Groundwater levels have been decreasing over time as temperatures and extraction increase. Porterville, Piketberg, Wittewater and Eendekuil are also supported partially by springs and boreholes. In Aurora, the groundwater levels have been low and in recent years the boreholes have dried up (Figure 37). There has also been the unlicensed extraction of water by farmers and the construction of dams which has increased the water problems in the area and made them more vulnerable to changes in climate. The three springs in Porterville have fractures and stakeholders indicate the springs are becoming erratic in their water supply. In addition, electricity is required for the water pumps and so a decline in electrical infrastructure will mean an increase in sensitivity to climate change impacts. As surface water extraction increases, so will reliance on ground water increase. Aurora is dependent on borehole water, whilst Redelinghuis relies on spring water (BM, 2022b; Figure 38).

The water audit report (BM, 2022b) indicates that farm populations are increasing by 1.5% per annum and the population on farms (29 675) is 38% of the total population. Agriculture relies quite heavily on ground water. Agriculture, Forestry and Fishing is the second largest contributor (23.2%), after manufacturing, to the GDP (WCG, 2021). The reliance of business activities in Piketberg on surrounding rural areas indicates that the town's economy is closely tied to agriculture (BM, 2022). Agricultural communities rely heavily on groundwater for irrigation. Groundwater recharge is highest in the far eastern regions of the municipality as well as the central and western regions between Goedverwacht, Velddrif and Redelinghuis (CapeFarmMapper 3; https://gis.elsenburg.com/apps/cfm/ which is based on the Groundwater Resource Assessment Phase 2 (DWS, 2005)). In contrast, it is lowest along coastal regions and in the agricultural regions between Porterville, Piketberg and Eendekuil.

A deteriorating water catchment system will consequently lead to lower inputs into the water supply systems and a lower overall water security due to lower natural retention and lower quality of water (DEA&DP, 2023). It is therefore important to maintain ecosystem functionality in the catchment area. The Western Cape Biodiversity Spatial Plan (Pool-Stanvliet et al., 2017), identified areas that are not specifically important for maintaining biodiversity, but which are vital for delivering ecosystem services—some of these being watercourse protection, water source protection and water recharge protection. Increasing temperatures, decreasing rainfall, increasing evapotranspiration and drought could impacts these areas thus leading to further reductions in water and increased water pressures.

Alien invasive species can also have a big impact on both biodiversity and water resources. Alien invasive plants and trees growing near rivers and other water sources tend to use more water and reduce the amount of water available. It is important to have plans to keep alien invasive species to a minimum. Areas with alien invasive will also increase the sensitivity of the area to climate change impacts. Besides water recharge, water storage will also be important going into the future. Areas that have low water storage capacities will likely be more sensitive to climate change. Increased fuel load due to dry conditions could lead to increased wildfires. For water resources this would mainly impact the water infrastructure and so fire impacts are discussed further in section 5.5.4.

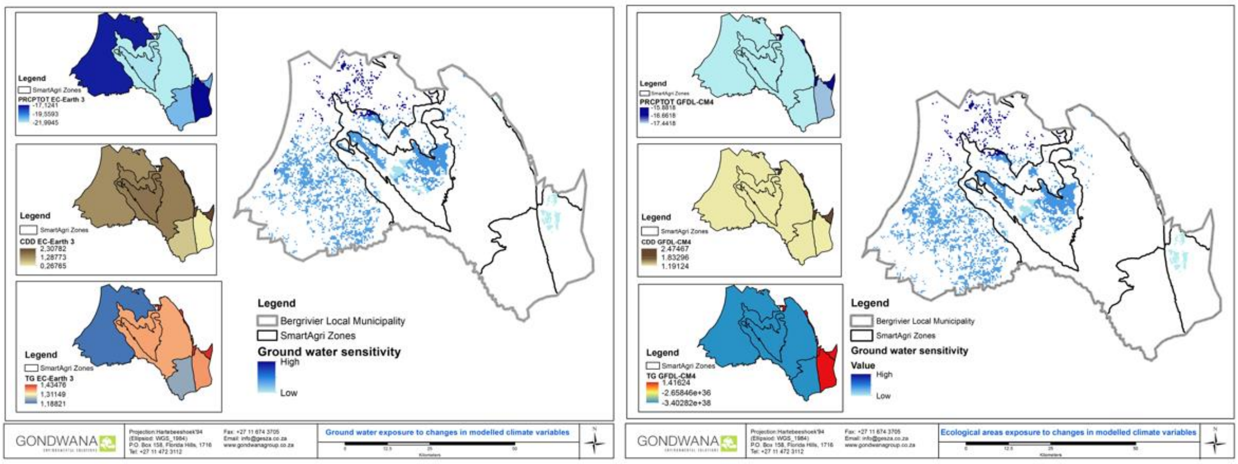


Figure 37: Ground water exposure and sensitivity to climate change variables in the Bergrivier Municipality (Left: EC-Earth3 climate model and Right: GFDL-CM4 climate model).

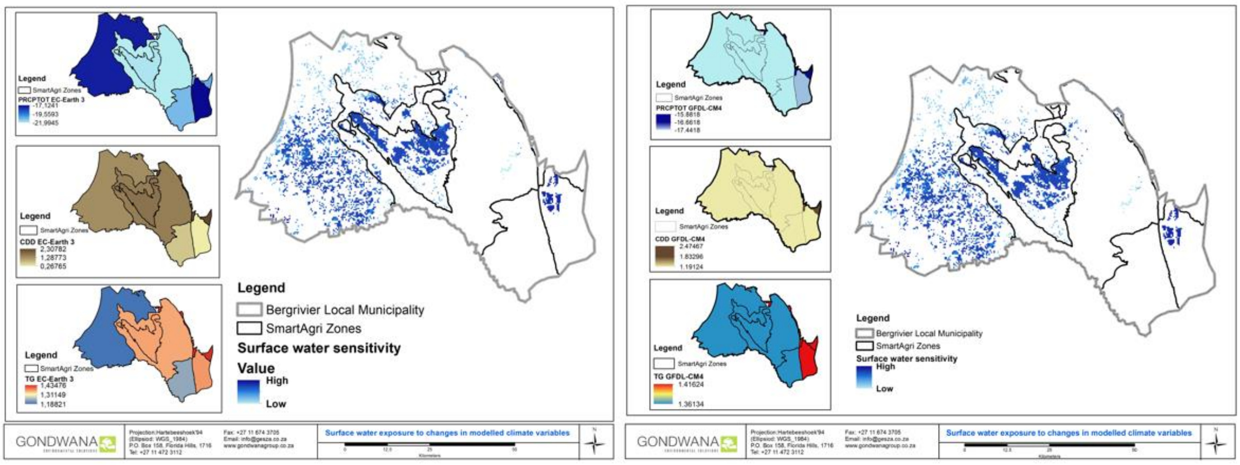


Figure 38: Surface water exposure and sensitivities to climate change variables in the Bergrivier Municipality.

5.4.1.3 Sensitivity score

A sensitivity score was developed for each of the main urban town based on information such as bulk water supply, storage capacity, water quality (green and blue drop scores), population growth rates, annual growth in consumer units, leakage index for water distribution systems, ground water recharge and economic activities in the region. A socio-economic index was also included, but this index was developed for the municipality as information is not available at the town level. This was added into the sensitivity score for each town.

The socio-economic capacity includes several components:

- *Education:*
  - *The Bergrivier Municipality's matric pass rate dropped sharply from 85.7% in 2018 to 77.6% in 2019 and remained the same in 2020. Although it increased*

to 79.6% in 2021 (WCG, 2021; WCG, 2022), it is the lowest in the district. The learner retention rate is 75.5% and there are 20 schools in the municipality. If a population is uneducated then the adaptive capacity will drop as the population is less aware of climate change issues and unaware of the dangers of climate change. In addition, they are not aware of types of actions that can be taken to reduce the impacts of climate change.

- Employment:
  - *The unemployment rate of 7.7% is incredibly low (WCG, 2022)—the lowest in the district—according to the narrow definition of unemployment which only includes those that are actively seeking jobs (i.e., not those that have given up looking). A population that is employed is also better able to implement actions and improve the adaptive capacity.*
  - *Most of the 'formally employed' consist of low-skilled (54.7%) and semi-skilled (29.2%) workers.*
  - *The dependency ratio is 45.6%, which is quite high and will also contribute to a lower adaptive capacity.*
  - *The income equality, represented by the Gini-coefficient, is at 0.6. This means there are high levels of inequality. Socio-economic disparities can result in differential access to resources. For example, communities with higher income levels may have better access to alternative water sources, reducing their dependence on groundwater. In contrast, marginalised communities may rely more heavily on groundwater, making them more vulnerable to its depletion.*
  - *Furthermore, the high poverty rate of 32.8% (Stats SA, 2020), suggests that a sizable portion of the population may struggle to adapt to the effects of climate change.*
- Health:
  - *The Human Development Index, which is a composite indicator reflecting education levels, health, and income, has improved in the Bergrivier area, from 0.67 in 2014 to 0.74 in 2020 (BM, 2021).*
  - *The municipality has a low immunisation rate of 60.8% (WCG, 2022).*
- Service delivery:
  - *Bergrivier Municipality has a remarkably high service delivery rate which increases the adaptive capacity:*
    - *Piped water inside dwellings/yard: 99.3%,*
    - *Electricity as primary source of lighting: 96.4%,*
    - *Flush/chemical toilets: 96.9%, and*
    - *Refuse removal at least once a week: 77.7%.*

The socio-economic situation indicates how sensitive a community would be to the climate impacts and therefore indicates their ability to respond. The overall socio-economic score was medium-high. Velddrif has the highest sensitivity because of its increasing population and water demand. Additionally, there is expected growth due to planned economic activities and the rise in tourism. The green drop score is lower than the other towns with an average blue drop score. On the other hand, the sensitivity in Velddrif is decreased because it has a large water storage capacity.

Table 14: Water resource sensitivity score.

	Sensitivity score
Piketberg	Medium
Porterville	Medium high
Velddrif	Medium high
Dwarskersbos	Medium high
Eendekuil	Medium
Aurora	Medium
Redelinghuis	Medium
Goedverwacht	Medium high
Wittewater	Medium
Average	Medium high

5.4.2 Agriculture

5.4.2.1 Impacts

The climate change impacts on agriculture are extensive as there are first order impacts (e.g. temperature changes, precipitation changes, frost), as well as second order (e.g. evapotranspiration, heat units, drought), third order (e.g. soil degradation, pests, and diseases) and fourth order (e.g. food security, jobs, and livelihoods) impacts. In addition, there are not only impacts on the crops and livestock but also on farm workers. The Western Cape Department of Agriculture initiated a project on Climate Change Impacts on the Agriculture sector in the Western Cape. The Status Quo document (WCG, 2016) provides detailed impacts on Agriculture, with a summary of the broad impacts being provided in Table 15.

Table 15: Examples of climate change impacts on agriculture.

Climate hazard	Possible impact
Seasonal shifts in the rainfall and runoff patterns	Some farmers abstract water directly from a river and are not part of a scheme with upstream storage. The majority of these farmers have licence conditions that prevent them from abstracting during the summer low flow period. The shifts in rainfall and runoff patterns could actually benefit these users if this results in increased flows during the spring and summer to coincide with irrigation demands.
Increased evaporation	This will lead to increased evaporation losses from reservoirs and streams particularly during the summer months, which reduces the availability of water for supply. Increasing evaporation will also increase irrigation demands and reduce runoff.

Increased temperatures and decreased precipitation	This leads to an increase in the irrigation demand for crops, particularly in the Western Cape where the peak irrigation demand is during the summer. With the availability of water already limited and possibly reducing in future as a result of climate change, increasing irrigation demands are unlikely to be met through a corresponding increase in supply. This is likely to have a negative impact on crop yields.
Sea level rise	Sea level rise and increased abstraction in coastal aquifers will increase the risk of sea water intrusion and significantly impact on the water quality from these boreholes. Sea level rise could increase the flooding risk in coastal areas with a raised downstream control potentially increasing the level of upstream flooding.
Increased flooding	Increased flooding risk may not be as severe as in other parts of the country, but it is still likely to have a negative impact on agriculture through loss of fertile land, damage to infrastructure (including roads, buildings, and pump stations), and reduced accessibility to fields for harvesting.
Heat stress	This can lead to a reduction in milk production of dairy cows and can lead to the death of cattle in general. Heat stress will also impact workers and there may need to be a shift in the times at which farm workers are active in the field, or they may need to take additional breaks.

The modelled climate variability projects a trend of increase in, minimum (1.18 – 1.41 ° C), and maximum (1.24 – 1.56 ° C) annual temperatures and consecutive dry days, with a reduction of precipitation. Variations in both minimum and maximum temperatures are crucial for agriculture. Winter crops often require a period of low temperatures for healthy development. If minimum temperatures increase due to climate change, it can disrupt the growth cycle of these crops and reduce yields (Figure 39).

These changes can fundamentally have the following types of impacts on the various Agro-zones in the municipality:

1. ***Rooikaroo - Aurora zone**:*
    - **Features**: Flat dry plains with low storage capacity. Crops grown include wheat, canola, and rooibos.
    - **Effects of climate change**:
        - **Increase in consecutive dry days**: This could lead to more frequent water stress for crops in this region, as there is limited water storage capacity.
        - **Reduction in precipitation**: Less rainfall can exacerbate water scarcity issues, making irrigation crucial for crop survival.
        - **Increase in temperature**: Higher temperatures can accelerate evaporation, potentially impacting the available moisture for crops.

2. ***Sandveld-south zone:***
   - **Features**: Dry shrubland on sandy infertile soils. Crops grown include wheat, potatoes, and rooibos.
   - **Effects of climate change**:
     - **Increase in consecutive dry days**: Prolonged dry spells can increase water stress on crops and reduce yields, particularly on infertile sandy soils.
     - **Reduction in precipitation**: Lower rainfall can lead to decreased soil moisture, making it challenging for crops to thrive.
     - **Increase in temperature**: Higher temperatures may exacerbate evaporation, leading to further moisture loss from the soil.

3. ***Swartland zone:***
   - **Features**: Fertile, undulating terrain bordered by mountains to the east. Crops grown include wheat, wine and table grapes, canola, and olives.
   - **Effects of climate change**:
     - **Increase in consecutive dry days**: Whilst this zone benefits from better soil quality, prolonged dry periods can still stress crops, especially during critical growth stages.
     - **Reduction in precipitation**: Decreased winter rainfall can affect grapevines and olive trees, which rely on seasonal moisture.
     - **Increase in temperature**: Higher temperatures can lead to earlier ripening of grapes, potentially affecting wine production. It may also influence crop pest dynamics.

4. ***Piketberg zone:***
   - ***Features:*** This is a unique island mountain climate, wetter and cooler than surrounding areas, with fertile shale soil and farm dams that support various farming activities (pears, fynbos flowers, stone fruit, wheat, citrus, herbs/essential oils, wine grapes, Cape rush, sheep, and cattle). However, the farm dams face a low storage capacity challenge which might threaten the agricultural business if the climate changes result in warmer temperatures and dry periods persist for longer periods in the future.
   - ***Effects of climate change on agriculture:***
     - **Increase in consecutive dry days:** Extended dry periods can lead to water stress which can reduce crop growths and yield due to dry soil making it hard for essential nutrients to be circulated, especially for water-sensitive plants like wine grapes and citrus. Livestock may also face challenges with limited access to water

sources. The agricultural economy within the municipality can be negatively affected which will affect livelihoods of the farming communities.

- **Decrease in precipitation**: Reduced precipitation can exacerbate the challenges posed by consecutive dry days. Insufficient rainfall may lead to drought conditions, affecting water availability for crops, livestock, and farm dams. This could result in a decline in agricultural productivity and potentially threaten the sustainability of certain farming activities.
- **Increase in temperature:** A rise in temperatures can have diverse effects on different crops. Some crops, like stone fruit and wine grapes, may be sensitive to higher temperatures, affecting their growth and quality. Additionally, increased temperatures can contribute to higher evaporation rates, intensifying water scarcity issues. Livestock may also experience heat stress, impacting their well-being.

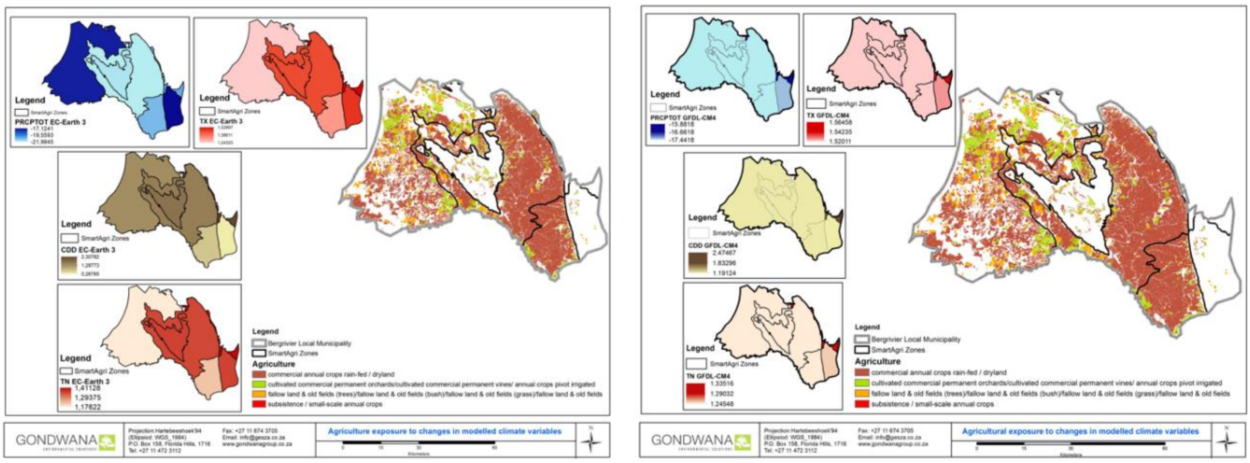


Figure 39: Agriculture exposure to climate change variables in the Bergrivier Municipality.

5.4.2.2 Exposure and sensitivities

Subsistence, small-scale and emerging farmers are more sensitive to climate change as they are often reliant on small farm dams for irrigation. With rising temperatures, declining rainfall, and increasing drought these water supplies will be under severe pressure as there will be reductions in water availability. The mixed farming in Redelinghuis, Aurora and the coast belt could have a higher adaptive capacity as they can adapt through diversification.

As rainfall declines, temperatures rise and evapotranspiration increases, so the demand for water will increase. Areas that have poor water supply and storage infrastructure will be more sensitive to climate changes. Due to the highly seasonal flow patterns and the mismatch between periods of supply (i.e. winter) and periods of peak demand for water (i.e. summer), agriculture is highly dependent on dams and water storage facilities (WCG, 2016). The Piket-bo-Berg area has significant fruit production which benefits from surface run-off and elevation. Expansion of agricultural development is, however, restricted by a shortage of surface water, with ground water extraction proving to be uneconomical.

Pome fruits, such as apples, require a cold winter climate as they need chilling for the emergence from dormancy in spring. Under climate warming, accumulation of chill units will decrease, eventually reaching a critical threshold at which apple production would no longer be commercially sustainable in currently warmer areas (Cartwright, 2002). Schulze and Maharaj (2010a) modelled the impacts of intermediate (2046-2065) and future (2081-2100) warming on accumulated positive chill units across South Africa. They found that warming of 1°C, 2°C and 3°C would lead to a 23%, 43% and 60% reduction in chill units in the Western Cape, with the percentage reduction most marked in warmer lower-lying areas. Heat stress, combined with high light levels, gives rise to a high incidence of sunburn on pome fruit in the Western Cape (Gindaba and Wand, 2005). Sunburn damage can amount to 20-30% of the fruit cull in the orchard and up to a 10% rejection of packed cartons thereafter.

Wheat, which is the dominant crop in the Bergrivier Municipality, requires a cool and moist climate followed by a warm dry season for harvesting. The main grain growing areas are between Piketberg, Porterville and Eendekuil with grain being cultivated on large scale, extensive farms. Dryland wheat production yields in SA are low compared to the major wheat producing countries such as China or Ukraine. The quality requirements for newly available cultivars may lead to slower than expected progress in yield increases of local breeding programmes. Other limiting factors are variable climate conditions (including dry, warm winters) and low soil fertility. During germination months (June/July), wheat needs rain, although dry periods can be handled for certain periods depending on the cultivar. Longer crop yields are favoured by good rainfall, especially in June and the end of August or September (with some rainfall in both months). Rainfall is critical for crop success. The future projections show the greatest decline of rainfall in JJA and therefore wheat could be impacted by this change.

Severe droughts, characterised by late starts and dry spells during the winter rainfall season, are the main concern for rooibos tea as they significantly reduce rooibos yields. Other impacts include increased fire risk due to dryness, wind erosion of the dry soils, water shortages for human and stock consumption and production, and climate-related increases in pests and pathogens (Archer et al., 2008). Potatoes are grown in the Sandveld region, and they are very reliant on groundwater for irrigation. The likely unsustainable use of Sandveld groundwater resources for agricultural irrigation (BM, 2019), particularly for potato pivot farming, means these areas will be more sensitive to climate change.

Livestock are also sensitive to heat stress with an upper threshold temperature range of 30 – 32ºC (WCG, 2016; Nesamvuni et al., 2012). Feedlot cattle are most at risk because of the high metabolic heat loads. In addition, other intensive farming, such as piggeries and chicken batteries, will also be affected by increasing temperatures. Dairy farmers are more sensitive to increasing temperatures as heat stress leads to reduced milk production and fertility rates (WCG, 2016).

5.4.2.3 Sensitivity score

Agriculture sensitivity scores were developed for each of the AgriSmart zones based on the extent of the various crop types and livestock farming activities in the region and their sensitivities as discussed above. Sensitivity also includes information on water storage capacity in terms of dams, and whether they are large dams (less sensitive) or smaller dams (more sensitive). The overall sensitivity scores (Table 16) indicates that the area that is most sensitive to climate change is the Rooikaroo-Aurora area due to the expanse of wheat and the livestock activities that occur in the region (CropFarmMapper). The socio-economic index, as described for the water resources, was also included in the sensitivity score for agriculture.

Table 16: Agriculture sensitivity score.

AgriSmart zone	Sensitivity score
Rooikaroo-Aurora	High
Swartland	Medium
Sandveld-south	Medium
Piketberg	Medium low
Bokkeveld	Medium low
Average	Medium

5.4.3 Infrastructure (Inland and coastal)

5.4.3.1 Impacts

The combination of more consecutive dry days, reduced precipitation, and increased temperatures due to climate change, can pose significant challenges to infrastructure in the municipality (Table 17), particularly in areas with informal housing, poor municipal service delivery, and a reliance on electrical substations and powerlines.

Table 17: Impacts of climate on infrastructure.

Climate hazard	Possible impacts
Increase in consecutive dry days	• **Informal housing**: Prolonged dry periods can lead to increased stress on informal housing structures, which may not have adequate roofing or drainage systems to handle extreme weather conditions. • **Road infrastructure**: Increase in consecutive dry days can lead to the deterioration of roads. • **Powerlines:** An increase in extended dry periods could lead to increased wear and tear on power lines. This can reduce insulation effectiveness and/or increased fire risks.
Reduction in precipitation	• **Infrastructure facilities**: Reduced rainfall can affect the water supply, sewerage systems, and other infrastructure facilities, leading to disruptions and maintenance challenges. • **Electrical substations and powerlines**: Lower precipitation can increase the risk of wildfires, potentially damaging electrical substations and powerlines, causing power outages and infrastructure damage. • **Informal housing**: A decrease in water availability can exacerbate sanitation issues in informal housing areas.
Increase in temperature	• **Informal housing**: Higher temperatures can lead to discomfort and health risks for residents in informal housing, as they may lack proper insulation or cooling systems. • **Rural population**: Rural communities may face heat-related health problems, and the increased demand for cooling systems can strain the electrical infrastructure. • Increases in the daily maximum temperature may result in additional stress on roads, potentially causing cracks and potholes.
Increase in wildfires	• This can damage power lines and disrupt electricity supply.
Increase in storms	• **Electrical substations and powerlines**: Although the projections don't seem to indicate an increase in rainfall and storms, the precipitation data is very uncertain. If there were to be an increase in storms this could poses a significant threat to Bergrivier's aging overhead electrical cables and infrastructure, making the municipality more vulnerable to power outages and damage during frequent thunderstorms.

Climate hazard	Possible impacts
	• **Roads**: This would lead to increased stormwater and would affect stormwater drainage. • **Sewage systems**: Increased storms leads to an increase of stormwater runoff which flows into the sewerage systems. In addition, houses often have their roof storm water flowing into the sewerage system further increasing the pressure on sewerage systems.
Coastal flooding and erosion	• Damage to coastal properties and local businesses. • Destruction of infrastructure.

<u>Coastal infrastructure impacts</u>

Coastal infrastructure will be impacted by sea level rises, coastal flooding, and coastal erosion. As per the South African Demarcation Board, the Bergrivier Municipality's coastline spans a distance of 46 kilometres. Figure 40 shows some of the coastal erosion happening around Laaiplek (images received from Bergrivier Municipality). The Berg River Estuary is considered the third most crucial estuary in South Africa in terms of its conservation significance. These estuaries are valuable assets that make substantial contributions to the local economy, through the tourism and fishing sectors (DEA&DP, 2021). Coastal erosion will turn costly for municipalities that need to protect infrastructure and properties from rising water. This will increasingly lead to liability-related legal action from private landowners.

The WCDM Climate Change Response framework identified the following climate change-related risks to the coastal zone (WCDM, 2019):

- *Increased coastal erosion and inundation,*
- *Increased or permanent inundation of infrastructure and utilities,*
- *Impacts on private and public harbours and boat ramps,*
- *Increased erosion or deterioration of coastal defences,*
- *Loss of private property and community assets,*
- *Loss of beach width, and*
- *Changes to wetland and estuary ecosystems due to sea level rise, erosion, and saline intrusion.*

Figure 40: Coastal erosion in Laaiplek.

5.4.3.2 Exposure and sensitivities

Increasing population, discussed in section 5.5.1.2, will lead to increased pressure on the infrastructure; areas where high population growth is expected will therefore be more sensitive to climate change. The roads in these areas are more travelled, which can cause wear and tear, ultimately making these surfaces more susceptible to further damage due to climate change (such as increased heat, increased rainfall, and floods). Increased heat causes roads to expand and contract and creates cracks which can then be further expanded through floods.

Increasing population also means an increase in waste, and a higher demand for water and electricity. Electricity is particularly important as increasing temperatures and heat waves will mean an increased need for cooling devices which rely on energy. Energy transmission infrastructure (Figure 41) can be affected by high temperatures and extreme events. If transmission lines are in coastal zones, they can be impacted by sea level rise and coastal flooding. Transmission lines are also sensitive to floods and strong winds. Poor maintenance means an increased sensitivity to climate impacts. High temperatures can also lead to increased vegetation fuel loads, and this means an increased risk of veldfires.

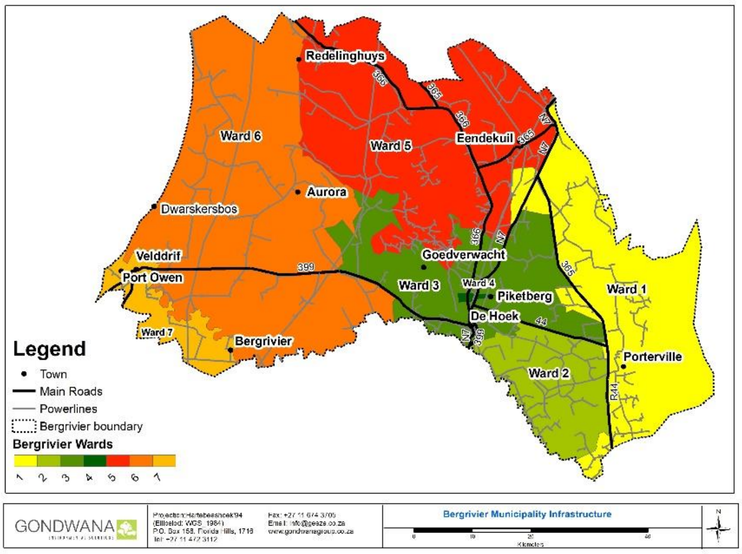


Figure 41: Powerlines and main roads in Bergrivier Municipality.

Areas of high economic growth will also put more stress on the infrastructure, making it more vulnerable to climate change impacts. The Economic Development Strategy (BM, 2019a), indicates that there are plans to encourage further industrial growth in Piketberg, and Velddrif who will be looking to build on value chain opportunities arising out of the increased investment in Saldanha Bay. The climate projections do not seem to indicate an increase in floods, but the precipitation data is very uncertain.

An issue which was highlighted by stakeholders is that with an increase in storms or storm intensity there is an increase in stormwater runoff which flows into the sewerage systems thereby putting pressure on the sewerage infrastructure. In addition, houses often have their roof storm water flowing into the sewerage system, further increasing the pressure on sewerage systems. Infrastructure that is situated in heavily vegetated areas would be at greater risk to wildfires. Increased CO_2 fertilisation can lead to increased fuel loads in natural vegetation areas and, with drier conditions, makes these areas more prone to fires.

5.4.4 *Coastal sensitivities*

The Bergrivier Municipality has significant infrastructure and many settlements located within the coastal zone. Based on sea-level rise scenarios combined with the risk posed by coastal erosion, the majority of the municipality's coastal infrastructure is at risk, including but not limited to, recreational facilities, water management infrastructure and transportation infrastructure (ports and roads). Increasing coastal floods lead to an increase in exposure of pipelines to salinity which risks a more rapid deterioration of the pipelines. Rising sea levels and their impacts are evident along the west coast, and properties are already being affected by the erosion. This is having significant impacts on resorts along the coast and will have consequences for tourism and the economy in the region. The areas that are most sensitive are the Berg River Estuary region and the coastal region between Port Owen and Dwarskersbos, as much of the infrastructure is found between these two tourist towns (Figure 42). The sewerage pipelines in Velddrif are located in the Stywelyne Beach Resort and Admiral Island, and there are reports that there is deterioration of these pipelines due to erosion. This would lead to contamination of the already saline estuaries.

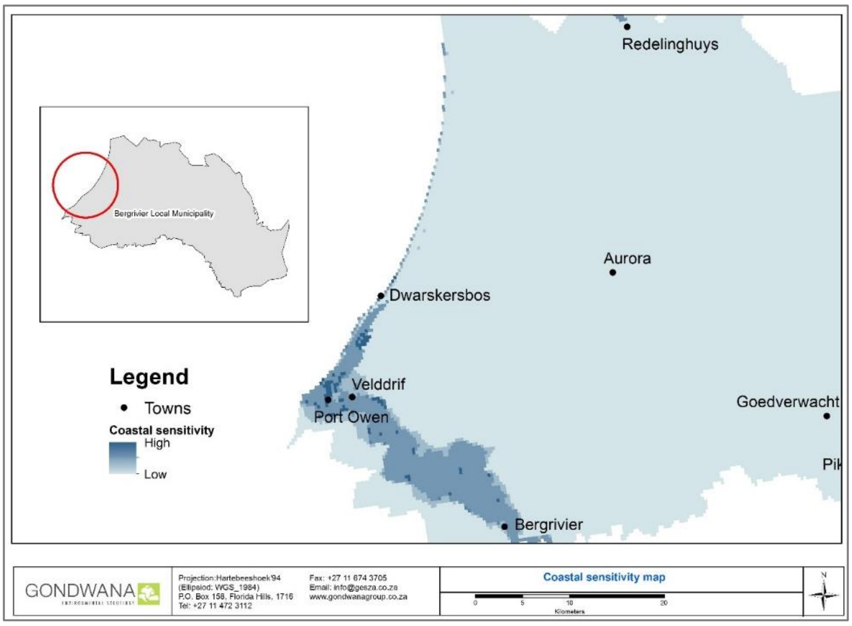


Figure 42: Coastal sensitivity to flooding and erosion in the Bergrivier Municipality (Source: DEA&DP, 2023).

5.4.4.1 Sensitivity score

An infrastructure sensitivity score (Table 18) was developed for each main urban town, considering the infrastructure in the area, the condition of the infrastructure, the population growth rate and economic growth potentials. As with the other sectors, the socio-economic index was also included in the score.

Velddrif had the highest score, followed by Piketberg. These two towns have the greatest infrastructure, population and expected growth, all of which will put pressure on the infrastructure. Velddrif has the added component of sea level rise, coastal flooding and erosion which impacts the infrastructure along the coast.

Table 18: Infrastructure sensitivity score.

	Sensitivity score
Piketberg	Medium high
Porterville	Medium
Velddrif	Medium high
Dwarskersbos	Medium high
Eendekuil	Medium
Aurora	Medium
Redelinghuis	Medium
Goedverwacht	Medium
Wittewater	Medium
Average	Medium

5.4.5 Biodiversity

5.4.5.1 Impacts

Bergrivier Municipality is characterised by its diverse ecological areas, including wetlands, grasslands, and forests (Figure 43). Climate change may have a number of direct impacts (Table 19) on the natural environment which could lead to further indirect impacts.

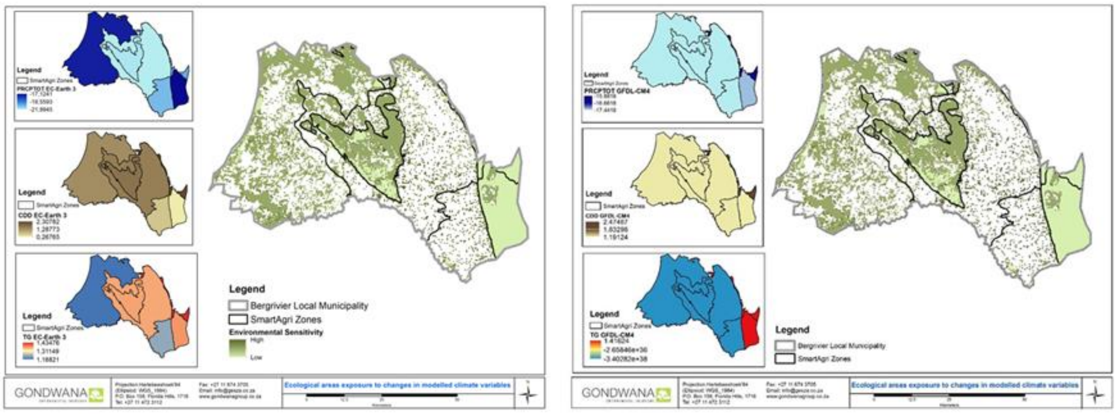


Figure 43: Ecological areas exposure to climate change variables in the Bergrivier Municipality.

Table 19: Potential impacts of climate change on the natural environment.

Climate hazard	Potential impact
Decreases in rainfall	• Reduced rainfall during the wet season has led to declining water levels in local rivers and wetlands. This has negatively impacted aquatic ecosystems and reduced the availability of water for local flora and fauna. • Reduced precipitation and declining groundwater levels, as well as possible water quality impacts, could increase the risks to wetlands and estuaries. Declining streamflow could impact on the salinity and ecosystem dynamics of estuaries.
Increasing temperature	• Rising temperatures trigger more frequent heatwaves. This causes stress to plant and animal species not adapted to such extreme heat. Some native species are struggling to survive, while invasive species are thriving in the new conditions.
Increase in consecutive dry days	• Extended periods of consecutive dry days can increase the risk of wildfires in Bergrivier. These wildfires have the ability to damage large swathes of natural habitat, threatening the survival of local wildlife.
Floods	• Low lying areas will be flooded, and this could lead to the destruction of vegetation, particularly along water courses. This would impact wetlands and estuaries.
Sea level rise	• Sea level rise, along with low water flows, could lead to greater penetration of saltwater incursions which would alter the ecological characteristics of the estuaries.

5.4.5.2 Exposure and sensitivities

The Western Cape Biodiversity Spatial Plan (Pool-Sandvliet et al., 2017) identified areas that are protected as well as areas that are critical biodiversity areas and ecological support areas. The areas that are most sensitive to climate change are those that are not actually protected but are critical biodiversity areas that need to be maintained in their natural condition to meet biodiversity targets. These areas are very fragmented which makes them even more vulnerable to changes. The degraded areas are also more sensitive to climate change.

The Berg River Estuary is sensitive to climate change as increasing temperature and decreasing rainfall means increased water stress and decreased water flow. These climate conditions also lead to greater extraction of water from the river which further impacts the estuary. Coupling low water flows and sea level rises could lead to increased penetration of salt water which may change the ecological characteristics of the estuary thereby altering the types of plant and fish species present. On the other hand, if there was to be flooding, then the low-lying areas along the floodplain of the Berg River would be inundated, thus causing a loss of vegetation and habitat.

5.4.5.3 Sensitivity score

As for agriculture, the sensitivity score for biodiversity is determined for each AgriSmart zone as the biodiversity is now not within the urban areas but rather between the towns. The sensitivity is based on the data from the Western Cape Biodiversity Spatial Plan (Pool-Sandvliet et al., 2017) and includes the sensitivity of the Berg River due to saltwater intrusions and flooding.

Table 20: Biodiversity sensitivity score.

AgriSmart zone	Sensitivity score
Rooikaroo-Aurora	Medium
Swartland	Medium
Sandveld-south	Medium high
Piketberg	Medium high
Bokkeveld	Medium low
Average	Medium

Projected climate changes will have a profound effect on the likelihood of fires within the Bergrivier Municipality. Multiple factors contribute to these changes, including: (a) a decrease in rainfall intensity and moisture during the dry summer period, (b) rising air temperatures leading to increased evaporation rates and fuel dryness and (c) a potential increase in lightning storms (Hoffman, D., Gillson, & M., 2011). The rise in biomass and fuel production due to higher CO2 levels, which improves plant water-use efficiency, is a key factor that could greatly change fire patterns in environmentally sensitive areas (Bond, Midgley, & Woodward, 2003). When combined, these drivers will greatly influence the number of days with a high fire risk (Midgley, et al., 2005).

The ongoing invasion of various species poses a major threat to the fynbos ecosystem, escalating the fuel load and consequently increasing the fire hazard and risk (Van Wilgen & Richardson, 1985; Le Maitre, Kotzee, & O'Farrell, 2014). This invasion also has the potential to alter hydrological responses. These factors collectively contribute to identifying the Fynbos biome as the most vulnerable region in the country concerning disaster risks from wildland fires, particularly when compounded by patterns of urbanisation, agriculture, and potential impacts on water catchment areas (DEAT, 2003).

An understanding of vegetation-related fire hazards is pivotal for assessing the likelihood of fires in an environment with both flammable natural vegetation and invasive plant species. This knowledge is crucial for evaluating the potential hazards to human lives, assets, and livelihoods in the event of a fire. The vegetation-related components can be categorised into natural vegetation and invading plants, each with subtypes that either accumulate or do not accumulate sufficient fuels to sustain fires (Forsyth, Kruger, & Le Maitre, 2010).

In the context of the Bergrivier Municipality, certain areas, such as Leipoldtville Sand Fynbos around Aurora, areas between Redelinghuis and the Engelsman se Baken, the region from Redelinghuis to Paleisheuwel and from Paleisheuwel north to Alexandershoek, are identified as hazard areas due to their fynbos vegetation type; a classification which aligns with the findings of the Global Environment Facility (GEF) Fynbos Fire Project (2015). The Spatial Development Framework for Bergrivier (BM, 2019) reveals that Piketberg is dominated by mountainous fynbos vegetation, further emphasising the need for proactive measures to address the heightened fire risk in these identified areas.

5.4.6 Human Settlements

5.4.6.1 Impacts

Climate change can have significant impacts on communities (Table 21).

Table 21: Impacts of climate change on settlements.

Type of impact	Description of impacts
Health impacts	Higher temperatures can lead to heat-related illnesses and worsen existing health conditions. Reduced precipitation can result in water scarcity and affect community access to clean drinking water, potentially leading to health crises. Areas such as Bokkeveld, which fall in a high altitude plain, are observed to have high (1.41624) change in mean daily temperatures. The area has a large storage facility and good water resources. While the rest of the communities in Bergrivier will experience low changes across the agri zones.
Transport	Increased temperatures may lead to: • Increased rate of infrastructure deterioration such as pavement failure including cracking, rutting, potholes, flushing, and stripping • Corrosion of steel reinforcement in concrete structures due to an increase in surface salt levels in some locations. • Increased infrastructure maintenance cost for road repair and reconstruction work, causing traffic delays and emergency service response delays. Increased rainfall, flooding and sea level rise may lead to: • Increased rate of infrastructure deterioration, especially in areas with poor infrastructure maintenance history. • Temporary and permanent flooding of road, rail, port, and airport infrastructure. • Structural integrity of roads, bridges and tunnels could be compromised by higher soil moisture levels. • Potential destruction of bridges and culverts. • Erosion of embankments and road bases which leads to the undermining of roads or railways. • Increased risk of landslides, slope failures, road washouts and closures.

Type of impact	Description of impacts
Agriculture and food security	Reduced precipitation and consecutive dry days can result in drought conditions, which impact agriculture and food production. This can lead to food shortages and price increases. Most communities within the SmartAgri zones in Bergrivier are projected to having less consecutive dry days, except for some parts of the Cederberg which is north of Bokkeveld. This may be due to the rivers having a low storage capacity and hot to very hot summers.
Water resources	Decreased precipitation affects water resources, including rivers, lakes, and aquifers. Communities dependent on these resources for drinking water, irrigation, and industry, can face shortages. A few of the agricultural zones depend on groundwater as they have low storage capacity—including Cederberg, Sandveld-south and north, Piketberg and the Rooikaroo. Decreases in rainfall may see these communities struggling, especially the agricultural communities.
Economic	Changes in temperature and precipitation patterns can disrupt industries, such as agriculture, tourism, and energy production. This can lead to job losses and economic downturns in affected regions.
Goods and services	Extreme weather events can lead to displacements and shortages of the supply of good and services within the municipality.
Energy	Power lines may face increased demand due to higher cooling needs.

5.4.6.2 Exposure and sensitivities

Rural communities face various challenges, including health issues, weakened social connections due to limited access to essential services, unequal land distribution, poverty, and limited education opportunities. In times of climate-related stress, these existing challenges will intensify and become more difficult to manage, rendering rural communities highly susceptible to the impacts of climate change (Reid & Vogel, 2006). The young and the old will be more vulnerable to heat stress and increasing disease. They are also more likely to face more risk in the face of fires as they are less able to remove themselves from a situation. Education and poverty also reduce the communities' ability to adapt. Housing, and in particular Reconstruction and Development Programme (RDP) units, do not really consider climate resilience in their design and should instead be built to consider cooling, storm resilience and water and energy efficiency where possible.

The Bergrivier municipal area faces significant challenges in education and preparing for the job market, which are worsened by a low literacy rate. Skills development is a serious challenge as the youth is not prepared for the potential employment market. The overall picture with regard to skills is that 55.5 % of the population is considered “low-skilled” (BM, 2019a). Low education levels mean there is little understanding of the climate change situation and reduced comprehension of the activity types that could be implemented to build resilience and adapt to climate change.

5.4.6.3 Sensitivity score

The sensitivity score for human settlements was determined by incorporating information on informal dwellings, population age (young and old being more sensitive), access to services and the socio-economic score (refer to 5.4.1.3) The score is based on the human aspects, such as poverty rates, and the impacts and their living conditions. A score is provided for each of the main urban towns, but it also considers that there is a large non-urban population which will be at risk from climate change. From a community perspective these non-urban areas are most sensitive to the impacts of climate change, mostly due to the living conditions and the difficulty in getting to health care facilities from these outlying areas.

Table 22: Human settlement sensitivity score.

	Sensitivity score
Piketberg	Medium high
Porterville	Medium high
Velddrif	Medium high
Dwarskersbos	Medium
Eendekuil	Medium high
Aurora	Medium high
Redelinghuis	Medium high
Goedverwacht	Medium high
Wittewater	Medium high
Non-urban	Medium high
Average	Medium high

5.5 Adaptive capacity

5.5.1 Governance and institutional capacities

The Bergrivier Municipality has a Municipal Manager and 4 directorates, namely Corporate Services, Technical Services, Community Services and Financial Services. Town Planning and Environmental Management falls under Corporate Services and there is one environmental officer, whereas Technical Services includes all the upgrading and maintenance of infrastructure and distribution of electricity. Disaster Management sits under the Community Service directorate, as does Housing Administration.

Although municipalities do receive support and guidance from the national government and other agencies, such as the South African Weather Service, to support their adaptation efforts, proper co-ordination is lacking, particularly as regards funding. The Bergrivier Municipality has limited resources and capacity to manage climate change impacts but are still able to act and implement plans to adapt to climate change.

Community participation is another important aspect of responding to climate change, one which is emphasised by the municipality. Communication in local government matters is encouraged, as borne out by the establishment of a series of committees to address various aspects of governance and community needs related to climate change. These committees include both Section 79 and Section 80 committees—as per the Municipal Structures Act, Act 117 of 1998—each with a specific focus. This engagement occurs through structures like Ward Committees, the IDP Representative Forum, and Sector Engagements. These forums facilitate two-way communication between the community and the municipality, which is essential for addressing climate vulnerabilities at the grassroots level.

Coping with climate change requires the participation of all public sector agencies and departments, from national to local government level. As climate change is a transboundary issue it is essential that collaborative governance is both horizontal and vertical, to ensure that the climate change issues are adequately addressed, and that complementary skills and resources from all relevant local, regional, and national institutions are deployed (Leck and Simon, 2018). Currently, South Africa experiences challenges in this regard, from the transformation from agenda-setting and information exchange between adjacent municipalities, to the implementation of collaborative adaptation measures.

In Bergrivier Municipality there is co-ordination with the West Coast District Municipality and the Western Cape Provincial Government, who work together to ensure municipal plans are consistent with provincial plans and strategies. The Western Cape Government proposed an institutional framework for the province to respond to climate change (see Section 2.4) in a co-ordinated way (DEA&DP, 2023a). Here, the existing intergovernmental structures related to municipal-provincial interactions anchored by the MINMAY (Minister-Mayor) engagements are recognised.

5.5.2 Human resource capacity

Although the Bergrivier Municipality does have a full-time environmental officer, their role for the implementation of the climate related adaptation activities is administrative and it is within the jurisdiction of sector heads to allocate resources and budgets for the implementation of projects.

As such, their ability to effectively manage and implement the adaptation activities may be constrained by the municipality's budget. Financial and human resources are limited, which further reduces the adaptive capacity of the municipality.

5.5.3 Support

Work has taken place with municipalities in the Western Cape to support climate change responses at a local level. Two district municipalities (West Coast and Eden) and six local municipalities (Bergrivier, Cape Agulhas, Drakenstein, George, Mossel Bay and Saldanha Bay), have to date been supported through the Western Cape Government's Climate Change Municipal Support Programme (WCG, 2016).

5.5.4 Supporting plans and strategies

Municipalities in the Western Cape have been supported in the development of adaptation and mitigation plans, as well as integrated response frameworks or strategies, but many of these don't get approved by the municipal council. This is one of the key challenges experienced by municipalities when trying to focus on an issue like climate change which is considered by some to not be a direct mandate activity of the municipality (WCG, 2016). Bergrivier Municipality does have an adaptation plan and the main purpose of the current project is to update this plan and include mitigation activities.

Municipalities are realising the importance of incorporating climate change responses in planning and decision-making and are starting to mainstream these responses into their day-to-day operations. There is very little capacity or budget to take on an additional portfolio such as climate change at the local level, so the approach is therefore to mainstream and embed climate change into local and district level line functions and master planning. Accordingly, measures are included in the Integrated Development Plans (IDPs), Spatial Development Frameworks (SDFs), Disaster Management Plans (DMPs) and sector plans such as Electricity Master Planning, Water Demand Management, and Integrated Transport Planning. The mainstreaming of climate change in the Bergrivier Municipality is limited, even though it was identified in the previous adaptation plan. Mainstreaming will likely be a focus area for the updated adaptation plan.

5.5.5 Awareness and uptake of adaptation activities

Most stakeholders were not aware of the Bergrivier Municipality Climate Change Adaptation Plan of 2014. Many of the concerns and issues highlighted in the last adaptation plan are being raise again, and so there was very low uptake of the actions set out in the previous adaptation plan. Awareness is one of the big challenges in the municipality as community awareness is low and some of the challenges being experienced are not often linked by community members to being impacts of climate change. There needs to be improved awareness training to get communities thinking about climate change and its effects and how they can contribute towards building resilience to climate change.

There are some adaptation activities occurring in the municipality such as:

- *The Western Cape Government's SmartAgri plan is seen to be important for the future adaptability and resilience of the sector in Bergrivier. The SmartAgri plan is based on the division of the Western Cape Province into a number of derived Agro-Climatic zones which have then been assessed for their key features, and the likely impact of climate change (temperature change). The plan sets out a number of priority SmartAgri Projects which are:*
    - *Conservation Agriculture for all commodities and farming systems,*
    - *Restored ecological infrastructure for increased landscape productivity, socio-ecological resilience, and soil carbon sequestration,*
    - *Collaborative integrated catchment management for improved water security (quality and quantity) and job creation,*
    - *Energy efficiency and renewable energy case studies to inspire the transition to low-carbon agriculture,*
    - *Climate-proofing the growth of agri-processing in the Western Cape, and*
    - *An integrated knowledge system for climate smart agricultural extension.*
- *Agri-businesses in the Western Cape are already developing renewable energy (mainly solar photovoltaic) and energy efficiency programmes (WCG, 2016).*
- *Many wheat farmers in the Western Cape region are already implementing Conservation Agriculture Practices (WCG, 2016), so there is a good uptake of these adaptation activities. In addition, there are numerous case studies showing the advantages from a crop, environmental and cost perspective.*
- *In the IDP (BM, 2022), it is mentioned that the Department of Energy awarded a private company a license to provide solar energy to be fed into the Eskom grid for provision to the vicinity of Aurora; this provides corporate social beneficiation to this community. It also indicates that the municipality needs to look at an alternative energy supply for low-cost housing, although funding remains a challenge.*
- *The water audit report indicates there are some re-use practices at the various WWTW:*
    - *Porterville – on-site stream leading to farmer's irrigation dam,*
    - *Piketberg – irrigation of town sports fields and school fields,*
    - *Velddrif – irrigation of sports fields, and*
    - *Eendekuil and Dwarskersbos – run-off goes to farm dams for irrigation purposes.*

These are the types of actions that can be further built on or expanded.

5.5.6 Physical capacity and resources

5.5.6.1 Infrastructure

- Water:
    - *Water is supplied via independent water distribution systems to all the towns in the Bergrivier municipal area, except for Velddrif and Dwarskersbos that receive bulk potable water from the West Coast District Municipality. The raw water supply originates from both surface and ground water sources.*
    - *According to the Blue Drop Watch Report (DWS, 2023) Piketberg received a Technical Site Assessment score of 88%, which means it has fully functional infrastructure and processes with minor imperfections. The Piketberg water system, which serves a population of approximately 13,400 people, has a well-functioning and well-maintained treatment plant and distribution system.*
    - *The municipality also had a Green Drop Score of 72%, which is an increase from 44% in 2013 (BM, 2022b). The Wastewater Risk Ratings were at low risk (<50%) for the Porterville-, Dwarskersbos- and Eendekuil WWTW and at medium risk for the Piketberg- and Velddrif WWTW (50% - <70%). These aspects indicate that the municipality has the ability to manage the water quality which will improve its' adaptive capacity.*
    - *On the other hand, the IDP (BM, 2022) indicates that water source infrastructure in Piketberg, Velddrif, Aurora and Dwarskersbos will need upgrading by 2025, and water storage is in a bad state in Eendekuil and urgently needs to be upgraded. Water storage facilities in Porterville, Redelinghuis and Dwarskersbos will also require upgrades by 2025. Water storage will be critical in a warming climate and poor infrastructure can lead to a reduced ability to respond to climate change impacts, so it is essential to ensure water infrastructure upgrade requirements are met.*
- Roads:
    - *The maintenance and upgrading of the roads network are a challenge in the whole of the Bergrivier municipal area (BM, 2022), with storm water management also being a challenge in Piketberg and Porterville due to the geographical nature of the towns and the cost involved in ensuring sufficient storm water channels.*
- Electricity:
    - *The municipality is responsible for the distribution of electricity in all urban areas except for Goedverwacht, Wittewater and De Hoek which are private towns. The*

municipality only distributes electricity to a small portion of Eendekuil where the low-cost houses are situated, while ESKOM provides the areas not serviced by the municipality. Large parts of the networks however do not have backup power which can leave consumers without electricity in fault conditions. There are miniature substations and switchgear that should be replaced due to ageing and high risk of failure, and the Monte Bertha 11kV overhead line feeder in Porterville requires upgrading as it cannot sustain any further growth into the future (BM, 2019). Electricity infrastructure in Velddrif, Porterville and Dwarskersbos needs immediate attention, while the infrastructure in Piketberg and Aurora need to be upgraded by 2025 (BM, 2019). Electricity will be another critical resource in the future as, with rising temperatures, more electricity will be required for cooling purposes.

- Health:
    - *As discussed in section 3.6.*

5.5.6.2 Natural resources

Bergrivier Municipality does have access to natural resources, such as rivers, estuaries, wetlands, and protected areas which could aid in making the municipality more resilient should they be managed properly.

5.5.6.3 Financial resources:

The municipality has access to financial resources such as budgets and grants, which can be used to fund climate change adaptation. The budget will, however, vary annually, and this could limit the municipality’s ability to effectively manage climate change impacts.

5.5.6.4 Data and information

The municipality has access to data and information to assist them in making informed decisions regarding climate change planning. The Western Cape region invests in significant high-quality climate change research and has many projects and activities currently underway. For example, a Climate Change Knowledge Sharing Network has been initiated and funded by the ACDI (African Climate Change Development Initiative) of the University of Cape Town. The Bergrivier Climate Knowledge Network was established as a trans- and interdisciplinary network comprising academics from the University of Cape Town, government practitioners and local community members who focus on climate change issues within the Bergrivier municipal area and the Berg River (BM, 2019). This has resulted in academic research taking place within the municipality and a wealth of expertise and resources being on hand when required. The Western

Cape Provincial Government is also very well informed in terms of climate change and provides a wealth of knowledge and expertise which the Bergrivier Municipality can draw on and use for support.

5.5.7 Adaptive capacity summary

All of the factors discussed above were taken into consideration and a score allocated to get an adaptive capacity value that could be used for determining vulnerabilities in the municipality. Data for the factors was obtained, or in some cases were assigned a value (high (3), medium (2) or low (1)) based on information and expert opinion. Results indicate that Bergrivier Municipality has a medium adaptive capacity (Table 23).

Table 23: Adaptive capacity score.

	Sensitivity score
Governance	High
Human resource capacity	Low
Climate change plans and strategies	Medium
Awareness and uptake	Low
Infrastructure resources	Medium
Natural resources	Medium
Financial resources	Low
Data and information	Medium
Average	Medium

5.6 Climate change risks and vulnerabilities

To assess and measure vulnerabilities in the municipality, information concerning exposures, sensitivities and adaptive capacity was used in determining risk. Details concerning hazards and several climate variables were also considered. Further combining this with hazard information indicates the risks. Several climate variables (Table 11) were included in the assessment. The number of consecutive dry days and the increase in the number of days that have a mean daily temperature over 30°C highlight the impacts of heat stress and possible drought.

5.6.1 Overall vulnerability within the different sectors in Bergrivier Municipality

The Bergrivier Municipality, known for its thriving agricultural sector, is facing significant vulnerability to changes in groundwater and surface water as a result of climate change. The agricultural communities, predominantly located around Piketberg, rely heavily on groundwater for irrigation. However, the reduced rainfall and rising temperatures associated with climate change pose a threat to groundwater recharge. Consequently, areas within Sandveld-south and Sandveld-north are expected to experience moderate to high vulnerability.

In addition, the Bokkeveld zone is susceptible to increased evaporation from farm dams and a subsequent reduction in water storage capacity due to elevated temperatures. The Rooikaroo - Aurora zone similarly faces a hotter and drier climate, coupled with unpredictable rainfall patterns, which can place immense stress on water resources. This surface water vulnerability is particularly concerning in areas that lack access to surface water and are confronted with prolonged dry spells. The consequences of water scarcity can be far-reaching, impacting households, agriculture, and industries alike. The communities residing in Piketberg and Sandveld-south are especially at risk when it comes to changes in surface water availability.

Multiple factors contribute to community vulnerability in agriculture, including economic hardship, food security, water stress, migration and displacement, health impacts, and reduced crop yields. Communities in different AgriZones within Bergrivier may experience vulnerability differently due to climate variability. For instance, whilst commercial farming communities may be better equipped to adapt, small farmers and low-income communities, particularly those in the Hardeveld zone, may be more affected. Climate change will also impact the agricultural workforce, with a potential decrease in productivity due to increased thermal discomfort levels, especially during summer. This will particularly affect tasks related to summer and multi-year crop cultivation, potentially requiring adjustments to working hours and breaks. Bergrivier's rural areas, with a population of over 30 000, are largely dependent on agriculture. As climate change affects agricultural stability and productivity, it may lead to reduced labour demands and higher unemployment levels in the municipality, especially in Piketberg, the centre of agricultural practices.

The costs of upgrading the Wittewater water infrastructure within the municipality cannot be determined until the current network is evaluated. The Bergrivier Municipality recognises the seriousness of climate change and the impact of the current drought and has therefore embarked on a process of comprehensive study to assess the sustainability of water resources considering expected economic growth and investments.

Low-lying areas along rivers and floodplains, such as Port Owen, are prone to flooding during extreme weather events, impacting both ecosystems and human settlements. Porterville, situated south of the municipality, has a high ecological sensitivity and is susceptible to water scarcity and drought, leading to prolonged dry spells and depletion of water resources. Agricultural areas are at risk due to changes in precipitation, temperature, and the spread of pests and diseases, potentially affecting crop yields and livestock. Protected areas, such as nature reserves and conservation areas, may face challenges like shifts in biodiversity, the spread of invasive species, and altered habitat conditions. Regions heavily dependent on tourism may be affected by changes in weather patterns, which can influence visitor numbers and have repercussions for the economy.

In the human settlement assessment, the non-urban class was included as this group will be most vulnerable to climate change, as these areas have more informal dwellings and reduced access to services and health facilities. After the non-urban areas, it is Velddrif that is once again impacted by climate change due to the larger informal housing percentage than other towns, perhaps due to the influx of workers or traders trying to cash in on tourism opportunities.

To address these vulnerabilities, it is imperative for the Bergrivier Municipality to develop climate-resilient strategies, with a particular focus on enhancing water infrastructure. By doing so, they can better mitigate the potential impacts of climate change on their water resources.

6 CLIMATE CHANGE ADAPTATION STRATEGY

Municipalities are well placed to develop and implement effective adaptation strategies due to their close contact with local people, knowledge, and experiences. An adaptation strategy should be a systematic, proactive, and coordinated response to enhanced climate variability and projected climate change. The adaptation plans at municipal level will be informed by the various tools of governance available nationally, provincially, and local government therefore has an important role to play in scaling national and regional adaptation plans from national to local level.

Adapting to climate change impacts is context dependent and complex, thereby making it difficult to have uniformity in adaptive planning. However, authorities should note that an adaptation strategy does not seek to make the community immune to climate change but rather resilient to the impacts of it. Communities therefore take appropriate steps to address the vulnerabilities of their localities and prepare them for projected climate change impacts (Giodarno et al., 2014). Factors such as gender, poverty, and social standing contribute to vulnerability to climate change. The gender aspect of climate-resilient infrastructure may affect men and women differently and requires careful consideration during the research process. For example, in societies where women are traditionally responsible for water collection, access to piped water can empower women.

In the face of escalating climate change variability and its anticipated impacts, Bergrivier Municipality is confronted with a myriad of challenges. The foundation for strategic climate change adaptation and mitigation initiatives lies in a comprehensive review of the Bergrivier Municipality: Climate Change Adaptation Plan, 2014 and the current Bergrivier Municipality Climate Change Risk and Vulnerability Assessment, coupled with an understanding of past climate trends and climate change projections specific to the municipality.

Key elements identified in the assessment are the potential increase in mean daily temperature, an increase in the maximum number of consecutive dry days, and a variable reduction in rainfall days which highlight the impacts of heat stress and possible drought. These changes have significant implications for sectors already grappling with socio-economic challenges. Notably, the primary climate change concern for Bergrivier Municipality lies in its water resources. The potential for a reduction in water resources pose a significant threat to all sectors, especially agriculture and the community’s access to water (for drinking and household use), with cascading economic implications. Additionally, coastal flooding and erosion emerge as a crucial risk, potentially impacting the growing economic activities and tourism industry in the Velddrif and Laaiplek town areas.

In response to these vulnerabilities and risks, the municipality must identify and prioritise adaptation and mitigation strategies to respond to the already changing climate. This imperative stems from the need to strengthen municipal resilience across all socio-economic sectors, especially those already burdened by existing challenges in the face of inevitable climatic shifts. A holistic approach at both national and local levels is required, ensuring the allocation of limited public investment capital to sectors and regions most susceptible to climate-related challenges. Currently, investments in public infrastructure often do not take climate resilience into account. Addressing this gap requires municipal actors to enhance their capacity to utilise climate risk and vulnerability information for strategic and operational planning. Embedding climate resilience systematically in public investment projects and developmental planning is crucial for long-term sustainability.

Recognising the interconnected nature of climate change impacts on people, infrastructure, and the economy, makes it imperative to mainstream climate considerations into the fabric of sector-departmental plans, developments, and decision-making processes. Climate change should not be relegated to a standalone environmental concern but rather embraced as an extensive lens through which the municipality shapes its functions. To operationalise these principles, a structured action plan is proposed for the municipal response strategy. This plan will delineate climate risks specific to each economic sector, aligning responsibilities to ensure that sector departmental plans align with prevailing and anticipated climate change variabilities and impacts. This proactive approach is instrumental in steering Bergrivier Municipality towards a resilient and sustainable future amidst the challenges posed by a changing climate.

The overarching approach to adaptation, as identified in the National Climate Change Response Plan (NCCRP), focuses on the development of adaptation responses that are flexible in the face of changing conditions, take local context and local knowledge into account, and are informed by rigorous research. The NCCRP identifies a set of key adaptation related sectors including water, health, human settlements, agriculture, biodiversity and ecosystems, and disaster risk reduction and management, and advocates the inclusion of climate change into plans for these sectors (DEA 2011).

The Department of Forestry, Fisheries and the Environment (DFFE) has prescribed the Desired Adaptation Outcomes (DAOs) for South Africa (Table 24), which are meant to direct the monitoring and evaluation efforts throughout the country with respect to responses to climate change (DEA, 2019). The adaptation activities for Bergrivier Municipality across the various sectors will thus be aligned to these DAOs to better monitor and evaluate the implementation of the adaptation plans in the municipality.

Table 24: Desired Adaption Outcomes for South Africa (DEA, 2019).

	Desired Adaptation Outcome
Inputs to enable effective adaptation	
1	Robust integrated plans, policies, programmes, and actions for climate change adaptation.
2	Appropriate processes and mechanisms for coordinating climate change adaptation.
3	Accurate weather forecasting, reliable seasonal predictions, climate projections & effective early warning systems for extreme weather & other climate-related events provided.
4	Capacity development, education, and awareness programmes (formal and informal) for climate change adaptation.
5	Resources and capacity (technologies, knowledge, research, and other cost-effective measures) to deliver climate change adaptation.
6	Climate change risks, impacts and vulnerabilities identified and addressed.
Impacts of adaptation interventions and associated measures	
7	Systems, resources, communities, and sectors less vulnerable to climate change impacts.
8	Reduction in non-climate pressures and threats to human and natural systems.
9	Secure food, water and energy supplies available for all.

6.1 Water sector

Bergrivier Municipality will be affected by reduced water resources brought about by drier conditions (i.e. warmer temperatures and lower precipitation). Reduced water has far-reaching implications and impacts all sectors, from agriculture to settlements and tourism. Also, the increased extraction or decreased recharge in one area can lead to water implications for another which is why an integrated management and adaptation plan is needed.

The Risk and Vulnerability Assessment results indicate that, in terms of water resources, Velddrif is the town most at risk due to its increasing population and expected growth in economic activities, which will lead to higher demand for water. With dry conditions expected to increase, this situation will be exacerbated. Extraction for growing agriculture in the region will increase and, with drier conditions, recharge rates will be reduced. Even though the scoring is presented for each of the main urban towns, as this is where most of the data is available, it is noted that there are rural villages spread between the towns that will also be affected. In terms of residential sanitation service levels, farms constitute 7 151 of the total 21 111 residential consumer units in the Bergrivier Municipality, which is 34%.

It is crucial for Bergrivier Municipality to develop climate-resilient strategies to improve water infrastructure, promote sustainable water management practices, enhance water quality monitoring, and ensure equitable access to water resources. By addressing the unique vulnerabilities of these communities, Bergrivier can better prepare for and adapt to the impacts of climate change on water resources.

Approaches to water resources management that will facilitate adaptation to a changed climate can be broadly divided into strategic resource management, flexibility in water use allocations, water demand management and water conservation measures, contingency planning for extreme events such as floods and droughts, communication, optimising the operation of existing infrastructure and constructing new infrastructure (Table 25).

Table 25: Adaptation Priority Action Plan for Water sector in Bergrivier Municipality.

Actions	Activities Required	DAO Addressed
Current stressors to systems: Water scarcity due to reduced groundwater levels, increasing water demands, variability in rainfall, and deteriorating surface water quality. **Climate Change Risk:** Reduced water availability in the municipality. **Goal:** Ensure water security.		
Water Management Strategy	• **Review and update** the municipal Water Services Development Plan (WSDP) to integrate the climate change risk on water resources. • **Ensure** climate considerations are taken into account when developing / revising infrastructure master plans. • **Regularly** review and update the strategy based on emerging climate data. • **Implement** emergency response plans for water scarcity periods. • **Conduct** feasibility studies for alternative water sources such as desalination of saline water sources. • Local Water Sector Plans – to be aligned with the Western Cape Integrated Drought and Water Response Plan.	1,2
Water Monitoring	• **Implement** a groundwater monitoring system. • **Monitor** stream flow and water levels, particularly for improved infrastructure planning and development. • **Install** water efficient taps in households, businesses and municipalities that have piped water.	2,9
Water conservation	• **Conduct** awareness and education campaigns for water conservation. • **Encourage** rainwater harvesting for flushing toilets, car washing, and irrigation. • **Provide** incentives to install gutters and tanks for rain harvesting in low-income communities. • **Identify** water losses in the water supply system and early leak detection mechanisms (within town infrastructure). • **Accelerate** the removal of alien invasive plant species (especially vegetation) and bug weeds (particularly from around water systems).	4, 7

Actions	Activities Required	DAO Addressed
	• **Collaborate** with DWS and other institutions to establish water consumption targets for all sectors and monitor water use e.g., irrigation.	
Conserve and restore aquatic ecosystems	• **Protect** and preserve wetlands and aquatic systems. • **Implement policies** that prevent development on wetlands. • **Rehabilitate** aquatic systems. • **Conduct** awareness and education campaigns. • **Ensure** adequate freshwater flow to estuaries as per required ecological reserve determinations.	1, 2, 4, 5 & 7
Flood and storm water management	• Storm water management plans to be updated with relevant and up to date flooding information and changes in rainfall patterns. • **Promote** the planting of indigenous vegetation around riverbanks to control runoff. • **Rehabilitate** riverbanks with natural vegetation. • **Provide** suitable access to rivers with erosion in mind. • **Improve** management of storm water. • **Investigate** alternative use of storm water. • **Avoid** and **remove** development within flood risk areas.	4, 5, 9
Water demand management/ Water supply	• **Monitor** unlawful water use and **Institute** measures to optimise water consumption patterns. • **Implement** technologies and policies that enhance water use efficiency across sectors. • **Establish** a cross-sectoral, inter-departmental governance framework to help integrate and mainstream climate change adaptation into all water related operations.	6,5,2

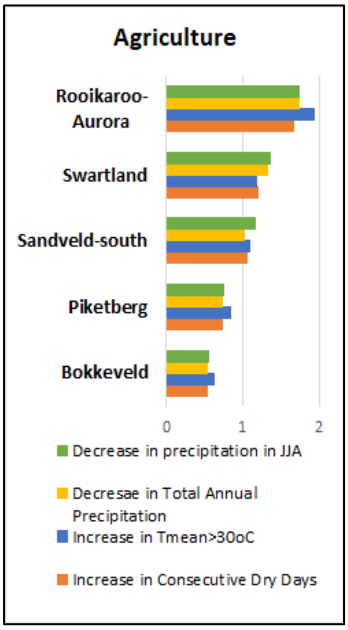
6.2 Agriculture sector

Income from the agricultural sector contributes significantly to the local Bergrivier Municipality economy. This sector consists mainly of:

- *Commercial small grain production,*
- *Diverse commercial irrigated crop production,*
- *Commercial irrigated potato production,*
- *Commercial dryland rooibos tea production,*
- *Subsistence crop and animal farming, and*
- *Commercial livestock and poultry production.*

The adaptation strategies for the different groups will differ significantly. The Long-Term Adaptation Scenarios Report for Agriculture (DEA, 2013) indicates that adaptation is about large-scale commercial farmers optimising climatic conditions to maximise output in a sustainable manner and to maintain a competitive edge. On the rural livelihood scale, adaptation needs to focus on the most vulnerable groups and areas so that livelihoods are not eroded by climate events. Instead, the affected communities should become more resilient to the expected changes in climate.

Not surprisingly, the agricultural areas in Rooikaroo-Aurora and Swartland area—the main agricultural zone—are indicated to be most affected by climate change. Rooikaroo-Aurora is the main wheat growing area and wheat may be affected by the warming temperatures and the shifts in the rainfall patterns. There is indicated to be reduced precipitation during the June, July, and August (JJA) period in this zone. This zone was also highlighted in the Smart-Agri Status quo report as being increasingly marginal for wheat. Livestock are also impacted, particularly the feedlots, piggeries, and chicken batteries where more intensive farming occurs and there are several of these (CapeFarmMapper) situated in the Rooikaroo-Aurora area. A similar pattern is seen for increased fire and floods.



The are multiple factors that contribute to community vulnerability when it comes to agriculture. These include, but are not limited to, economic hardship, food security, water stress, migration and displacement, health impacts and reduced crop yields.

- *Communities located within the different Agri Zones within Bergrivier municipal area will experience vulnerability differently due to the variability of the changes in climate factors Commercial farming communities may not experience these changes as extremely as small farmers and low-income communities as they are equipped with resources to adapt.*
- *The effects of climate change will extend to the agricultural workforce as well. A rise in thermal discomfort levels resulting from climate change, particularly during the summer season, suggests a potential decrease in the productivity of agricultural workers, as indicated by the DFFE (formerly known as Department of Environmental Affairs) (DEA, 2013). This impact will be particularly significant for those involved in tasks related to summer and multi-year crop cultivation. Consequently, adjustments to working hours and starting times may be necessary, with the potential need for longer midday breaks to address these challenges.*
- *The rural areas of Bergrivier Municipality consist of over 30 000 people, some of which are dependent upon agriculture. Piketberg has the second largest population, and it is the center of the agricultural practices within the municipality. As climate changes affect the agricultural sector's stability and productivity, it may lead to reduced labour demands and subsequently higher levels of unemployment within the municipality.*

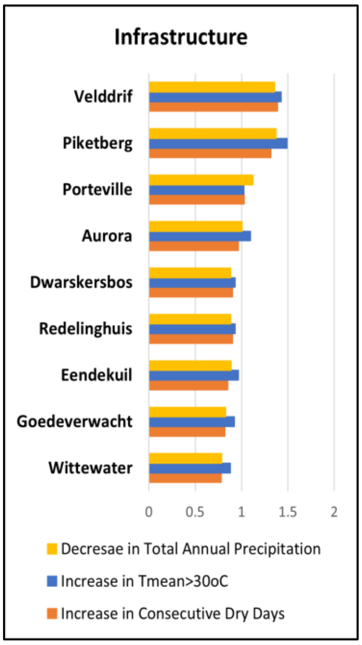
Considering the significance of the agricultural sector within the local economy of Bergrivier, it is imperative for farming enterprises and practices to undergo transformation in response to the challenges posed by climate change and vulnerabilities in resources, landscape, and habitat. In this context, the SmartAgri plan implemented by the Western Cape Government is perceived as crucial for fostering future adaptability and resilience within the Bergrivier agricultural sector (Table 26).

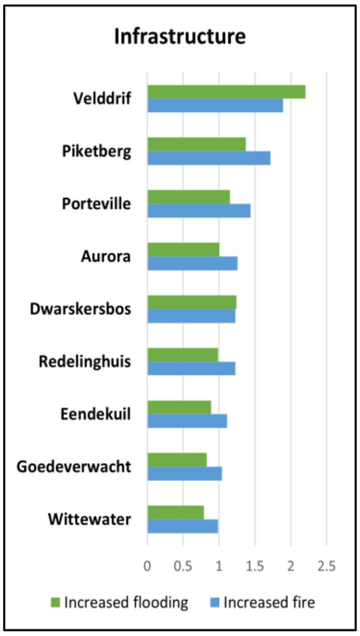
Table 26: Adaptation Priority Action Plan for Agriculture in Bergrivier Municipality.

Actions	Activities Required	DAO addressed
Current stressors to systems: Decline in water availability and quality for irrigation and livestock farming and farm dam storages. **Climate Change Risk:** Reduced water availability for agricultural use. **Goal:** Ensure food security and sustainable livelihoods.		
Food security	• **Preserve** agricultural land through good farming practices. Prevent fragmentation and preserving land for agriculture by reducing the need for land use conversions of high potential agricultural land. • **Protect** and develop productivity of agricultural potential through promotions and incentives in Bergrivier Municipality. • **Promote** the expansion of food garden programmes outside of land classified as agricultural land or farmland to reduce food insecurity and hunger. • **Promote** the development of vegetable gardens at schools and in household backyards. • **Support** subsistence farmers with farming knowledge to increase productivity.	9,1
Crop management and yields	• **Provide** access to and promote the cultivation of crops with higher heat tolerance, and shorter growing periods (e.g., short season maize), which will lower water requirements. • **Promote** diversification, e.g., mixed crops or mixed crops and livestock farming • **Promote** the cultivation of crops which can take advantage of higher ambient CO_2 conditions.	9,4
Control of flood water	• **Promote** natural vegetation buffers along rivers on farms. • Decrease wind erosion and flood runoff by using belts of natural vegetation (not alien species).	10,9

Actions	Activities Required	DAO addressed
Water availability for irrigation	• **Implement/ Improve** the groundwater monitoring system. • **Investigate** the long-term costs and benefits of groundwater extraction for irrigation purposes. • **Support** the agricultural sector to use and manage water more sustainably through the promotion and subsidisation of water conservation technologies. • **Enforce** compliance with water use allocations and license conditions and prosecute water theft.	1
Sustainable farming practises	• **Collaborate** with the district and Department of Agriculture and capacitate farmers in the municipality on changes in agricultural management practices, such as a change in planting dates, row spacing, planting density, cultivar choice, and other measures, which would counteract the effects of limited moisture. • **Promote** crop rotation. • **Establish** the stages of converting to conservation agriculture and the necessary steps. • **Promote** conservation, regenerative and climate smart agriculture by incentivising conversion through subsidies. • **Conduct** awareness campaigns explaining conservation agriculture and the conversion steps. • **Increase** the efficiency of irrigation through maintenance of infrastructure. • **Establish** a local resource and training center for conservation agriculture. • **Integrate** agroforestry into existing farmer-support programmes.	10, 4
Livestock farm management	• **Promote** planting of indigenous trees (or agroforestry) to improve shading for livestock and labourers. • **Provide** early warning of imminent disasters, particularly to vulnerable communities (See Disaster Risk Management on 6.7). • **Prepare** veterinary animal health services for the potential spread in animal diseases in collaboration with the district and province. • **Monitor** livestock and game stocking densities on farms to prevent overgrazing and land degradation. • Currently farmers purchase water for livestock farming, **Establish** water-efficient systems for livestock farming, including improved watering systems and water recycling. • **Educate** farmers on the optimal times for watering livestock to reduce water consumption.	3, 4, 2
Community-Based Climate Information Systems and knowledge sharing	• **Establish** community-based climate information systems to provide farmers with accurate and timely weather forecasts. • **Train** farmers to interpret climate information and adjust their farming practices accordingly. • **Facilitate** collaboration between farmers, agricultural experts, and research institutions to share knowledge and best practices for climate-resilient agriculture. • **Establish** a platform for farmers to share their experiences and learn from each other.	4,5

6.3 Infrastructure (Inland and Coastal)





In terms of infrastructure Velddrif, followed by Piketberg, is most at risk to climate change impacts. This is mainly as most of the infrastructure is found in these areas and where growth, particularly economically, is expected in the future. Velddrif is particularly vulnerable as it falls within the coastal zone that is prone to coastal flooding and erosion. The infrastructure along the coast, between Velddrif (Laaiplek and Port Owen) and Dwarskersbos, is likely to be impacted by coastal flooding and erosion. There is also a lot of tourism in this area, and this will be vulnerable to changes in climate.

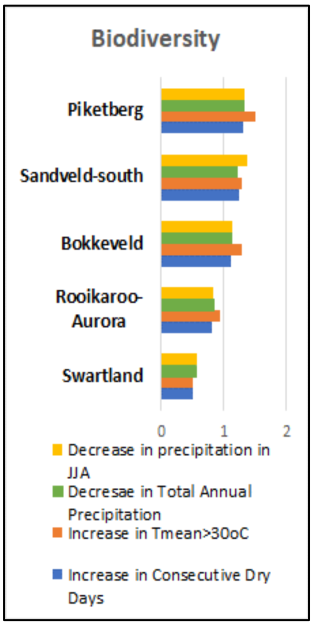
Secondary roads and dirt roads have the highest vulnerabilities, particularly to floods and wind. For powerlines, increasing temperatures will lead to increased wear and tear, but the main vulnerability with powerlines is related to fires. Powerlines in the Sandveld-south region, where there is more natural vegetation and increased fuel loads, will be more vulnerable. Increased load shedding and declining infrastructure will leave communities and businesses more vulnerable to climate change as electricity is essential for cooling and for pumping (water in particular). It will be essential to seek out alternative sustainable energy sources in the municipality, such as solar energy (Table 27). This will not only improve climate resilience but will also contribute towards a reduction in GHG emissions (i.e. mitigation activity).

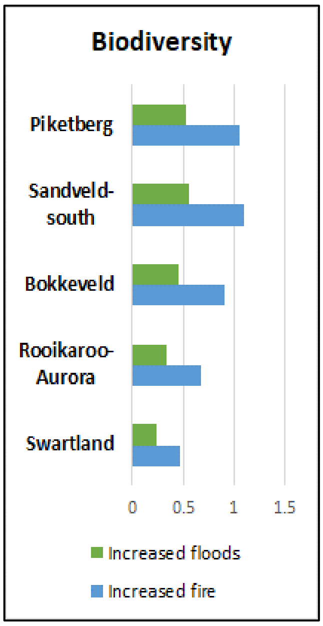
Table 27: Priority Adaptation Action Plan for Inland and Coastal Infrastructure in Bergrivier Municipality.

Actions	Activities Required	DAO addressed
Current stressors to systems: Deteriorating infrastructure. flooding of low-lying areas and coastal flooding and erosion causing infrastructure risk. **Climate Change Risk:** Increased coastal flooding and erosion and elevated wildfire risk. **Goal:** Enhance resilience and mitigate the impacts of climate change on critical infrastructure.		
Improve infrastructure: roads, storm water, and housing	• **Maintain** and upgrade storm water infrastructure. • **Improve** road infrastructure to become resilient to climate change. • **Maintain** and **improve** natural barriers for storm water surges (such as wetlands in more rural areas, indigenous trees as barriers, estuarine functional zones, coastal vegetation, and primary dunes). • **Convert** municipal buildings to Green buildings. • **Support** new housing schemes which are resilient to climate change impacts and introduce innovative water conservation, water efficiency and sanitation measures, as well as energy efficient technologies. • **Introduce** low-carbon transportation infrastructure in new housing schemes, ensuring that pedestrian walkways and cycling lanes are strategically placed near key transport hubs and amenities such as schools, shopping centers, and healthcare facilities etc. • **Implement** policies for future development projects to include a climate change risk assessment when following pertinent procedures like Environmental Impact Assessments (EIAs) and Water Use Licenses (WULAs) to align with Bergrivier Municipality's sustainability development objectives.	5,8,9
Reduce physical isolation of rural communities	• **Identify** alternative access routes to rural communities. • **Identify** roads at risk of flooding and erosion and prioritise those for upgrading and maintenance. • **Identify** local responses that will reduce isolation of rural communities.	8

Actions	Activities Required	DAO addressed
Coastal Infrastructure Protection	• **Conduct** a comprehensive assessment of comparative costs and benefits, to inform the selection of appropriate coastal adaptation measures to mitigate the impact of coastal flooding and erosion in vulnerable areas like Velddrif, Laaiplek and Port Owen. • **Explore** natural coastal defenses such as dune restoration, mangrove conservation, and wetland preservation for cost-effective and recreational-friendly solutions. • **Evaluate** planned retreat as an option, allowing natural processes and relocating infrastructure from high-risk areas. • **Implement** zoning regulations to restrict new developments in high-risk coastal zones. • **Conduct** regular risk assessments to identify vulnerabilities and adapt tourism infrastructure accordingly.	5, 6
Powerline Protection	• **Implement** regular inspections and maintenance programs for powerlines, particularly in the Sandveld-south region which faces higher fire risk. • **Introduce** firebreaks along powerline routes to reduce the risk of fire spreading to critical infrastructure. • **Upgrade** the old overhead powerline infrastructure and include underground cables to enhance reliability and efficiency. • **Pro-actively** identify routes for new powerlines to service renewable energy generation facilities.	5,6, 7, 9

6.4 Biodiversity





The areas in the Piketberg and Sandveld-south zones are most at risk of climate change. These areas are where the majority of the unprotected critical biodiversity zones occur. These areas are very fragmented which increases their vulnerability. The other main risk to these biodiversity areas is alien invasive species. There was insufficient data on the distribution of alien invasives to really include this in the assessment as this would highlight further vulnerable areas. Alien invasive species are also a threat to existing protected areas such as those found in the Bokkeveld zone. All these biodiversity areas are also critical for maintain ecosystem services and will play a critical role in recharging ground water supplies.

Another large threat to biodiversity is fire and, as temperature increase and rainfall decreases, so the risk of fire increases. These fires then also threaten neighbouring settlements and powerlines.

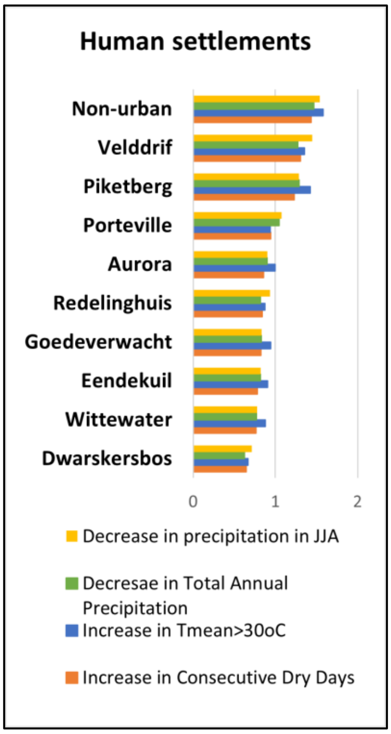
Biodiversity in the Bergrivier Municipality supports tourism and so any impacts on biodiversity will also have consequences for tourism and the economy. Regions heavily reliant on tourism may be impacted by changes in weather patterns, affecting visitor numbers and, by inference, the economy (Table 28).

Table 28: Adaptation Priority Action Plan for Biodiversity, Environment and Tourism in Bergrivier Municipality.

Actions	Activities	DAO addressed
Current stresses to systems: Invasive alien species, Habitat fragmentation, unprotected critical ecological areas, land use change **Climate Change Risk:** Fire risk and ecosystem services risk **Goal:** Conservation and protection of critical biodiversity areas and preserve ecosystem services		
Conservation of biome areas and wetlands	• **Identify** habitats of significant value for consolidation through purchase or conservancies. • **Establish** and enforce regulations to protect climate corridors and critical biodiversity zones in accordance with the recent Western Cape Biodiversity Spatial Plan, particularly in the Piketberg and Sandveld-south zones. This includes implementing land use planning that not only minimises fragmentation but also prioritises the creation and preservation of corridors connecting key habitats. • **Integrate** climate considerations into infrastructure planning to protect biodiversity areas.	1,2, 9
Ecosystem Services	• **Communicate** the importance of biodiversity areas in maintaining ecosystem services, particularly in recharging groundwater supplies within the municipality. Implement measures to ensure the continued provision of these services, including sustainable land management practices.	
Rehabilitation of natural ecosystems	• **Promote** the planting of indigenous plant and tree species to *green* the urban areas (see Human Settlement Adaptation Table 5.4.6). • **Rehabilitate** degraded land such as landfill sites and riverine areas. • **Restore** and rehabilitate degraded wetlands. • **Accelerate** the removal of alien invasive plant species. • **Conduct** information and awareness campaigns to inform the public about alien species.	1, 9
Community Engagement and Education	• **Engage** local communities in biodiversity conservation efforts. Conduct educational programs to raise awareness about the importance of biodiversity, the threats it faces, and the role communities can play in conservation. • **Facilitate** stakeholder engagement initiatives to promote ecotourism and greening projects in economic areas. • **Collaborate** with private landowners to establish land banking initiatives for biodiversity conservation, ensuring compliance with legislative requirements.	

6.5 Human Settlements

In the human settlement assessment, the non-urban class was included as this group will be most vulnerable to climate change.



The gender aspect of climate-resilient settlements is significant. Climate change vulnerability is shaped by various socio-economic factors, which encompass gender, poverty, and social standing. Men and women might have distinct requirements for infrastructure services. For instance, in societies where women are traditionally responsible for water collection, access to piped water can play a pivotal role in empowering women.

Community-based adaptation activities should be considered in these areas. This is where interventions are tailored to the specific needs of the social groups within the community.

This process should include (Mitchell & Tanner, 2006; CARE, 2014):

- *a thorough understanding of local factors and context,*
- *helping communities develop an understanding of the main climate risks and how they impact the community (through a learning-by-doing approach),*
- *promoting inclusive and informed participation and decision-making, thereby empowering local stakeholders to participate in and contribute to adaptation processes,*
- *emphasizing active participation of community members in all stages of an adaptation intervention (design, implementation, monitoring),*
- *encouraging the strong participation of women, recognizing their role as community resource managers, whilst also acknowledging their specific roles and vulnerability to climate risks, and*
- *investing in long-term resilience-building efforts, which also meet immediate development needs.*

In this sector, four main areas for adaptation have been identified, namely:

- *Infrastructure maintenance and improvement,*
- *Greening to reduce the heat island effect,*
- *Improved land use planning and*

- *Increasing access to basic resources in rural areas.*

Infrastructure needs to be maintained and improved to reduce the impacts of climate change. To reduce the impacts of flooding and increased runoff, storm water drainage systems need to be maintained and upgraded. Runoff can be slowed by improving natural barriers and increasing the water holding capacity, by harvesting rainwater and increasing vegetation cover for example.

Climate change must be taken into consideration during the building process to avoid costly impacts in the future. Neglecting this crucial aspect could result in various problems, such as sick building syndrome, roof and drainage issues, deterioration of cladding and exterior façade, and foundation problems. Moreover, adopting a proactive approach to understanding and addressing these issues presents an opportunity to enhance buildings with alternative green technologies. By doing so, we can reduce vulnerability to climate change impacts and minimise emissions. This not only benefits the environment but also offers long-term economic advantages.

Greening of town areas improves their resilience to climate change. Trees absorb the carbon dioxide released by industries and release oxygen, which is vital for human beings to breathe. They also prevent soil erosion by holding water during heavy rainstorms and provide windbreaks when planted in rows. Trees also reduce smog levels, absorb small particles and gases of air pollution, absorb rain, and thereby reduce the amount of water to be removed by stormwater drainage. One adaptation strategy is to increase the number of (indigenous) trees in the Bergrivier Municipal towns.

In rural areas, increasing access to basic resources will reduce the vulnerability of these areas to climate change. Other adaptations strategies discussed in the water, agriculture and human health sectors will also contribute to the resilience of rural areas (Table 29).

Table 29: Priority Adaptation Action Plan for Human Health in Bergrivier Municipality.

Action	Activities Required	DAO addressed
Current stressors to systems: Informal settlements, health facilities, growing population and economic activities. **Climate Change Risk:** Extreme weather events such as heatwaves, floods, and drought. **Goal:** Empower communities to adapt and become resilient to the changing environmental and climate conditions.		
Monitoring of health impacts	• **Conduct** public awareness campaigns on health risks due to increased temperatures and implement response actions (especially on the effects and management of heat stress). • **Observe** and monitor human health issues relating to extreme events. • **Monitor** the incidence and distribution of disease vectors. • **Support** research into the impacts of climate change on health.	4, 8
Early warning systems	• **Ensure** there is an early warning system in place. • **Identify** communities that have the least capacity to respond to increased temperatures or flood risks. • **Conduct** a detailed GIS mapping project to identify flood prone areas. • **Provide** early warnings of imminent disasters, particularly to vulnerable communities (link to Disaster Risk Management Adaptation Table on section 6.7).	3, 4, 5
Health care services	• **Maintain** and upgrade all health care services, especially mobile health care services, to deal with heat related and vector-borne diseases. • **Maintain** health care emergency services. • **Leverage** community health workers to communicate the hazards of climate change and the required adaptation strategies.	5, 8
Prioritise water and sanitation provision	• **Provide** adequate infrastructure and sanitation services to rural communities- such as Enviro-loo.	5,8

6.6 Waste Management

Timeous collection of refuse is important in maintaining a healthy living environment free from pests, odour, and disease. Accumulation of solid waste in undesignated areas also presents a problem during heavy rain periods where waste clogs up drainage systems and leads to flooding. The principles of waste separation, waste disposal and collection are especially pertinent as temperatures are projected to rise. Separation of waste reduces excessive odours during the hotter seasons. Bergrivier Municipality currently does not have any operational landfills. All household waste is collected every week, whilst business and other waste is collected upon request. The municipality has cooperative agreements with neighbouring municipalities—Swartland and Saldanha Bay Local Municipalities—to transport refuse to transfer stations located in Piketberg. From there, the waste is transported to the Highlands landfill located near Malmesbury. Waste from the Velddrif Transfer Station is directed to the Vredenburg landfill site (BM, 2019).

Table 30 lists the potential impacts of climate change on solid waste. These likely impacts cut across sectors to tourism, health, and water pollution, therefore the proper management of waste, as with most other sectors in a municipality, requires a holistic and cross sectoral approach.

Table 30: Potential impacts of climate change on waste.

Change in climate variable	Impact
Increased temperatures; increased heat waves	**Increase in odour and pests (rodents and flies) in unseparated waste,** • *influences the tourism experience and may lead to a reduction in visitors.* **Changes in decomposition rate of waste,** • *increases the risk of fires at dumping sites.* **Increased exposure of communities to flies which breed more in higher temperature and in rotting organic waste. This** • *leads to illnesses which increases the load on health care facilities and emergency services.*

Change in climate variable	Impact
Changes in frequency and intensity of rainfall events	**Increase in contaminated leachate during high rainfall seasons causes groundwater pollution.** **Increased extreme events can cause,** • *Stress on sewage systems and storm water infrastructure and* • *Blockages of storm water drainage system from uncollected waste.* **Increased costs due to**: • *Road maintenance or repair and* • *Emergency preparedness requirements.*

The adaptation options for the waste sector deal mostly with avoiding or reducing the amount of waste produced and promoting recycling and re-use. This also includes the improved use of biomass waste. In this way the amount of waste being disposed of in the landfill sites is minimised, thus leading to reduced emissions from these sites. Education and awareness programmes to inform the public of what and how to compost would assist the composting within the municipality.

Recyclable wastes should be separated as near to source as possible to limit the costs of labour and machinery associated with sorting after collection. This also prevents recyclables, like paper, being soiled by other waste products as, once paper or cardboard is soiled, it cannot be recycled. Therefore, an important aspect of waste reduction, re-use and recycling is community involvement; this and the requisite commitment is essential for the success of waste minimisation initiatives. One method of garnering the needed support is through the conducting of public awareness campaigns.

Companies, schools, NGOs, and community clubs/programmes should also be encouraged to support or promote recycling initiatives. Paper banks can be set up at schools, housing complexes, offices, and community organisations. Paper is usually collected by the established recycling companies or their agents, and the business is often paid a sum of money for the material recovered. Thus, not only is the business making money from the paper sold, but also saving money by disposing of less waste. Furthermore, if these initiatives are started in schools, they can also be used to educate the learners about the importance of recycling (Table 31).

Table 31: Plan for the Waste Sector in Bergrivier Municipality.

Action	Activities Required	DAO addressed
Reduce reuse, recycle	• **Encourage** formation of waste picker groups for paper and plastics so that informal waste collectors can integrate, improve, and regularise their operations. Communication to residents on a yearly basis. • **Promote** the composting of plant and food material. Residents are to be encouraged to collect free plastic container composters (to recycle food and plant waste). • **Conduct** public awareness campaigns for waste management in public areas such as taxi ranks and schools. • **Promote** digitisation by encouraging a decrease in the amount of material printed on paper. This could involve using digital formats for documents, reports, and communication wherever possible to minimise the use of paper. • **Implemen**t registration of commercial recyclers. • **Promote** recycling by providing suitable storage bins or facilities for different types of waste. • **Investigate** the purchase of other recyclable items for use in municipal departments. • **Collect** information on recycling material types and quantities for the municipality. • **Promote** and regulate reusable shopping bags, unpackaged products, and packaging reuse. • **Support** recycling initiatives in the form of by-laws that facilitate the location, operation, and use of these facilities. • **Enforce** sorting of waste at source.	1,4,7
Waste Collection	• **Maintain** and improve infrastructure for waste collection. • **Improve** waste collection services in rural areas.	7, 5
Landfills	• **Monitor** landfill sites licensed for closure to deter illegal dumping. • **Make** use of licensed regional landfill database	

6.7 Disaster Risk Management and Early Warning Systems

Due to climate change, Bergrivier Municipality is projected to experience rising temperature and increased incidents of droughts and floods. Under the Disaster Management Amendment Act 16 of 2015, the municipality is required to develop and implement a Disaster Management Plan which would incorporate and address the risks brought about by climate change. The Bergrivier Municipality should work hand in hand with West Coast District Municipality to implement the plan.

Disaster risk management entails:

- *Emergency preparedness,*
- *Effective early warning systems,*
- *Timeous response,*
- *Community involvement, and*
- *Resource/infrastructure availability to better respond to emergencies.*

The natural vegetation (fynbos and renosterveld biome) prevalent in the municipality puts the area at high risk of forest and veld fires (Figure 44). The increased number of hot days naturally increases the chances of fires occurring in Bergrivier Municipality. Various early warning systems should be established, and local government authorities need to work with stakeholders, including with communities at risk, to establish a strategic and operational partnership. Municipalities need to facilitate community participation through training, preparedness planning and awareness raising activities and programmes (DEA, 2016). Various government departments at national, provincial, and local level engage in different community outreach activities, such as the Extended Public Works Programme's Working on Fire (WoF) programme. Also, the Department of Agriculture conducts various programmes for farming communities on risks and disaster preparedness. In addition, there are other tools, such as the Advanced Fire Information System (AFIS) and ground-based lightning detectors and near-real-time warning system (Maqsooda, 2021) which could assist in detecting fires and reducing the impact of fire damage.

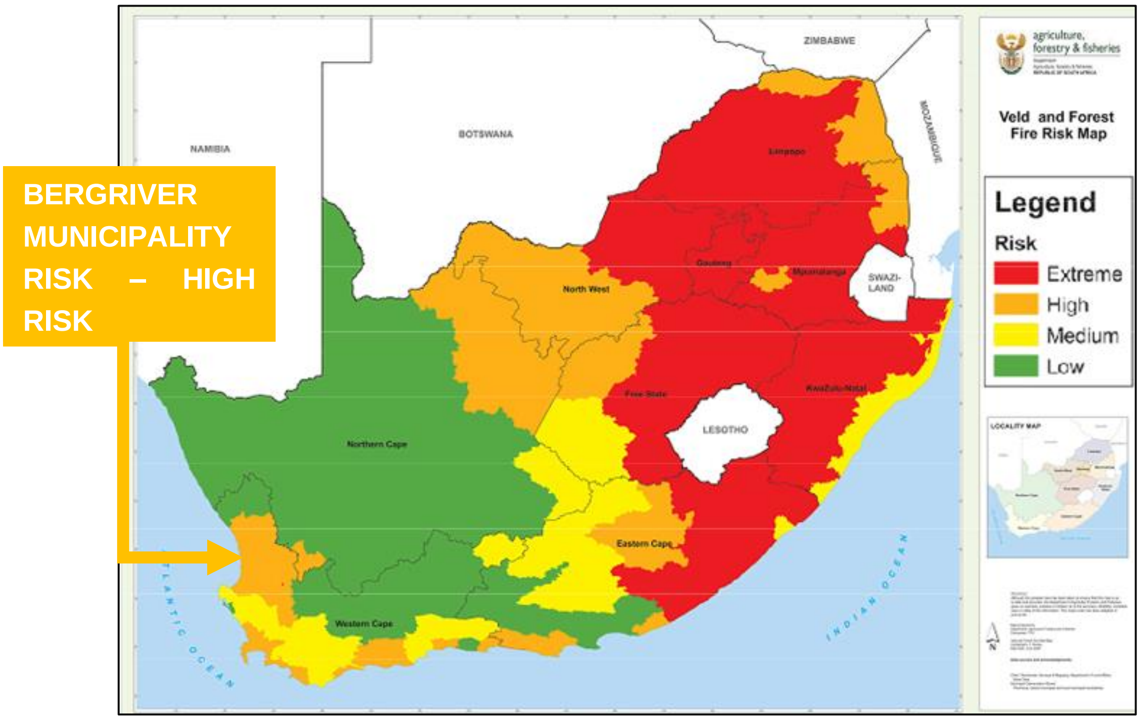


Figure 44: Veld and forest fire risk map.

Table 32 Priority Adaptation Action Plan for Disaster Risk Management in Bergrivier Municipality.

Action	Activities Required	DAO addressed
Disaster risk management planning	• **Update** a risk assessment as per the Disaster Management Amendment Act 16 of 2015 - **Support** the district in the Ward based risk assessment. • **Remain** active and **support** the district disaster management plan. • **Collaborate** with various provincial and national government departments, as well as communities, to **provide** disaster preparedness training.	1
Climate monitoring	• **Develop** links with water research institutes and SAWS to ensure early preparation for extreme events (such as flooding). • **Work** together with relevant departments to increase the number of climate monitoring stations in Bergrivier Municipality.	1,2
Reduce fire risks	• **Improve** fire breaks around vulnerable communities, agricultural lands, and cultural heritage sites. • **Link** to various fire detection early warning systems with the district and provincial government and local groups, FPAs, to provide advanced warning and assist with fire management. • **Ensure** that membership for the Greater Cederberg Fire Protection Associations (FPA) is renewed timeously to ensure the support and assistance of prevention and control of wildfires.	9

7 MITIGATION STRATEGY

The reductions of greenhouse gas (GHG) emissions are at the core of a climate change mitigation strategy. The impacts of GHG's on temperature increase and subsequent climatic changes make it imperative for governments structures to seek to reduce these emissions to slow down the effects of climate change. Greenhouse gas emissions play an important role in climate change and, for the developing of appropriate mitigation strategies, it is critical that countries adequately account for their GHG emissions by developing GHG inventories. South Africa is a signatory to international agreements such as the Paris Agreement where it has pledged to reduce its GHG contributions. In 2015 the country submitted its Nationally Determined Contributions where it indicates it commitments to shift from a "business-as-usual" into a "peak, plateau and decline" GHG emissions trajectory range, with the objective to cap its GHG emissions between 398 and 614 Mt CO_2e up until 2035 and decline in its GHG emissions from 2036 onwards.

South Africa's updated Nationally Determined Contributions (NDC) 2020/21 mark a substantial advancement from its initial commitment. The nation now pledges to cap greenhouse gas emissions at 398-510 MtCO2e by 2025 and 350-420 MtCO2e by 2030, a notable improvement from the 398 and 614 MtCO2e range specified in the first NDC for the period between 2025 and 2030. These targets, as identified by the DFFE, were based on an assessment of South Africa's "fair share" of global emissions for 2025 and 2030, with consideration for the latest science and the Paris Agreement's long-term temperature goal of keeping global warming to "well below 2 degrees Celsius" and making efforts to keep warming within 1.5 degrees. Furthermore, they were based on an assessment of the likely GHG emissions outcome of the implementation of current South African policies with a potentially significant mitigation impact, including the Integrated Resource Plan 2019 (IRP 2019), the draft post-2015 National Energy Efficiency Strategy, the Green Transport Strategy (GTS), and the carbon tax. Targets were set conservatively to consider uncertainties in the estimation of national GHG emissions and in policy implementation (DFFE, 2021).

Additionally, the revised NDC includes South Africa's inaugural adaptation communication, outlining comprehensive measures for adaptation. Notably, the country has set an ambitious target to achieve net-zero emissions by 2050 as part of its Low-Emission Development Strategy. Efforts to achieve this and other targets have been set in motion through the National Climate Change Response Policy. Whilst the targets may seem ambitious, considering the heavy dependence of the SA economy on fossils fuels, considerable financial and technical support may go a long way in ensuring that these targets are met.

This section of the report discusses possible mitigation measures[13] which could be implemented in the Bergrivier Municipality.

7.1 GHG Emissions background

7.1.1 GHG Emissions in South Africa

South Africa, like many other developing economies, relies heavily on the use of fossil fuels to produce energy. Recent developments have seen much discussion on how the country can incorporate renewable energy alternatives into the energy mix. As highlighted earlier in this report, carbon dioxide (CO_2) remains the largest contributor to South Africa's GHG emissions with a contribution of 83.6% of total emissions in 2020, with the energy sector contributing 94.7% of the CO_2 emissions (DFFE, 2022). The greenhouse gas (GHG) emissions profile of the Western Cape exhibited a similar trajectory in carbon emissions, wherein the energy sector accounted for 88% of the province's total emissions in 2018. This was followed by contributions from the waste (6%), agriculture, forestry, and other land use (AFOLU) (5%), and industrial processes and product use (IPPU) (1%) sectors (WCG DEA:DP, 2023).

Increasing anthropogenic GHG emissions have an indirect yet severe impact on South Africa's economy, natural environment, and people. Without the implementation of any mitigation measures[13], South Africa's emissions would continue to grow (Figure 45). Immediate action is required to mitigate emissions and scale up efforts for future reductions in line with the country's updated Nationally Determined Contributions.

[13]Actions which are implemented to slow down the build-up of greenhouse gases and remove them from the atmosphere.

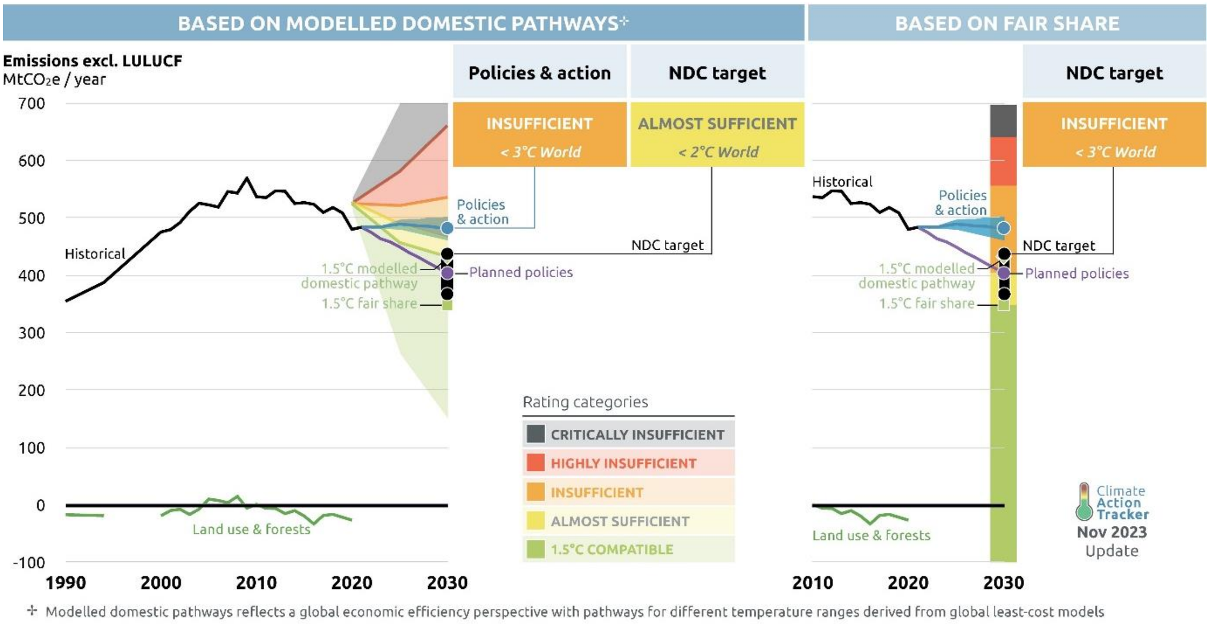


Figure 45: GHG emission reductions and limits under various scenarios (DFFE, 2021).

Marquard et al., (2011) suggested that South Africa adopt a two-stage mechanism for mitigation of GHG emissions. Firstly, since climate mitigation actions must begin immediately, there should be no delay in implementing a handful of key flagship mitigation programmes. Secondly, for the longer-term actions, a low carbon development plan should be established for future reductions. Marquard et al. (2011), also provided a ranking of mitigation measures by cumulative emissions (between 2003 and 2050) savings in relation to a 'Business as Usual' trajectory in the short, medium and long term (Table 33). This showed that industrial energy efficiency measures have the highest savings in the short term, but that electricity supply mitigation options had larger savings in the medium and long term.

South Africa's strategy to mitigate greenhouse gas (GHG) emissions between 2025 and 2030 revolves around a multifaceted approach aimed at transitioning to a low-carbon economy. This involves increasing the deployment of renewable energy sources, enhancing energy efficiency measures across sectors, and gradually phasing out coal-fired power generation while promoting cleaner alternatives as per the Integrated Resource Plan (IRP) 2019. The country's GHG mitigation strategy also includes exploring carbon pricing mechanisms to incentivise emissions reductions and drive investment in low-carbon technologies. Additionally, sustainable transportation modes are being promoted to reduce emissions from the transportation sector, alongside efforts to enhance carbon sinks through reforestation and afforestation initiatives. Adaptation measures to address climate change impacts are also prioritised. South Africa's new policy recommendations, as outlined in its Nationally Determined Contributions (NDC), emphasise the importance of these strategies while potentially introducing updated targets, regulations, and initiatives to align with international climate goals and advance the country's Low Emission Development Strategy (LEDS).

Table 33: Mitigation measures ranked by impact in the short, medium, and long term – largest to smallest for each time period. (Source: Marquard et al., 2011).

2010-2020	2021-2030	2031-2040
Industrial energy efficiency	Electricity supply options	Electricity supply options
Electricity supply options	Industrial energy efficiency	Industrial energy efficiency
Land use- fire/savannah	Synfuels CO_2 CCS	Improved vehicle efficiency
Waste management	Land use- fire/ savannah	Synfuels CO_2 CCS
Agriculture- enteric fermentation	Waste management	Passenger modal shift
Residential energy efficiency	Residential efficiency	Electric vehicle/ hybrids
Agriculture- reduced tillage	Commercial efficiency	Residential energy efficiency
Solar Water Heating system (SWH)	Improved vehicle efficiency	Commercial energy efficiency
Commercial energy efficiency	Electric vehicles	Waste management
Synfuel methane reduction	Afforestation	SWH
Afforestation	Agriculture enteric fermentation	Land use- fire/ savannah
Biofuels	SWH	Cleaner coal
Improved vehicles efficiency	Hybrids	Agriculture enteric fermentation
Passenger modal shift	Passenger modal shift	Biofuels

7.2 Climate change mitigation strategies for Bergrivier Municipality

This section articulates sector appropriate mitigation actions for Bergrivier Municipality. These actions can be implemented in the short, medium, and long term and have therefore been sectioned accordingly. The short-term mitigation measures are those actions which can be implemented in the short term and lay the groundwork for the long-term emissions reduction. Other actions may take time to put in place and so would only be implemented or become active in the medium and long term. Mitigation actions are progressive and may require significant changes in behaviour (at a personal and local level), technologies and policies (at a national level). Actions which may seem to have an insignificant impact on GHG emissions will in the long term, if widely adopted, result in significant reduction in emissions (e.g. change in mode of transportation). Local municipalities are rightly placed to effect these changes at a local level and such strategies will aid in providing short to long term direction with respect to climate change mitigation.

7.3 Energy/Electricity Generation

Most South Africa's emissions come from the energy sector. Electricity supply is the largest source of emissions at the national scale, followed by industry, transport and liquid fuels supply (DEA, 2016). Mitigation measures in this sector therefore include interventions in energy supply (using alternative energy sources), and interventions to reduce energy demand by improving energy efficiency. Municipalities should lead by example and ensure that communities are educated on energy efficient practices. Such practices include changing street lighting, converting municipal buildings to green buildings, options for reducing electricity and water consumption in municipal buildings which can then also be adopted by households and business. Energy efficiency is both cost effective and ensures reduction of GHG emissions through decreased demand for electricity from hydrocarbon fired plants.

According to the State of Energy in South African Cities Report 2020, energy consumption is higher in metropolitan areas compared to other cities/towns. However, energy usage per person is higher in industrial cities. This is because industrial cities have energy-intensive industries like smelters and mines, despite having smaller populations than metros. Excluding industrial cities, energy consumption per person is higher in most metros than in secondary and smaller cities. This is due to the concentration of economic activities, such as industrial and commercial activities, which require more energy. Energy consumption per person also seems to be higher in secondary cities compared to smaller cities, but there is not enough data to confirm this. Overall, energy consumption is increasing in metros and decreasing in other cities on average.
Cities are setting the example, by improving the energy efficiency of municipal buildings. Municipal buildings make up a substantial part of a city's-built environment, and so can have a significant impact on its energy use. The targets in the Post-2015 National Energy Efficiency Strategy (NEES) include:

- a *20% reduction in energy intensity, measured as energy consumption per head of population served, for electricity-intensive municipal services, i.e., street lighting, traffic lights, water supply and wastewater treatment, and*
- a *30% reduction of fossil fuel intensity of municipal vehicle fleets.*

Several municipalities have effectively upgraded their traffic lights and some streetlights. Now, they are focusing on more costly projects like heating, ventilation, and air conditioning (HVAC) systems and wastewater treatment plant (WWTP) motors. Both HVAC and WWTP systems require a lot of energy - WWTPs are typically the biggest electricity user in a city and can account for 30-60% of the total electrical consumption. In some cases, up to 85% of the electricity is used for the motors (Sustainable Energy Africa, 2020).

The use of waste-to-energy projects, such as the use of bio-digesters on farms and in rural households, to produce energy from agricultural and organic waste, should be supported. Biogas is widely used in countries such as Germany, China, Nepal, and India. African countries have been much slower in taking advantage of this potentially large energy source. In terms of bio-digesters, SA has a high level of technology development (Amigun & von Blottnitz, 2010), and should be making use of this energy source, particularly since there are incentives available under the Renewable Energy Independent Power Producer Procurement Programme (REIPP) set up by the Department of Energy (DoE). Biogas has potential both on a small scale (domestic or small farms) and on a commercial and industrial scale (Agama Energy, 2007).

Replacing household fuelwood use with biogas can result in a reduction of 85% of emissions (Msibi & Kornelius, 2017). It should, however, be noted that sufficient feed stock and water is required for the biodigesters so it may not be appropriate in all regions. Community digesters could be installed and connected to centralised local ablution facilities or schools to make use of flushing water, thus limiting the water demand. Some studies have shown that a greater percentage of fuel for cooking needs can be achieved in summer, whereas, in winter, biogas production can be minimal due to cold temperatures (Nape, et al., 2019). The best feedstock is cattle and pig waste, while other livestock do not generally produce enough feedstock to make it viable (Msibi & Kornelius, 2017). It would therefore be good to assess the viability of biodigesters in the Bergrivier Municipality before doing installations.

In addition to the reduction of GHG, renewable energy sources offer economic opportunities for the local population. The municipality should therefore establish an environment that encourages the uptake of renewable energy and the development of the green economy. An intervention on renewable energy can be the rooftop photovoltaic (PV) system, which can be a good solution for municipalities, rooftop owners, and other electricity consumers. It can help municipalities meet their emission reduction goals by being integrated into the municipal electricity grid. According to the Western Cape Government rooftop solar PV systems project, SA has abundant solar resources, making it one of the best places in the world for solar energy. The Western Cape Government is taking advantage of this by installing PV systems in its buildings, with each PV system being tailored to the specific location and needs of the building.

Table 34 presents mitigation measures proposed for the reduction of GHG in the energy sector. The Integrated Development Plan of the Bergrivier Municipality highlights the necessity to explore alternative energy sources for affordable housing. However, financial constraints pose a challenge in this endeavour. Additionally, there's an emphasis on devising inventive approaches to oversee energy provision, especially concerning new constructions. The focus extends to exploring renewable energy solutions as part of this initiative.

Table 34: Mitigation measures for energy.

Sector	Short	Medium	Long
Energy supply/renewable energy	Encourage solar system installations in residential areas. Include and plan to subsidise the installation of solar systems for water heating in residential areas.	Collaborate with institutions doing research and innovation in renewable energies (e.g. CSIR). Support and encourage the installation of biodigesters. Support the use of small systems in the municipality such as rooftop photovoltaic (PV) system.	Erect solar street lighting in the municipal jurisdiction
	Establish the use of alternative clean energy in public infrastructure (schools, hospitals, clinics, and community service buildings).	Power public schools using sustainable technologies i.e., biogas system.	
Energy efficiency	Conduct energy audits in all municipal facilities to monitor energy use. Implement awareness campaigns to sensitise users of municipal buildings on how to become more energy efficient.	Install smart meters in all public buildings. If government buildings are old, make recommendations for retrofitting.	
	Replace incandescent lighting with energy efficient LED lighting in all municipal buildings.	Ensure that future municipal buildings are built according to the SANS 10400-XA and 204 for energy efficient buildings.	
	Participate in public information campaigns around the economic and climate protection advantages of heat pumps.	Devise a financial and technical plan to install heat pumps in clinics and hospitals.	
	Implement energy efficient lighting and smart controls in all government buildings.	Conduct public awareness campaigns on energy efficient appliances.	
Waste-to-energy		Promotion of bio-digesters on farms and rural households to produce energy from agricultural waste.	

7.3.1 Available financing options for energy efficiency and renewable energy projects

Municipalities can make use of provisions put in place to encourage energy efficiency (EE) and the uptake of renewable energy (RE) technologies. EE interventions such as installation and retrofitting of EE lighting is supported under the Municipal Infrastructure Grant (MIG). This funding vehicle seeks to empower local municipalities to deliver sustainable solutions and services to poor communities e.g. in the provision of solar powered street lighting, energy efficient water pumps and construction of EE municipal buildings (SALGA, 2017). Other financing avenues are the Regional Bulk Infrastructure Grant and the Water Services Infrastructure Grant (Table 35).

Table 35: Financing opportunities for EE/RE projects for municipalities (Adapted from: (SALGA, 2017)).

Opportunity for EE/RE investment	Municipal Infrastructure Grant	Water Services Infrastructure grant	Regional Bulk infrastructure grant
Street lighting	☺		
Municipal buildings	☺		
Water and Wastewater		☺	☺
Vehicle fleet			
Solar lighting	☺		
Solar buildings	☺		
Solar Water Pumps	☺		

7.4 Road Transport

Vehicle emissions contribute significantly to GHG in the atmosphere due to the combustion of fossil fuels. Emissions from road transport emissions consists of fuel consumption by light duty vehicles, heavy-duty vehicles, and motorcycles (DEA, 2016).

The Department of Transport, in line with the Climate Change response White Paper (DEA, 2011), developed the Green Transport Strategy (DoT, 2017) dedicated towards building a climate resilient and a low carbon economy. Due to a lack of spatial planning foresight, some communities have to commute long distances to their places of work which results in more emissions being released. The road networks do not allow for other modes of transport such as cycling. The key areas for mitigation for the national transport sector (DoT, 2017) therefore include (Table 36):

- *Reducing travel distances for goods and people,*
- *Improving fuel efficiency, and*
- *Embracing cleaner modes of transport.*

The primary mode of transport in the Bergrivier Municipality is predominantly facilitated by mini-bus taxis, serving as the dominant public transportation option within the area (BM, 2019) These mini-bus taxis operate along main transport routes, catering to the public's transportation needs within the municipality.

Table 36: Mitigation actions for the transport sector.

Sector	Short term	Medium term	Long term
Passenger modal shift	Encourage other forms of transport such as cycling, walking.	Provide infrastructure to ensure safe usage of alternative transportation and pedestrians.	Develop extensive network for cycling and pedestrian-friendly infrastructure.
Public transportation	Encourage increased vehicle occupancy rate through car sharing and use of public transport.	Regulate and implement preferential bus and taxi lanes.	Decrease in private transport and commensurate increase in public transport, zero emissions vehicles and non-motorised transport, electric vehicle charging infrastructure, alignment between transport and spatial planning objectives.
Municipal Vehicle fleet	Vehicle inspection, maintenance, and upgrade of current vehicles.	Replace old inefficient vehicles with new and more fuel-efficient vehicles.	Implement a transition to electric or low-emission vehicle fleets.

7.5 Agriculture

Agriculture releases significant amounts of CH_4 and N_2O into the atmosphere. CH_4 is produced when organic materials decompose in oxygen-deprived conditions (enteric fermentation, manure management), and N_2O is generated by the microbial transformation of nitrogen in soils and manures. The DFFE realises that agriculture forms an essential component of the economy and developed the Climate Change Adaptation and Mitigation Plan for the Agriculture and Forestry Sectors. This section outlines the mitigation measures require for specific agricultural activities and seeks to protect the economic viability of this sector in light of the impacts of climate change (DAFF, 2015). Many of the adaptation actions in agriculture (such as conservation and regenerative agriculture practices) are also mitigation actions, as they lead to improved soil carbon sequestration. These activities are listed Table 37 under adaptation and mitigation action plans and are not listed again in this section.

According to the Bergrivier Municipality Spatial Development Framework, agriculture and community services sectors show a high concentration of low-skilled workers, constituting 75.6% and 68.7% of their respective workforces. Given the prevalence of low-skilled labour in agriculture, this sector is susceptible to economic upheavals, posing a risk of heightened poverty rates unless agricultural workers receive enhanced skills or training to adapt to changes. The economy of Bergrivier Municipality relies heavily on agriculture, raising concerns about climate change's adverse effects on this sector, subsequently affecting the local economy. Despite observable everyday signs hinting at potential climate change impacts, such as fruit ripening irregularities and increased baboon activity in residential areas, accurately forecasting its precise effects on the Bergrivier area remains challenging. Therefore, the municipality requires comprehensive plans for climate change adaptation and mitigation to safeguard against these uncertainties. The suggested mitigation actions must focus on the types of agricultural activities within the municipality.

In addition to the suggested mitigation actions, it is also recommended that Bergrivier Municipality promote and support research on:

- *Impacts of climate smart agriculture on production, carbon stocks and GHG emissions,*
- *Dietary additives that can reduce livestock emissions,*
- *Agroforestry,*
- *Regenerative farming,*
- *Livestock manure management practices, and*
- *Local studies on climate change impacts on agriculture.*

Other mitigation options relate to waste reduction, as minimising waste contributes to preserving land for agriculture and reducing the need for land use conversions. Food wastage is greatest at the agricultural production and post-harvest handling level (Figure 46). Waste reduction on farms can be achieved by linking farmers to markets so they can sell their produce, thereby ensuring less waste, and by improving on-farm storage (both storage for grains and cold storage for produce). Agricultural co-operatives are useful, particularly where finances are limited, as the groups can come together and assist one another by pooling their financial resources and supplementing these with contributions at regular intervals. Waste reduction can also be achieved by improving road infrastructure as a lot of food gets bruised during transportation to the market.

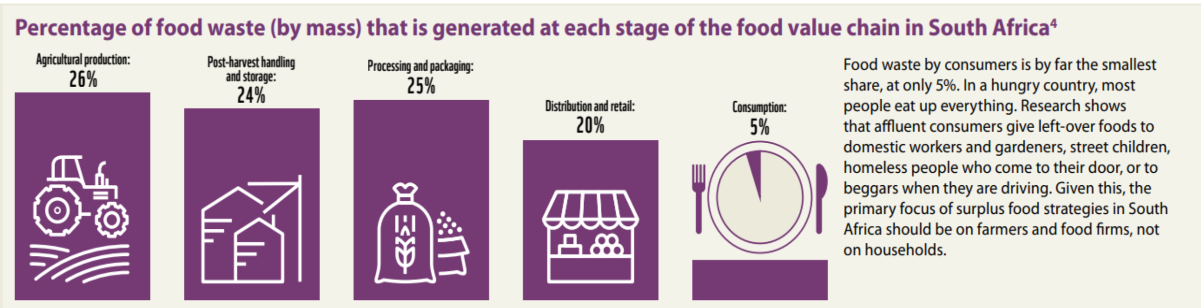


Figure 46: Food wastage in South Africa, Source: (WWF, 2018).

Most livestock emissions are CH_4 emissions from enteric fermentation. Reducing these emissions can be done by selecting livestock varieties with high feed efficiencies and reduced methane yields as different livestock varieties produce different levels of methane. In addition, improving the feed quality of the livestock leads to higher digestibility and reduced methane yields. Reducing the maturity of the pasture or silage can further reduce methane yields. Grazing systems which include rotational grazing will tend to reduce forage maturity, which improves forage digestibility and therefore, reduces methane production (Mc Geough , et al., 2010). Cattle fed with corn silage and small grain silages, rather than grass silage, and hay, can also lower CH_4 production (Vellinga & Hoving, 2011).

Table 37: Mitigation actions for the agriculture sector.

Sector	Short term	Medium term	Long term
Agricultural baseline	Continuously map agricultural areas at regular intervals, including types of agriculture and whether it is subsistence or commercial. Improve understanding of the extent of climate smart or conservation agriculture.	Continuously update agricultural GHG inventory for Bergrivier Municipality.	
Sustainable farming	Conduct educational campaigns to inform farmers of climate-smart or conservation agricultural activities in accordance with the SmartAgri Programme The Priority SmartAgri Projects are identified as follows: 1. *Conservation Agriculture for all commodities and farming systems,* 2. *Restored ecological infrastructure for increased landscape productivity, socio-ecological resilience, and soil carbon sequestration,* 3. *Collaborative integrated catchment management for improved water security (quality and quantity) and job creation,* 4. *Energy efficiency and renewable energy case studies to inspire the transition to low- carbon agriculture, and* 5. *Climate-proofing the growth of agri-processing in the Western Cape* An integrated knowledge system for climate-smart agricultural extension.	Develop agricultural subsidy system for small scale organic farmers and other alternative farmers. Support of urban agriculture is encouraged, facilitation of food gardens and small-scale agriculture, protection of well-located urban agriculture properties, must form part of a municipality's social resilience programme	

Sector	Short term	Medium term	Long term
Farm-level N efficiency	Conduct educational campaigns to promote: • *reduced or more efficient fertilizer use,* • *addition of legumes/N-fixing crops into rotations, and* • *application of manure to croplands.*		
Soil management	Promote the reduction of tillage; crop rotation; increased cover. Promote the application of compost and residues on crops. Promote the introduction of a diverse cover-crop mixture.		
Agroforestry	Conduct a study to determine the extent and opportunities for agroforestry.	Promote agroforestry systems that are appropriate for the different land tenure systems[14], and Support the inclusion of agroforestry in the implementation of current policies.	
Livestock and game farming	Determine optimal grazing intensities. Determine optimal pasture management. Determine best livestock feed options. Improve feed quality through straw ammonisation and silages. Veld reinforcement and rehabilitation. Strategic destocking. Sharing information with farmers.	Optimise grazing intensity to reduce land degradation.	Provide incentives for the adoption of agroforestry. Replanting (to improve feed quality), and rehabilitation of pastures.

[14] This would only occur if the initial study indicated there are opportunities for agroforestry in Bergrivier Municipality.

7.6 Land use and land use change

Land use change is a significant contributor to emissions or sequestration of carbon in the environment, which is why the monitoring of land use is important going forward. Degradation of grasslands, mainly due to overgrazing and erosion, should be reduced, and the land rehabilitated through physical replanting and erosion control.

In several ecosystems, natural fires are essential to maintaining ecosystem dynamics, biodiversity, and productivity. Fire is also an important and widely used tool to meet land management goals, however, unexpected wildfires can lead to a loss of biodiversity areas. Wildfires are a significant source of GHG emissions, and their incidence is likely to increase because of climate change. Integrated fire management is essential for biodiversity conservation and as a part of climate change adaptation and mitigation strategies. Strengthening capacities to prevent wildfires, or to reduce risk of large, disastrous wildfires, can contribute to protecting storage and sequestration of carbon in natural vegetation or plantation (Table 38).

Table 38: Mitigation actions for land use change.

<table>
<tr><th>Sector</th><th>Short term</th><th>Medium term</th><th>Long term</th></tr>
<tr><td rowspan="2">Land use change</td><td colspan="3">Enhance monitoring and review mechanisms for existing long-term land-use planning frameworks to ensure they effectively address environmental and climate change considerations. This includes regular assessments of the Bergrivier Municipal Spatial Development Framework (Bergrivier MSDF) and its amendments, with a focus on strengthening provisions related to environmental sustainability and climate resilience. Implement feedback loops and stakeholder engagement processes to incorporate diverse perspectives and expertise in the ongoing refinement of land use planning strategies.</td></tr>
<tr><td colspan="3">Continue to develop land-use change maps for the municipality.</td></tr>
<tr><td>Natural Vegetation and Biodiversity</td><td>Conduct an educational campaign on how to reduce degradation of biodiversity.</td><td colspan="2">Work with projects such as the Expanded Public Works Program to implement grassland rehabilitation projects.</td></tr>
<tr><td>Land degradation and rehabilitation</td><td>Monitor erosion and land degradation, and develop measures to reduce land degradation.
Conduct information and awareness campaigns to inform the public about alien</td><td>Implement measures to reduce land degradation.</td><td></td></tr>
</table>

Sector	Short term	Medium term	Long term
	species and possible value-added opportunities. **Provide incentives** to households to utilise wood from alien invasive plant species as opposed to collecting wood from indigenous trees.		

7.7 Waste

7.7.1 Landfills

Without the presence of oxygen (anaerobic fermentation), waste decomposes and slowly produces landfill gas. This gas contains 40-60% methane, and the global warming potential (GWP) of methane is 23 times that of CO_2. An option available for the reduction of CH_4 from landfill gas is to harness it in the production of electricity. One such independent landfill gas-to-power plant began its operations in 2016 at a Johannesburg landfill, producing 3 MW of electricity (this is enough electricity to provide power to 5500 homes) (SEA, 2017). Whilst the potential for harnessing methane from landfills to produce energy is vast, a more sustainable vision should be for a zero-waste trajectory. This means waste reduction through reuse, recycling, and composting. Composting facilities should be set up within the municipality's closed landfill sites to reduce the amount of organic waste in the landfills and thereby reduce emissions. This would be in line with the National Organic Waste Composting Strategy (DEA, 2013). Table 39 outlines the mitigation strategies for the waste sector that Bergrivier Municipality could consider in the short, medium to long term.

Table 39: Mitigation actions for waste.

Sector	Short term	Medium Term	Long term
Waste Management	Encourage recycling in the rural and town communities through awareness raising campaigns.	Enforce a waste separation and recycling waste collection system.	
	Setup, monitor and improve the functioning of the Buy-Back Centre.		
	Encourage composting of organic waste for rural communities.		
	Encourage recycling and conduct educational campaigns on waste sorting at source.		
	Implement Integrated Waste Management Plan (IWMP).		
	Diversion of waste from landfills and monitor landfill sites.		
	Cleaning and Greening project.	Conduct regular community clean-up initiatives in public spaces.	
Waste management infrastructure	Install bins around high-volume areas.	Introduce labelled recycling bins at strategic centres.	
	Ensure the closure of unlicensed/ illegal landfills and make use of licensed regional licensed landfill.	Reduce the total volume of waste disposed to landfill each year.	

Sector	Short term	Medium Term	Long term
	Procure recycling bins for separation of waste.		
	Increase waste collection through purchase of waste collection vehicles.	Improve waste collection rates to unserved communities.	
	Establish a transfer station in communities that rely heavily on waste burning.		
Waste to energy	Conduct feasibility studies on the landfill gas generation potential of the municipal landfills.	Support Landfill Gas (LFG) flaring from small landfills where it is uneconomical to capture the gas. Promote the adoption of waste-to-energy technologies.	Promote the utilisation of methane from anaerobic digesters.
Empowerment and employment creation	Encourage waste picking cooperatives. Formalise activities of waste pickers.	Increase the number of buy back centres.	Add value to waste by producing products from collected waste.

7.7.2 Wastewater treatment plants (WWTPs)

Bergrivier Municipality has operating wastewater treatment plants at Dwarskersbos, Eendekuil, Piketberg, Porterville and Velddrif. The carbon footprint of WWTPs emanates from direct and indirect sources (Table 40). WWTPs consume large quantities of electricity, and it has become imperative to optimise energy efficiency and develop opportunities for energy generation from wastewater and sludge as part of the municipal wastewater business. International best estimates indicate that energy gains and savings of 5-30% are realistic (Scheepers & vd Merwe- Botha, 2013).

Table 40: Direct and indirect sources of GHG emissions from WWTPs (Source: Paravicci et al., (2016)).

Direct GHG emission sources	Indirect GHG emissions sources
Wastewater collection- sewer system	Electricity Supply.
Wastewater treatment (WWTPS)	Transportation (e.g. chemicals, sewage sludge).
Wastewater discharge in water bodies	Use of chemicals and additives (including GHG emissions in the upstream stages of production).
	Disposal/reuse of residuals (bio solids).

Several of the suggested mitigation actions therefore relate to the improvement of energy efficiency at wastewater treatment plants (Table 41). Key energy demand areas are pumping over wide service areas, asset condition and pipe leakage, treatment by aeration, and pumping raw and treated effluent (Global Water Research Coalition, 2010). Up to 50% energy savings have been demonstrated by case studies in wastewater processes focused on aeration, therefore the installation of speed control mechanisms for aerators is included as a mitigation action. Bergrivier Municipality should conduct energy audits at the wastewater treatment plants to identify the energy saving opportunities.

Table 41: Mitigation actions for wastewater treatment plants.

Sector	Short term	Medium Term	Long term
Energy efficiency in wastewater treatment	Conduct an energy audit at all wastewater treatment plants. Regular maintenance of pumps and motors. Retrofit old pumps with more energy efficient pumps or upgrade pumping technology. Ensure that the right pumps are used for the correct volume.	Promote combined heat and power (CHP) generation. Promote biogas technology at WWTPs to enable self-sufficient energy supplies at these sites.	Install control mechanisms to control the speed of aerators. Installation of automatic controls.

8 IMPLEMENTATION PLAN

8.1 Mainstreaming of Climate Change Adaptation into Municipal Governance

In the 2014 Municipal Adaptation Plan, a primary focus was placed on the integration of climate change adaptation into municipal governance. This emphasis remains a key intervention in the current climate change implementation plan, underscoring the ongoing importance of integrating adaptation and mitigation measures into the operational framework of municipal governance.

In fostering increased political buy-in for the updated climate adaptation and mitigation plan, strategic measures should be implemented to underscore the tangible benefits and long-term advantages associated with adaptive and mitigation initiatives. The municipality needs to employ clear and compelling communication strategies to emphasise the positive impact of climate adaptation interventions, such as heightened resilience, economic stability, and public health benefits, resonating effectively with municipal governance objectives. Additionally, aligning these efforts with broader policy objectives and showcasing the potential for job creation and economic growth can further attract political buy-in. Establishing a transparent and accountable funding mechanism, with a focus on exploring diverse funding sources, is crucial to addressing the identified interventions promptly. Moreover, fostering collaboration and coordination between environmental forums and structures will strengthen the overall implementation process by demonstrating a unified front and reinforcing the importance of political commitment to achieving climate resilience goals.

The municipality should engage in collaborative efforts to integrate adaptation and mitigation initiatives into its strategic and master plans across various sector departments. This collaboration is crucial because the responsibility for these initiatives lies with the municipal sector agencies and departments. Examples of such responsibilities include the development of master plans for spatial planning and land-use management, as well as the management and maintenance of critical infrastructure such as roads, stormwater systems, and buildings (Table 43). Given that these aspects can be significantly influenced by climate change, it becomes imperative to align them with updated climate change adaptation and mitigation strategies. This alignment ensures that the municipality is well-prepared to address the challenges posed by climate change and safeguard its various sector departments from potential impacts.

Each directorate has specific line functions, and they collectively cover a wide range of municipal responsibilities, from administration and legal support to technical service, environmental management, community services, building control and the management of strategic services and project management. Understanding the factors influencing climate change is crucial for acknowledging responsibility for this phenomenon. Several municipal institutions lack the institutional capacity required to play a proactive role in addressing climate change. Therefore, the appointment of skilled personnel is essential to empower them as drivers for climate change initiatives. Table 42 illustrates the significance of capacity-building projects aimed at integrating climate change adaptation and mitigation actions into municipal operational functions, as outlined in the Municipal Adaptation Plan 2014. These projects remain relevant in the context of the updated plan.

The Implementation Plan for the Bergrivier Municipality Climate Change Response Strategy is presented in the tables that follow (Table 44 and Table 45). For each of the sectors, and in collaboration with the responsible stakeholder(s), appropriate actions are set, activities needed to achieve each objective have been identified, and timeframes required to achieve the objective are suggested. Generic timeframes, ranging between short term (1 – 2 years), medium term (3 – 5 years), and long term (5 – 10 years), have been assigned. Responsibilities have been allocated to relevant stakeholders.

Table 42: Mainstreaming of climate change adaptation and mitigation into municipal governance (BM, 2014).

Project	Detail	Project Drivers	Existing Stakeholders	Budget	Support
Capacity building and awareness – officials and decision makers to create buy in.	Training and information dissemination.	Strategic Manager (BM).	DEADP (Climate Change Directorate), Councillors, and municipal officials.	In-house.	African Climate Development Initiative (ACDI). University of Cape Town (UCT).
Capacity building – community	Seminar to create awareness and information dissemination. Green Ambassadors – Youth Development Programme (EPWP).	Strategic Manager (BM).	DEADP – EPWP co-ordinator.	In-house.	Provincial EPWP Co-ordinators. DEADP (Climate Change Directorate). ACDI Climate Change Network.
Environment sector engagement	Targeted participatory planning process to include environmental issues in IDP (Environment sector engagements).	Municipal Manager (BM).	Ward committees, Berg Estuary Advisory Forum (BEAF), Greater Cederberg Biodiversity Corridor Steering Committee Meeting (GCBC), Cape West Coast Biosphere Reserve, and local interested stakeholders.	In-house.	CapeNature.

Table 43: Summary of municipal line roles and responsibilities.

FUNCTIONAL DIVISION				
Office of the Municipal Manager	**Directorate Financial Services**	**Directorate Technical Services**	**Directorate Corporate Services**	**Directorate Community Services**
• ***Line function including, but not limited to:*** • ***Recruitment & Selection, Discipline, Asset Management, Security, Office accommodation, etc.*** • ***International Relations, International Fund Raising.*** • ***Intergovernmental Relations.*** • ***Support Services to the Executive Mayor.***	• *Line function including, but not limited to:* • *Revenue Management: Income processes, Credit Control, Debtors, Collections, Reconciliations, Meter Reading, Property valuations & tax.* • *Expenditure & SCM: Creditors, Salaries, Purchases, Tenders, Asset Register,*	• *Line function including, but not limited to:* • *Civil Engineering Services: Solid Waste Management, Roads and Stormwater, Water Distribution, Sewage Distribution, Fleet Management.* • *General maintenance of all municipal services*	• *Line function including, but not limited to:* • *Administration & Legal Support: Office Administration, Committee Services, Policy formulation, ICT & GIS, Secretarial Functions, Legal Support Services.* • *Human Resource Services: Personnel Provisioning, Benefits Administration,*	• *Line function including, but not limited to:* • *Facilities Management: maintenance of community facilities, cleaning of sidewalks, parks, cemeteries, swimming pools, sport fields, resorts & beaches.* • *Community Projects & Development: Sport*

FUNCTIONAL DIVISION				
Office of the Municipal Manager	**Directorate Financial Services**	**Directorate Technical Services**	**Directorate Corporate Services**	**Directorate Community Services**
• ***Strategic Services – IDP, Reporting, Public Participation, Tourism, performance, and strategic projects management.*** • ***Internal Audit & Risk Management.*** • ***Communication and Coordination.***	*Insurance, Supply Chain Management.* • *Support services for the Director.*	*(technical and community).* • *Electrical Engineering Services.* • *Project Management & Building Control: Construction projects, Building control, Project support.* • *Support services for the Director.*	*Labour Relations, Employee Wellness, Training and Development.* • *Town Planning & Environmental Management, Land Use Management, Town Planning, GIS, Monitoring air quality, Business & Liquor Licenses.* • *Support services for the Director.*	*Development, Library Services, Museums, Housing administration.* • *Protection Services: Traffic Services, Law Enforcement, Disaster Management, Fire prevention, Monitoring security cameras.* • *Support services for the Director.*

Table 44: Implementation plan for adaptation actions.

Sector	Action	Responsibility	Start	Achieved by
Water	Conduct training programs and capacity-building initiatives for municipal staff and contractors working in the water sector, to align climate adaption processes with their line of work.	**Lead:** Bergrivier Municipality (Technical Services Directorate). **Support:** West Coast District Municipality (WCDM) and DEA&DP.	Short term (2024 - 2026).	
	Integrate climate change considerations into water resource management strategies.	**Lead:** Bergrivier Municipality (Technical Services Directorate). **Support:** WCDM.	Medium term (2026 - 2031).	
	Develop feasibility studies on water conservation strategy – for example, a study on the alternative sources of water e.g. desalination plant.	**Lead:** Bergrivier Municipality (Technical Services Directorate). **Support:** WCDM.	Long term (2026 - 2031).	
	Conduct a study on the behaviour of the municipal springs to plan water capacity.	**Lead:** Bergrivier Municipality (Technical Services Directorate). **Support:** WCDM.	Medium term (2026 - 2031).	
	Integrate climate change projections into the design and planning of new water infrastructure (i.e., masterplan to upgrade the stormwater infrastructure).	**Lead:** Bergrivier Municipality (Technical Services Directorate). **Support:** WCDM.	Short term (2024 - 2026).	
	Conduct regular assessments to identify and address vulnerabilities in existing infrastructure.	**Lead**: Bergrivier Municipality. (Technical Services Directorate). **Support:** WCDM	Short term (2024 - 2026).	
	Conduct awareness campaigns on water conservation and preservation of wetland systems.	**Lead:** Bergrivier Municipality (Technical Services Directorate).	Short term (2024 -	

Sector	Action	Responsibility	Start	Achieved by
		Support: WCDM.	2026) – Ongoing.	
	Develop adaptive policies that allow for flexible allocation of water resources based on changing climatic conditions.	**Lead**: WCDM and Bergrivier Municipality (Technical Services Directorate).	Medium term (2026 - 2031).	
	National Government to assist in mitigation measures for the extraction of groundwater.	**Lead:** National Government. **Support:** Bergrivier Municipality (Technical Services Directorate).	Medium term (2026 - 2031).	
	Develop robust contingency plans to address the impacts of extreme weather events such as floods and droughts.	**Lead:** WCDM and Bergrivier Municipality (Technical Services Directorate).	Medium term (2026 - 2031).	
	Provide incentives to setup up communal water harvesting systems.	**Lead:** WCDM and Bergrivier Municipality (Technical Services Directorate).	Medium term (2026 - 2031) – ongoing.	
	Collaborate with relevant agencies to enhance preparedness and response capacities.	**Lead:** WCDM and Bergrivier Municipality (Technical Services Directorate).	Short term (2024 - 2026) – ongoing.	
	Establish early warning systems to facilitate timely responses to impending extreme events.	**Lead:** WCDM and Bergrivier Municipality (Technical Services Directorate).	Medium term (2026 - 2031) – ongoing.	
	Conduct a study to set up water consumption targets for each sector.	**Lead:** WCDM and Bergrivier Municipality (Technical Services Directorate)	Medium term (2026 - 2031) – ongoing.	

Sector	Action	Responsibility	Start	Achieved by
	Implement mechanisms to dynamically adjust water allocations in response to varying demand and availability.	**Lead:** Bergrivier Municipality (Technical Services Directorate).	Medium term (2026 - 2031) – ongoing.	
	Set up a streamflow and groundwater monitoring programme.	**Lead:** WCDM and Bergrivier Municipality (Technical Services Directorate).	Medium term (2026 - 2031) – ongoing.	
	Implement smart technologies for real-time monitoring and management of water systems.	**Lead:** WCDM and Bergrivier Municipality (Technical Services Directorate).	Medium term (2026 - 2031) – ongoing.	
	Employ advanced technologies for efficient monitoring and assessment of water availability.	**Lead:** WCDM and Bergrivier Municipality (Technical Services Directorate).	Long term – ongoing.	
	Ensure alien invasive plant removal programme targets species on riverbanks and in the Berg River specifically where water hyacinth is a constant problem for decades.	WCDM in collaboration with relevant National Department.	Short term (2024 - 2026) – ongoing.	
	Provide controlled access point to rivers to reduce erosion and vegetation degradation around rivers.	**Lead:** WCDM and Department of Agriculture and Bergrivier Municipality, DEA&DP, and farmers (where applicable).	Medium term (2026 - 2031) – ongoing.	
	Establish a water auditing and accounting programme.	**Lead:** WCDM and Bergrivier Municipality (Technical Services Directorate).	Medium term (2026 - 2031) – ongoing.	

Sector	Action	Responsibility	Start	Achieved by
	Develop a study to evaluate and understand impact of severe storm water episodes going into the sewerage systems and affecting water capacity.	**Lead:** Bergrivier Municipality (Technical Services Directorate).	Medium term (2026 - 2031) – ongoing.	
Agriculture	Provide agricultural extension services with proper training on climate change. Agriculture extension officers should be well trained and have access to the latest information. They should visit farmers regularly to update them and any new technologies or techniques that they can implement on the farm. Should also be able to distribute up-to-date information on climate, market-based activities, crop varieties (i.e. short cycle fast growing varieties), so they can assist farmers in farming smartly. Extension officers can also provide education training on various climate smart techniques (composting, crop rotation, smart fertiliser, agricultural developments involving the transformation of natural vegetation and water application, etc.). Extension services should be free, so it is easily accessible to all.	**Lead:** National Department of Agriculture supported by the district municipality.	Short term (2024 - 2026) – ongoing.	
	Establish agricultural seed banks that maintain a variety of seed types that preserve biological diversity and provide farmers with an opportunity to make informed choices could be used to counteract the	**Lead:** WCDM in collaboration with DALRRD and WCDoA.	Short term (2024 - 2026) – ongoing.	

Sector	Action	Responsibility	Start	Achieved by
	effects of climate change, maintain food security, and establish possibilities for profitable specialisation.			
	Provide farmers with tenure agreements.	**Lead:** WCDM in collaboration with DALRRD and WCDoA's, WCDM Manager: Agricultural Producer Support and Development (APSD) West Coast.	Medium term (2026 - 2031) – ongoing.	
	Education campaigns to inform farmers of climate smart/conservation/regenerative agricultural practices.	**Lead:** WCDM in collaboration with DALRRD and WCDoA.	Short term (2024 - 2026) - ongoing	
	Provide farmers with access to affordable credit.	**Lead:** WCDM in collaboration with DALRRD and Trade & Industry.	Medium term (2026 – 2031) – ongoing	
	Encourage farmers to incorporate crop residues and animal manure into the soils instead of removing or burning these.	**Lead:** WCDM in collaboration with WCDoA.	Short term (2024 - 2031) - ongoing	
	Strengthen veterinary services in the area to help farmers stress with stressors from climate change impacts.	**Lead:** WCD in collaboration with WCDoA.	Medium term (2026 - 2031) - ongoing	
	Plant indigenous trees on farms to provide shading for livestock.	**Lead:** WCDM in collaboration with DFFE, DALRRD; DEA&DP and WCDoA.	Short term (2024 - 2026) - ongoing	

Sector	Action	Responsibility	Start	Achieved by
Biodiversity and tourism	Enforce regulations on the protection and conservation of biodiversity and natural resources.	**Lead:** DFFE supported by the West Coast District Municipality in collaboration with DWS; DALLRD and DEA&DP.	Short term (2024 - 2026) - ongoing	
	Remove alien invasive species at municipal properties through the National Environmental Management Act (NEMA) and Alien Clearing Plans of local municipality.	**Lead:** Bergrivier Municipality **Support:** Western Cape Department of Agriculture and WCDM in collaboration with the DFFE, DEA&DP, Lower Berg irrigation Board, Kromantonies Water Use Association (WUA), SA Birdlife, Working for Water Programme (WfW) and CapeNature.	Short term (2024 - 2026) - ongoing	
	Remove alien invasive species at rivers, floodplains, and estuaries by making use of NEMBA Regulations which hold landowners responsible if they are part of a formal/Provincial Nature Reserve – CapeNature (Sec 73. 2 (a) of NEMBA).	**Lead:** Western Cape Department of Agriculture and WCDM in collaboration with the DFFE, DEA&DP, Lower Berg irrigation Board, Kromantonies Water Use Association (WUA), SA Birdlife, Working for Water Programme (WfW) and CapeNature. **Support:** WCDM (Strategic Services Department).	Short term (2026 - 2031) - ongoing	
	The Green Business Value Chain is a Clear to grow initiative in partnership with DFFE.	**Lead:** WCDM in collaboration with the DFFE.	Medium term (2026 - 2031) - ongoing	

Sector	Action	Responsibility	Start	Achieved by
	Identify areas for conservation and protection.	**Lead:** Bergrivier Municipality in collaboration with the DFFE, WCDM, CapeNature.	Short term (2024 - 2026) - ongoing	
	Develop a wetland protection policy – given that wetlands play a significant role in stormwater management, especially in urban areas.	**Lead:** WCDM in collaboration with the DFFE; DWS; DEA&DP.	Medium (2026 - 2031) - ongoing	
	Protect the Berg River estuaries from the overflow of the sewerage - strengthen wastewater treatment management actions and operational plans – budget accordingly and upgrading sewerage stations/plants and having backup systems/generators in place during loadshedding overflows to prevent spillages.	**Lead:** Bergrivier Municipality. **Support:** WCDM in collaboration with the DFFE; DEA&DP; DWS.	Short term (2024 - 2026) - ongoing	
	Implement programs and policies to protect the fragmentation of Critical Biodiversity Areas and climate change adaptation corridors as per the Western Cape Biodiversity Spatial Plan 2023.	**Lead:** CapeNature SANBI. **Support:** Bergrivier Municipality and WCDM in collaboration with DFFE.	Short term (2024 - 2026) – ongoing.	
	Conduct public awareness campaigns and site inspections for alien species on all properties within Bergrivier Municipality. This is a DFFE (Biosecurity) issue in terms of CARA and NEMBA legislation (again Sec 73. 2 (a) of NEMBA).	**Lead:** DFFE **Support:** Bergrivier Municipality and WCDM in collaboration with DFFE; DEA&DP; DWS; DALRRD & WCDoA; CMA; WUAs.	Short term (2024 - 2026) – ongoing.	

Sector	Action	Responsibility	Start	Achieved by
Infrastructure (Inland and Coastal)	Improve municipal infrastructure, including storm water drainage systems to manage more intense rainfall episodes.	**Lead:** WCDM and Bergrivier Municipality (Technical Services Directorate and Community Service Directorate).	Short term (2024 - 2026) – ongoing.	
	Incorporate climate change risk assessments in the zoning scheme bylaws once they are revised. Incorporate a climate change risk assessment questionnaire into the municipal building plan checklist.	**Lead:** Bergrivier Municipality (Town Planning and Environmental Management Department under the Corporate Services Directorate and Building Control Department under the Technical Directorate). **Support:** DEA&DP.	Short term (2024 - 2026) – ongoing.	
	Develop policies for future development projects to include a climate change risk assessment when following pertinent procedures like Environmental Impact Assessments (EIAs) and Water Use Licences (WULAs) to align with Bergrivier Municipality's sustainability development objectives. Municipality to comment on and agree conditions to support and implement actions within the Climate Change Strategy, specifically as apply to new development applications / land use applications, which require approval via by the Town Planning Sections/Councils.	**Lead:** DEA&DP. **Support:** Bergrivier Municipality and WCDM Municipality.	Medium term (2026-2031).	

Sector	Action	Responsibility	Start	Achieved by
	National Government to assist in redesigning the basic RDP units and make them compatible with the changing climate.	**Lead:** National Government. **Support:** Bergrivier Municipality (community services) Directorate.	Medium term (2026-2031).	
	Encourage the construction and provision of cycling lanes and pedestrian walkways between towns and within new housing developments.	**Lead:** Bergrivier Municipality and DEA&DP. **Support:** National Government.	Medium term (2026 - 2031).	
	Appoint an expert to suggest how to adapt the municipal buildings to extreme heat and storm events, rainwater harvesting, energy efficient municipal green buildings. Similar action can be applied to powerlines, pipelines, roads, and railways.	**Lead:** Bergrivier Municipality (Community Services Directorate and Technical Services Directorate). **Support:** WCDM.	Medium term (2026 - 2031) – ongoing.	
	To enforce zoning rules limiting new construction in vulnerable coastal areas, utilise the Coastal Management Line (CML) and the 5 m Contour method around estuaries, as outlined by the DEA&DP's CML processes.	**Lead:** Bergrivier Municipality (Town Planning Department). **Support:** WCDM and DEA&DP.	Short term (2024 - 2026) – ongoing.	
	Conduct a study to determine the use of natural coastal defences such as dune restoration and conservation, and wetland preservation, as cost-effective and recreational-friendly solutions to coastal flooding and the erosion of municipal property or the retreat option (Refer to Sec 15 (1) & (2) of ICMA. Implement a planned retreat for properties close to the coast as a sustainable option to rising sea levels and floods.	**Lead:** Bergrivier Municipality. **Support:** DEA&DP and WCDM.	Short term (2024 - 2026) – ongoing.	

Sector	Action	Responsibility	Start	Achieved by
	Identify alternative access routes to rural communities. Identify roads at risk of flooding and erosion and prioritise those which need upgrading and maintenance. Identify local responses that will reduce the isolation of rural communities from receiving needed aid.	**Lead:** Bergrivier Municipality and WCDM Disaster Management.	Short term (2026 - 2031) – ongoing.	
Health	Conduct public awareness campaigns on health risks posed by increased temperatures and implement response actions.	**Lead:** WCDM (Environmental Health Directorate) and Bergrivier Municipality	Short term (2024 - 2026) – ongoing.	
	Set up a water quality monitoring programme to reduce impacts of climate change.	**Lead:** Bergrivier Municipality **Support:** WCDM and WCDM Municipality (Environmental Health Directorate).	Medium term (2026 - 2031) – ongoing.	
	Increase the number of mobile health facilities.	**Lead:** WCDM (Environmental Health Directorate) in collaboration with the Provincial Department of Health	Short term (2024 - 2026) – ongoing.	
	Develop and maintain a database of incidences reported, such as extreme events and day to day incidences, that build up to longer time-series.	**Lead:** WCDM (Environmental Health Directorate) in collaboration with the Provincial Dept of Health	Short term (2024 - 2026) – ongoing.	

Sector	Action	Responsibility	Start	Achieved by
Disaster risk management	Set up a system to get early warnings out to farmers for any possible climate related changes which may cripple their productions.	**Lead:** SA Weather Services and Disaster Management and WCDM in collaboration with National Department of Agriculture.	Short term (2024 - 2026) – ongoing	
	Set up early warning systems for community health in extreme events.	**Lead:** WCDM in collaboration with Bergrivier Municipality (Community Services Directorate).	Medium term (2026 - 2031) - ongoing	
	Develop and maintain a database of incidences reported about hazards, for records and tracking purposes.	**Lead:** WCDM in collaboration with Bergrivier Municipality (Community Services Directorate).	Medium term (2026 - 2031) – ongoing.	
	Maintain and upgrade storm water infrastructure.	**Lead:** Bergrivier Municipality (Technical Services Directorate) **Support:** WCDM and Bergrivier Municipality (Community Services Directorate), Public Works.	Short term (2026 - 2031) – ongoing.	

Sector	Action	Responsibility	Start	Achieved by
Waste Management	**Include** recycling options into the Integrated Waste Management Plan as part of the Integrated Development Plan.	**Lead:** Bergrivier Municipality (Technical Services Directorate) with possible support from the WCDM.	Short term (2026 - 2031) - ongoing	
	Support recycling initiatives in the form of bylaws that facilitate the location, operation, and use of these facilities. **Enforce** the sorting of waste at source.	**Lead:** Bergrivier Municipality waste management strategy (Technical Services Directorate).	Short term (2026 - 2031) - ongoing	
	Conduct public awareness of recycling/composting.	**Lead:** Bergrivier Municipality (Technical Services Directorate).	Short term (2026 - 2031) - ongoing	
	Ensure 100% kerbside collection coverage.	**Lead:** Bergrivier Municipality (Technical Services Directorate).	Long-term	
	Continue to provide public awareness for communities to organise their residential waste into the three-plastic bag system (Recyclable, Garden refuse and General waste bin).	**Lead:** Bergrivier Municipality (Technical Services Directorate).	Short term (2026 - 2031) - ongoing	
	Encourage the public to make use of the compost bag provided by the municipality to re-use organic waste for their gardens to avoid organic waste going into the transfer stations.	**Lead:** WCDM and Bergrivier Municipality (Technical Services Directorate).	Short term (2026 - 2031) - ongoing	

Table 45: Implementation plan for mitigation actions.

Sector	Action	Responsibility	Start by	Achieve by
Energy	Subsidise the installation of solar systems for water heating in the municipal infrastructure.	**Lead:** Bergrivier Municipality (Technical Services Directorate).	Medium term (2026 - 2031) – ongoing.	
	Conduct a study to redesign the municipal property electrical infrastructure to integrate renewable energy sources, energy storage systems for energy efficiency, and backup power purposes.	**Lead:** Bergrivier Municipality (Technical Services Directorate) and WCDM.	Medium term (2026 - 2031) – ongoing.	
	Develop a demand-side management implementation strategy.	**Lead:** Bergrivier Municipality (Technical Services Directorate).	Long term – ongoing.	
	Implement electricity wheeling programs to improve generation capacity at a reduced tariff.	**Lead:** Bergrivier Municipality (Technical Services Directorate).	Long term.	
	Solar assist project for the installation of variable speed drive pumps to assist the municipal water systems and air conditioning in municipal schools.	**Lead:** Bergrivier Municipality (Technical Services Directorate) and WCDM.	Medium term (2026 - 2031) – ongoing.	
	Establish the use of alternative clean energy in public infrastructure (schools, hospitals, clinics, and community service buildings) such as solar, wind or biogas energy.	**Lead:** WCDM and Bergrivier Municipality (Technical Services Directorate) with support from the DEA&DP and DFFE).	Medium term (2026 - 2031) – ongoing.	
	Implement alternative energy projects (incentivise private companies and residential households going off the grid, battery backup systems, charging stations and solar plant project).	**Lead:** Bergrivier Municipality (Technical Services Directorate).	Medium term (2026 - 2031).	

Sector	Action	Responsibility	Start by	Achieve by
	Retrofitting municipal sports grounds and streets lights with LED lights to save energy.	**Lead:** Bergrivier Municipality.	Medium term (2026 - 2031) – ongoing.	
	Conduct energy audits in all municipal facilities/buildings to monitor energy use.	**Lead:** WCDM and Bergrivier Municipality.	Medium term (2026 - 2031) – ongoing.	
	Implement awareness campaigns to sensitise users of municipal buildings on how to become more energy efficient.	**Lead:** WCDM and Bergrivier Municipality	Medium term (2026 - 2031) – ongoing.	
	Vehicle inspection, maintenance, and upgrade of current fleet.	**Lead:** Bergrivier Municipalities	Medium term (2026 - 2031) - ongoing	
	Conduct a feasibility study on the use of electric vehicles for public transport and private car users using renewable energy as the primary energy source	**Lead:** WCDM and Bergrivier Municipality	Long term	
Agriculture	Conduct a study to determine the extent and opportunities for agroforestry in the Bergrivier Municipality	**Lead:** WCDM **Support**: Bergrivier Municipality	Medium term (2026 - 2031) - ongoing	
	Improve livestock feed quality by providing access to sustainable feed options (Grass-fed and pasture-raised, feeds made from crops such as soybeans, corn, and wheat that are sustainably grown without excessive use of pesticides or synthetic fertilizers), thus reducing the impact on feed production.	**Lead:** Department of Agriculture and DALRRD.	Medium term (2026 - 2031) – ongoing.	

Sector	Action	Responsibility	Start by	Achieve by
	Rehabilitate pastures to restore productivity, improve soil health, increase biodiversity, and mitigate environmental impacts.	**Lead:** Department of Agriculture and DALRRD.	Medium term (2026 - 2031) – ongoing.	
	Monitor livestock numbers and enforce by-laws to limit the number of livestock per farm and monitor stocking densities (Especially regarding piggeries and dairies).	**Lead:** Department of Agriculture with DALRRD; DEA&DP in terms of NEMA EIA Regulations regarding the triggering of animal densities., EIA approvals are also required from DEA&DP.	Medium term (2026 - 2031) – ongoing.	
	Rehabilitate degraded plantations and revegetate temporary unplanted areas (TUP).	**Lead:** Department of Agriculture.	Medium term (2026 - 2031) – ongoing.	
	Conduct educational campaigns with the farmers and communities on how to reduce grassland degradation.	**Lead:** Department of Agriculture and Bergrivier Municipality in collaboration with National Departments of Forestry and Environment, DEA&DP and CapeNature.	Medium term (2026 - 2031) – ongoing.	
Waste Management	Increase household composting through awareness campaign.	**Lead:** Bergrivier Municipality (Technical Services Directorate) with support from WCDM.	Medium term (2026 - 2031) – ongoing.	
	Maintain a composting facility.	**Lead:** Bergrivier Municipality (Technical Services Directorate) with support from WCDM.	Medium term (2026 - 2031) – ongoing.	

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10 APPENDIX

APPENDIX A 1

Scoring approach applied for the Climate Risk and Vulnerability assessment (Climate change impacts, exposures, and sensitivities).

Sector	Element	Data and scoring
All	Hazard	The hazards assessed were the temperature and precipitation data. Temperature has been increasing in the past and the projections show an increase in the future. The projections also indicate temperature changes are significant. These hazards were therefore given a value of 3 (High). Decreased rainfall has also occurred in the historical data and is projected in the future. However, due to high variability in precipitation projections the change data is, in most cases, not significant. The precipitation data was therefore given a value of 2 (medium). In all cases data was normalised before being combined. Magnitude of the temperature and precipitation changes were included based on the projection data presented relative to the ranges found within the Western Cape. The values were normalised based on the data in the municipality. For fire, the data indicates a low to medium risk for fire so a value of 2 (medium) was applied. Data indicates that flood numbers have been low in the past and future predictions do not really suggest an increase in floods although there is some uncertainty associated with this. For these reasons floods were assigned a value of 1. Floods and fires did not include a magnitude aspect as there was not specific data available for these. Coastal floods and erosion were included and so Velddrif was given a value of 2 for coastal floods, especially as there is evidence of floods and erosion from sea level rise, and this is expected to continue.
Water resources	Exposure	What is exposed to climate change are water resources, water infrastructure and vegetation. These are broad and essentially the whole of the municipal area would be exposed as rainfall anywhere could impact the water resources, as is the case with temperature. Water infrastructure was based on the water distribution network (km) from BM (2022b),
	Sensitivity	Water infrastructure, water quality data, population data, population growth, groundwater dependent towns and economic activities (BM, 2022b). Data presented/given/used was per town except for the vegetation data, this was organised per the AgriSmart agriculture zones. Then data was allocated to the towns based on which zones the towns fall into. Ground recharge data from CapeFarmMapper was used. Scoring: the higher the amount of infrastructure the lower the sensitivity and the better the water quality the lower the sensitivity; the higher the population the lower the sensitivity. Agriculture as an economic activity was given the highest score due to water extraction for irrigation.
Agriculture	Exposure	Agriculture crop areas (DFFE, 2022b; CropFarmMapper) and livestock population (CropFarmMapper) that are exposed to the hazards.
	Sensitivity	Grains and pome fruit were seen to be more sensitive to changes in temperature and rainfall so were assigned a higher sensitivity value (4), while other crop areas were given a lower sensitivity value (1). Livestock numbers

		(CropFarmMapper) were estimated and the number of dairies, piggeries, chicken batteries and feedlots were obtained. These were also assigned a sensitivity value (dairies having the highest sensitivity (5) and sheep having the lowest value (1)). Water storage was also seen to be important and would be impacted therefore the water sources, and storage capacity from the AgriSmart project (WCG, 2016) were included. There was, however, insufficient data to include the sensitivity of farmworkers.
Infrastructure	Exposure	Infrastructure is distributed across the municipality, especially roads and powerlines, so the whole area will be exposed.
	Sensitivity	The higher the number of infrastructure components (WWTW sites, WTW sites, water pumps, reservoirs, towers, ports), the higher the risk of climate impacts. Population, population growth and economic growth were also included – the higher the growth the greater the sensitivity. Sensitivity factor to the different climate impacts was included – the magnitude of the impacts of changes in temperature and rainfall was considered to be low, while the magnitude of the impacts of fire and flooding is much greater.
Biodiversity	Exposure	All natural vegetation is exposed in this section but exposure levels depend on the type of vegetation. This makes it important to monitor and restore habitats in the area.
	Sensitivity	The biodiversity categories from the EIIF study (DEA&DP, 2021b) were utilised. Critical biodiversity areas were seen as having the highest sensitivity (especially degraded ones), then ecological support areas and protected areas. The critical biodiversity areas are not currently projected and are very fragmented thus increasing their sensitivity.
Human settlements	Exposure	Here population and settlements are exposed, including rural settlements. These are distributed across the municipality and there needs to be a prioritization for development strategies, to minimize vulnerabilities and maximize sustainable communities.
	Sensitivity	Sensitivity is related to the population age structure, with young and old being more sensitive to changes in temperature and rainfall. Informal houses are also more sensitive, along with rural areas, due to their possibility of being cut-off during floods. The poverty, service delivery, health and infrastructure are also important, but these factors are already considered in the adaptive capacity.