A Climate Change Vulnerability Assessment for the Namakwa District, South Africa
The 2015 Revision

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Preface

Climate change is among the most pervasive threats to people and biodiversity today. Without action it will cause the extinction of countless species, destroy some of the world's most precious ecosystems, and devastate human livelihoods. Regardless of mitigation actions put in place today, a certain level of climate change is now inevitable. We will have to adapt in order to conserve our natural resources, achieve continued economic growth, and ensure social equity and poverty alleviation in the face of adverse impacts of climate change. Protecting the world's most vulnerable people and the environments they depend on from the adverse effects of climate change is a moral imperative in line with the constitution and all other major legislation of South Africa.

Climate change will place additional stress on Succulent Karoo ecosystems in the Namakwa District with all climate models indicating the Municipality will become hotter and drier, with more intense storms, floods, and droughts. These changes are already apparent, with coastal storms and droughts over the last 10 years costing the local economy millions of Rands in damage to infrastructure alone. Since our lifestyles are inextricably linked to the natural world, defending the resilience of ecosystems and the services they provide is essential to withstanding future climatic changes.

This report, and update to the 2012 report of the same name using new information and an adjusted methodology, is a milestone consolidation of information on the vulnerability of the ecosystems, socio-economic condition, and institutional structures of the Namakwa District. Here we provide an assessment of the Namakwa District Municipality's vulnerability to climate change in terms of ecosystem health, socioeconomic conditions, and institutional arrangements. The report also provides an index of this vulnerability as well as recommendations for reducing the vulnerability of local communities living in the NDM. Understanding the possible impacts of climate change, and directing effort towards reducing vulnerability and building resilience in vulnerable communities is essential.

We encourage partners in government, business, NGOs, communities, and the donor community to make use this information freely for planning.

Acknowledgements

The Namakwa District Municipality Climate Vulnerability Assessment report was a collective effort with significant contributions from many individuals and organisations. Conservation South Africa would particularly like to acknowledge the work of Dr Stephen Holness, Professor Guy Midgley, Dr James Cullis, the Department of Environmental Affairs, South African Local Government Association (SALGA), Department of Cooperative Governance (DCoG), Namakwa District Municipality leadership, and each of the local municipalities. This report would have not been possible without the immense contribution and dedicated participation of these committed individuals and institutions in climate change events held in the District.

Building on these successful partnerships with government and civil society, CSA aims to promote sustainable land management practices among farmers and other land users, promoting healthy ecosystems at a landscape level that ensure biodiversity conservation and the sustained provision of ecosystem services such as water flow, fertile soil, wildlife stocks, forage production, and flooding buffers, which are essential for coping with unpredictable climatic conditions.

Within Conservation South Africa, the authors would like to thank Sarah Frazee and Ronald Newman for their ongoing support and guidance. And in the wider Conservation International team, the authors would like to thanks colleagues Daniela Raik, David Hole, Bailey Evans, Shyla Raghav, Lee Hannah, and Ravic Nijbroek for their input and comment on earlier drafts.

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Citation

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Executive Summary

The impacts of climate change are now recognised globally as presenting a significant challenge to economic development and human well-being. Local managers and decision makers require an holistic approach when responding to climate change. This includes the need to understand the vulnerability of local communities in the context of the interactions between social and ecological systems.

This report presents a local level vulnerability assessment for the Namakwa District Municipality (NDM) in the Northern Cape, South Africa. It aims to complement the existing NDM bioregional plan by providing a tool for the rapid assessment of district scale social and ecological **vulnerability** as well as the identification of priority areas for planning and implementing **Ecosystem-based adaptation (EbA)**.

Here, we present a description of the likely future changes in rainfall and temperature and an overview of the ecological and socio-economic vulnerabilities in the district alongside institutional capacity for implementing climate change response activities.

Based on regional dynamical downscaling of three Global Climate Models, climate change projections for the NDM can be summarised as follows:

• Temperature projections are clear and predict an increase of 1.8°C over the medium term (2040-2059) and 3.9°C over the long term (2081-2100).
• Slight variations in temperature projections are evident between inland and coastal areas. Coastal areas are not projected to warm as much as the interior, with the interior projected to warm about 20% more than the coastal areas.
• Precipitation projections predict an overall reduction in rainfall in the District. The amount of reduction expected is variable across the region, but increases over time. There is also a lot of variation between models, and one model projects increases in rainfall in some areas, mainly the interior in autumn, over the long term.

ECOSYSTEM BASED ADAPTATION PRIORITY AREAS

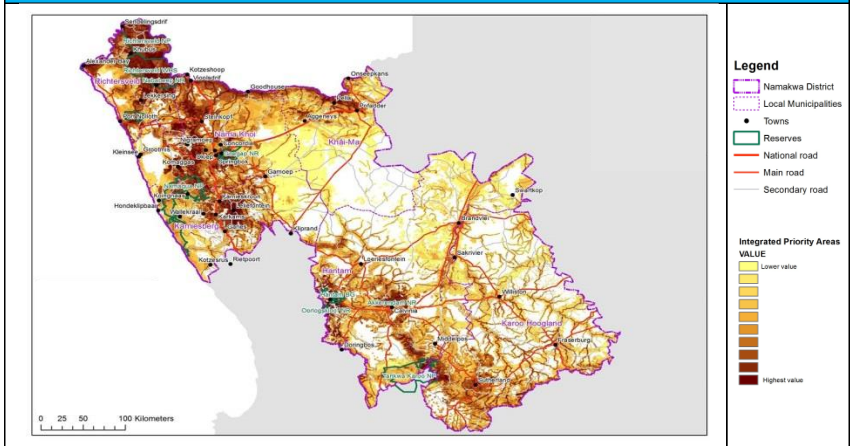

Figure a: Integrated map of areas important for Ecosystem-based Adaptation in the NDM

To generate the **Ecosystem-based Adaptation** priority map shown in **Figure a,** an integrated approach was used (see **Figure b** below). This included mapping and describing a number of social and ecological priority areas for the district, including:

• Water related ecological infrastructure (**Figure c**)
• Biodiversity priorities (or 'other ecological infrastructure') (**Figure d**)
• Natural features supporting climate resilience (**Figure e**)
• Socio-economic priority areas (**Figure f**)

Concentrating restoration and land management activities in these EbA priority areas will likely maximise the potential for natural ecosystems to contribute to building social and ecological resilience to climate change, ultimately reducing the vulnerability of the people living in the NDM.

Specifically, the effective management and protection of **water related ecological infrastructure** (**Figure c**)**,** ecosystems that deliver valuable water resources for people, is important for water production, flood attenuation, erosional control and maintaining water quality in this arid and water scarce region.

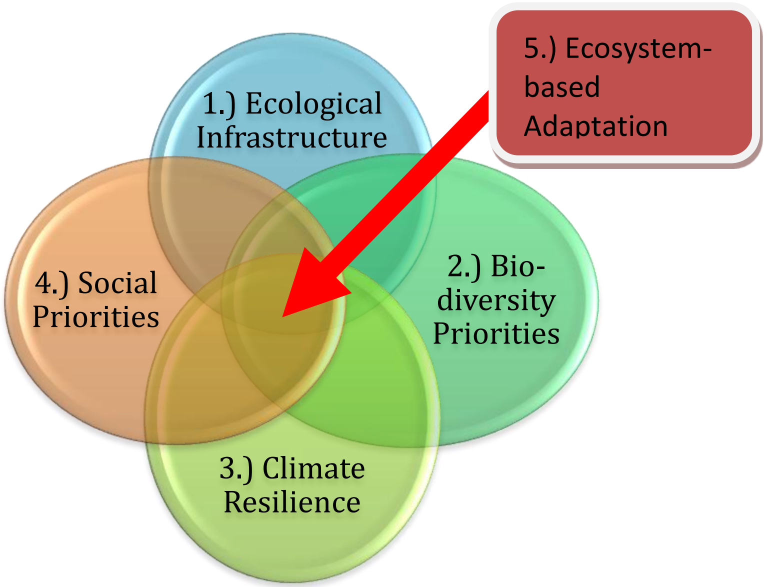

Figure b: Summary of the analysis process

WATER RELATED ECOLOGICAL INFRASTRUCTURE PRIORITY AREAS

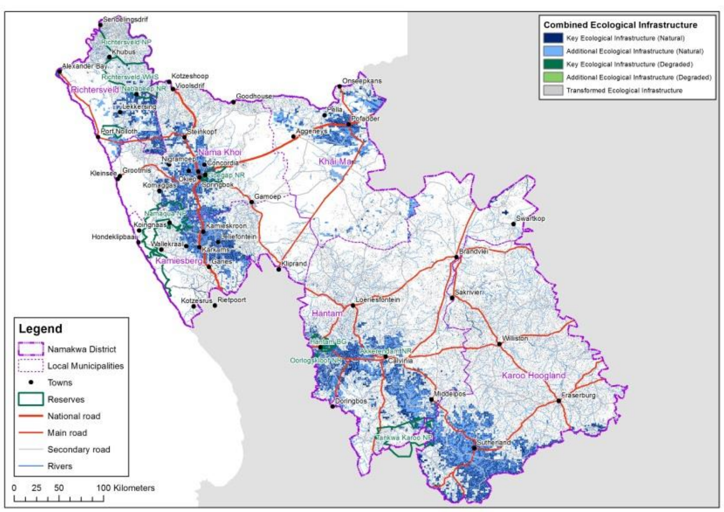

Figure c: Integrated map of water related ecological infrastructure for the NDM

Biodiversity priorities look at other ecological infrastructure, including the presence of threatened habitats, the degree of protection of areas with high biodiversity, and areas important for supporting natural resilience to climate shocks and stresses which need to be carefully managed (see **Figure d**).

BIODIVERSITY PRIORITY AREAS

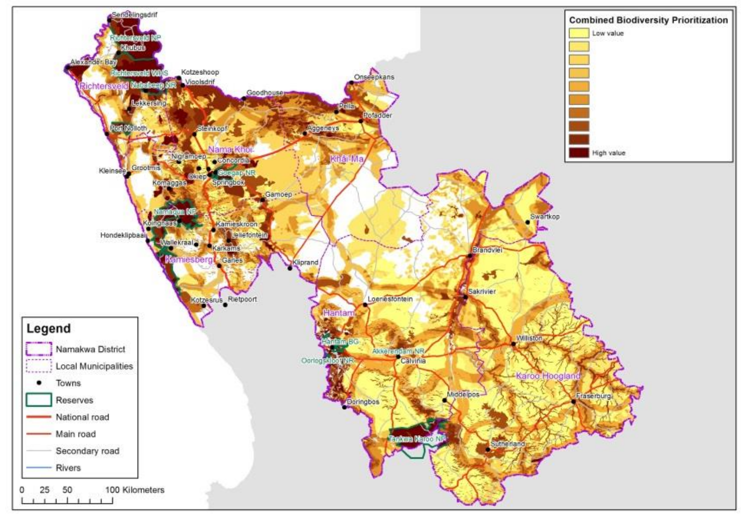

Figure d: Integrated map of biodiversity priorities in the NDM

Some features in the landscape are more likely to support climate resilience than others. These include riparian corridors and buffers; coastal corridors; areas with temperature, rainfall and altitudinal gradients; areas of high diversity; areas of high plant endemism; refuge sites including south-facing slopes and kloofs; and priority large unfragmented landscapes. Areas with natural features supporting climate resilience occur throughout the NDM (see **Figure e**).

Keeping these areas in a natural or near-natural state will allow ecosystems and species to adapt naturally to climate change, thus supporting healthy landscapes and the ability of ecosystems to continue to provide ecosystem services.

CLIMATE RESILIENCE PRIORITY AREAS

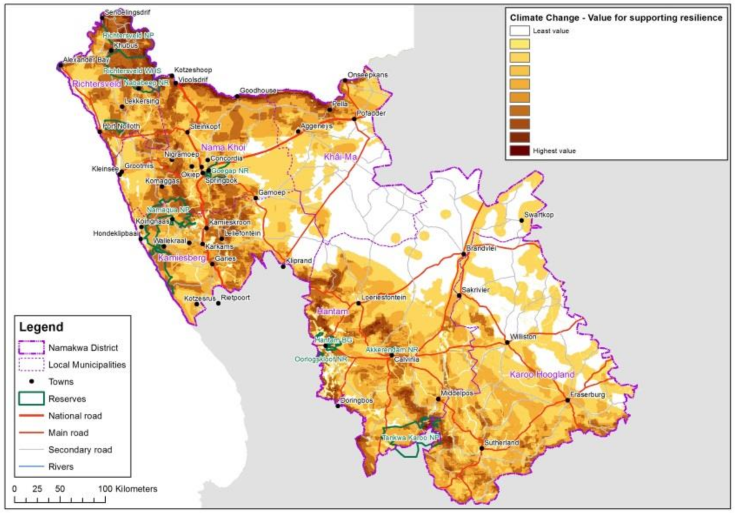

Figure e: Integrated map of natural features supporting climate resilience in the NDM

SOCIO-ECONOMIC PRIORITY AREAS

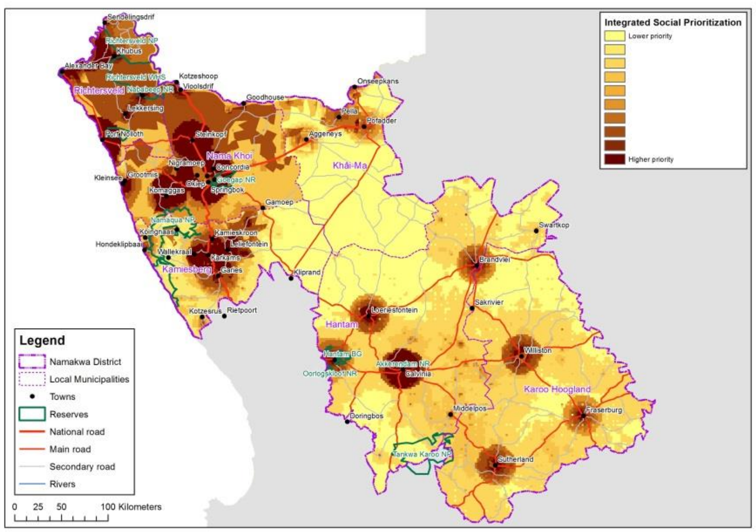

Figure f: Integrated map of socio-economic climate resilience priorities in the NDM

The rural nature of the NDM and high levels of direct dependence on ecological infrastructure places pressure on natural resources. We used several indicators, such as population density, income (employed/unemployed), and reliance on natural resources to develop a map of socio-economic priority areas in the context of climate change (see **Figure f**).

This vulnerability assessment provides scaled down climate change information useful for highlighting important areas for building and promoting resilience to climate change in the NDM. The production of comprehensive summary maps have allowed for a broad, at-a-glance assessment of the NDM's vulnerability to climate change.

Further, we have developed an index of vulnerability to climate change to allow for the measurement or quantification of vulnerability in the NDM. This index draws data from the spatial analysis conducted as part of this NDM climate change vulnerability assessment, the South African National Census 2011, the South African national Long Term Adaptation Scenarios, and a small amount of primary data collected through surveys using the South African Department of Environmental Affairs' climate change situational analysis and needs assessment questionnaire.

Applying the vulnerability index results in a simple score on a sliding scale of 1-5, where 1 is the ideal desired result (least vulnerable) and 5 is the worst possible result (most vulnerable) scores. Scores are presented for the medium term and the longer term.

Over the medium term, the NDM achieved an **overall vulnerability score of 2.4**. Over the longer term this **shifts closer to 3** (at 2.9). This can mostly be attributed to deepening climate change related stresses in terms of temperature and rainfall change, which we expect to impact on ecological infrastructure and place increasing pressure on pockets of biome climatic stability in the District. Since this analysis did not include socio-economic modelling, we have had to assume that the broad socio-economic context holds constant. See **Figure g** to **Figure j** below for visualisations of the vulnerability index.

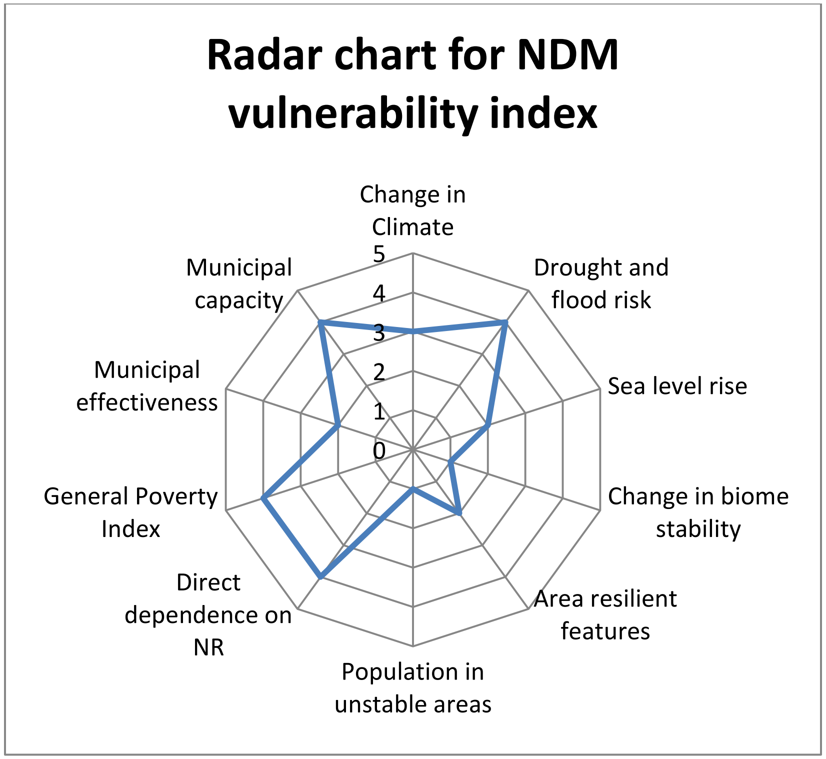

Figure g: Radar chart showing medium term vulnerabilities to climate change in the NDM

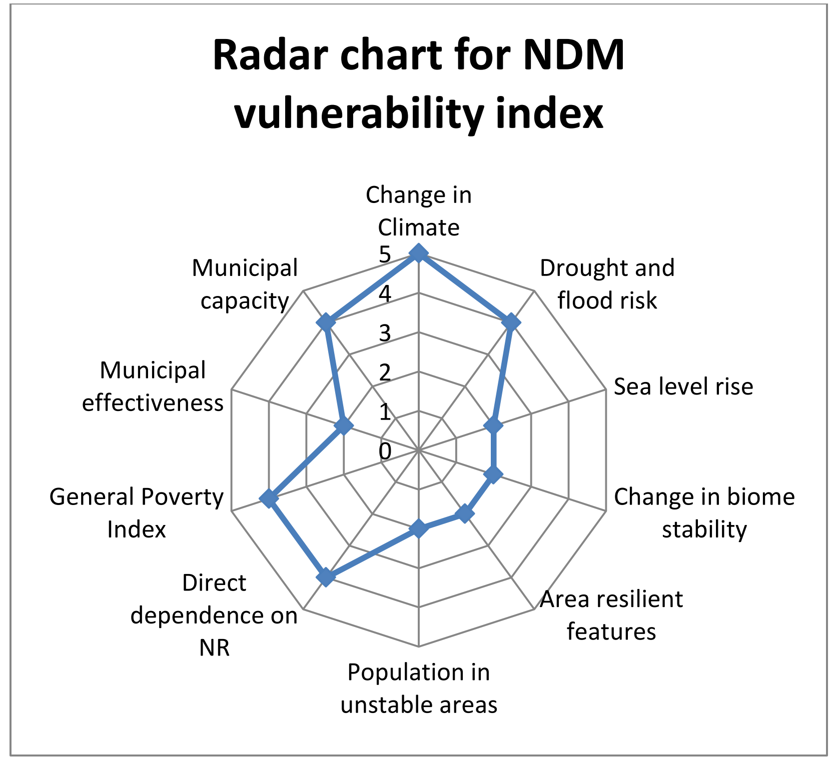

Figure i: Radar chart showing long term vulnerabilities to climate change in the NDM

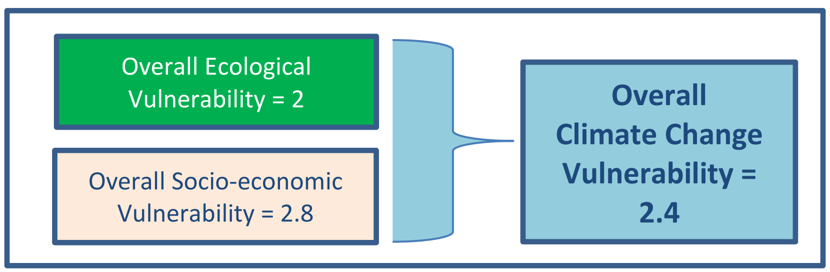

Figure h: The overall ecological and socio-economic scores were averaged to obtain an overall vulnerability index for the NDM in the medium term of 2.4

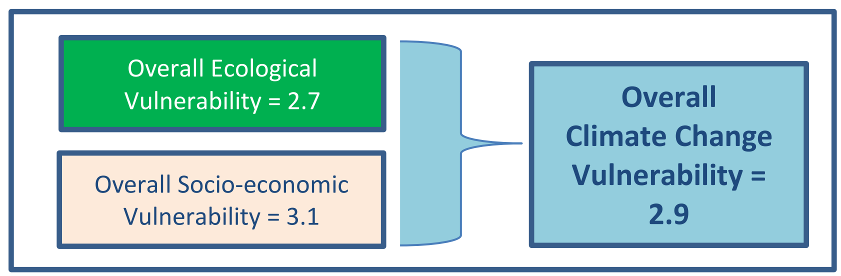

Figure j: The overall ecological and socio-economic scores were averaged to obtain an overall vulnerability index for the NDM in the long term of 2.9

The impacts of climate change are cross-cutting and therefore require a coordinated and cross-cutting response. Only such an approach will ensure that communities are able to withstand the impacts of climate change and adapt to the possible climate futures presented here. The rural nature of the NDM and high level to which its constituents depend directly on its ecological infrastructure for their livelihoods make this region a sound option **for Ecosystem-Based Adaptation** approaches.

Efforts should be made to reduce socio-economic vulnerabilities generally, and to increase institutional capacities. This is important as enhanced capacities will result in an improvement in people's wellbeing, as well as an improved understanding of the importance of the value of ecosystems and the services they provide in the NDM. Reduced socio-economic stress and increased institutional capacity will contribute greatly to successful adaptation in the NDM.

Although the current assessment represents a major step forward in our understanding of the vulnerabilities in the NDM, particularly in terms of our spatial representation of the available information, a number of the analyses will require further refinement in order for them to be integrated meaningfully into business as usual planning processes in the NDM.

Particularly, as a next step, spatially defined priority areas need to be linked explicitly with clear, site specific implementation activities. This is best achieved through a participatory planning process in the District and CSA recommends the use of the Lets' Respond Toolkit: Integrating Climate Change Risks and Opportunities into Municipal Planning, produced by the Departments of Environmental Affairs and of Cooperative Governance, along with the South Africa Local Government Association, as a useful tool for guiding the operationalisation of this assessment.

It should be noted that climate change science advances continuously, and it may be necessary to update this analysis as climate assessments improve. The Vulnerability Index is designed to be updated regularly using new information and should be reassessed every 5 years, alongside District Integrated Development Planning update and review processes.

In short, the actionable results of this report are as follows:

From chapter 3, temperature and rainfall projections

- All climate models used predict increases in temperatures over time. Proactive adaptation measures to address heat stress are needed.
- There is a lot of variability in the rainfall projections. Infrastructure must handle the full range of potential rainfall.
- Aridity can be expected to increase regardless and agricultural adaptations to a more arid environment are needed.

From chapter 4, biome stability modelling

- The Fynbos biome is highly vulnerable, and the Nama Karoo biome seems sensitive to desertification. The Succulent Karoo biome appears to hold relatively stable into the future. However, this result must be treated with caution, because the biome is climatically unique and large changes can occur without shifting biome climate envelope. Changes in biome need to be monitored, and farmers need to prepare for increasingly harsh conditions.

From chapter 5, water ecological infrastructure, chapter 6, biodiversity priorities, and chapter 7, climate resilient ecosystem priorities

- High priority ecological infrastructure should be maintained in a natural or near-natural state through conservation, biodiversity stewardship, and sound management
- Degraded areas important for ecological infrastructure should be actively rehabilitated to enhance their ability to deliver climate related ecosystem services for adaptation in the NDM.

From chapter 8, socio-economic vulnerability to climate change

- Poverty undermines adaptive capacity and must be urgently addressed through health, education, skills development, and job creation activities

- Many people in the NDM are entirely dependent on groundwater for their freshwater and these and other water resources must be carefully managed through a package of water supply and demand management projects.
- Sound management and development of communal rangelands will assist in building resilience.

From chapter 9, ecosystem based adaptation priority areas

- Priority areas in the NDM for ecosystem based adaptation to climate change identified through this process should be prioritised for adaptation action.

From chapter 10, the vulnerability index

- Maintain areas of strength in the NDM – good municipal service delivery effectiveness, low numbers of people living in climatically unstable areas, large areas of natural features contributing to climate resilience, low exposure to sea level rise, and reasonably stable biome climatic envelopes.
- Build the climate preparedness capacity of NDM staff and institutions, continue and enhance mainstreaming of climate change information into all development planning and action, and undertake detailed, coordinated, and participatory municipal planning to be in a better position to respond effectively to climate change.

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Chapter 1: Introduction

1.1 Climate change vulnerability

Climate change presents a significant challenge to human well-being. It is likely that climate change will exacerbate the existing vulnerabilities of people living in South Africa.

The latest IPCC[1] review completed in 2014 defines Vulnerability as the propensity or predisposition to be adversely affected. The review emphasises that the term vulnerability encompasses a variety of concepts and elements including sensitivity (or susceptibility to harm), and adaptive capacity (or ability to cope and respond).

We also considered two new terms from this report, namely *Contextual and OutcomeVulnerability*[1]. These terms assist in framing a start and end point for vulnerability. These terms permit defining a position of vulnerability 'before', and 'after', adaptation or other response interventions are implemented (see **Box 1** and **Box 2**).

1.2 Report aim

The purpose of this report is to present findings of a local level vulnerability assessment for the Namakwa District Municipality (NDM) in the Northern Cape, South Africa.

We use the latest IPCC definitions as a framework for placing vulnerability in the context of adaptation, adaptive capacity, and resilience[1] (see **Box 1** and **Box 2**).

> **Box 1: IPCC AR5 Definitions**
>
> **Vulnerability**
> The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including exposure to risk, sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
>
> **Contextual Vulnerability (Starting-point Vulnerability):**
> A present inability to cope with external pressures or changes such as changing climate conditions.
>
> **Outcome Vulnerability (End-Point Vulnerability):**
> The end-point after adaptation has been implemented. This process can begin with the development of climate scenarios moving to biophysical impacts studies and then the identification of adaptive options.
>
> Once adaptation has been implemented, any remaining limitations in ability to cope with external pressures defines the levels of vulnerability that may still exist after intervention.

Specifically, we aim to

- present climate change projections at a relevant local scale and in an accessible spatial and table format for use in decision-making;
- identify current sources of vulnerability in the landscape;
- inform the implementation of **Ecosystem-based Adaptation** (EbA) in the district (see **Box 3**); and
- provide an overall **Vulnerability Index** for the NDM; a repeatable measure that can be used locally to track changes in vulnerability and resilience over time.

[1] UNFCCC Intergovernmental Panel on Climate Change, 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Parts A and B: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

1.3 Relevance: local managers and decision makers

Responding to climate change at a local level requires an holistic approach that considers vulnerability in the context of the interactions between social and ecological systems. Socio-ecological interactions that affect ecosystem services are particularly important in rural areas such as the NDM. This is because the link between people and the environment that supports them is far more direct than in more urbanised environments.

The effects of climate related shocks and stresses such as floods, droughts, and an unpredictable rainy season is very close to home for these communities. Climate variability and change impacts directly on people's incomes, assets and livelihoods, and can lead to negative impacts in terms of social disruption and unrest, or poor health.

Mapping the spatial distribution of social resources, such as access to basic services or ownership of assets, as well as ecological resources, such as areas critical for supplying ecosystem services and supporting climate resilience, provides an opportunity for decision makers at the local level to plan and implement win-win adaptation interventions.

The NDM has recognised the importance of understanding the impacts of climate change in the District and have developed an NDM bioregional management plan. The plan includes present climate conditions, and how to best develop in a manner which will not have a negative impact on the District's ability to adapt later.

The maps presented in this report showing **Ecosystem-based Adaptation** (EbA) priority areas, together with the **Vulnerability Index** (VI), complement the existing NDM bioregional plan and integrated development plan by providing a tool for the rapid assessment of District scale vulnerability as well as EbA requirements. The VI provides a measure for assessing change in vulnerability over a set period for the District.

Box 2: IPCC AR5 Definitions

Adaptation
The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Incremental adaptation
Adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale.

Transformational adaptation
Adaptation that changes the fundamental attributes of a system in response to climate and its effects.

Adaptive capacity
The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences

Resilience
The capacity of social, economic, and environmental systems to cope with a hazardous event, trend, or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

Box 3: Ecosystem-based Adaptation (EbA)

Ecosystem-based adaptation focuses on managing, conserving and restoring ecosystems to buffer humans from the impacts of climate change. The Convention on Biological Diversity defines ecosystem-based adaptation as "the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change".

The approach is suggested to be particularly effective in helping society cope with extreme climate events such as droughts, floods and storms as well as incremental changes in temperature and rainfall. In many cases, ecosystem-based adaptation can work hand in hand with engineered adaptation responses (such as building gabions or weirs).

South Africa's National Climate Change Response White Paper fully supports an EbA approach.

1.4 Report outline

This report includes 11 chapters and 6 Annexes.

Chapter 1: the current chapter has served to introduce the overall aim and relevance of the report.

Chapter 2: provides an introduction to the NDM including descriptions of the geography, current climate, socio-economic conditions, and institutional and policy context.

Chapter 3: presents rainfall and temperature changes projected by the climate models for the NDM from now to 2050 and 2100.

Chapter 4: presents the results of biome climatic envelope modelling used to determine plausible shifts in suitable climate zones for existing biomes as well as determine likely areas of biome stability.

Chapter 5: presents maps of water-related Ecological Infrastructure (EI) for the District including areas important for water production and stream flow augmentation, erosion control, water quality, and flood attenuation. An integrated water EI map is also presented.

Chapter 6: provides maps of spatial biodiversity priorities for the District which can be used, among other things, for prioritising areas for conservation action.

Chapter 7: presents maps of natural features important for supporting the resilience of biodiversity, and the ecosystem services they provide, to climate change.

Chapter 8: provides a visual depiction of socio-economic vulnerability, drawing on National Census data, and with a focus on areas with high levels of general poverty and high levels of direct dependence on natural resources.

Chapter 9: presents **Ecosystem-based Adaptation** priority areas for the NDM, drawing on the datasets presented in chapters 3-8. EbA priority areas comprise specific areas in the landscape where people are most directly dependent on the environment and which are most critical for supplying ecosystems services and supporting climate change resilience.

Chapter 10: provides an overall **Vulnerability Index** for the NDM. The above spatial data and narratives are used together with national level climate change research and input from local government and community members to develop Ecological and Socio-economic Vulnerability Indices, which are then integrated into an overall **Vulnerability Index** for the NDM.

The index is a useful measure to summarise climate change vulnerability for the district at a specific point in time.

Chapter 11: concludes the report and suggests a way forward for the NDM.

The **Annexes 1-5** present detailed methods and data sources for additional information on some sections of the assessment presented here.

Specifically, **Annex 1** contains an overview of the Institutional and Policy context in which climate change response planning takes place.

Annexes 2-5 contain additional data and methods discussions for the spatial analysis of water EI, biodiversity, climate resilience, and socio-economic priorities.

Annex 6 contains all the maps shown here, and selected additional maps used in the analysis, in a larger format.

Chapter 2: Background and Context

2.1 Geographic context and topography

The Namakwa District Municipality (126 860 km^2) is located in the north western corner of the Northern Cape Province in South Africa. It is bordered in the North by South Africa's neighbour Namibia, to the south by the Western Cape Province, and to the west by the Northern Cape Districts of Siyanda and Pixley ka Seme (**Figure 1**).

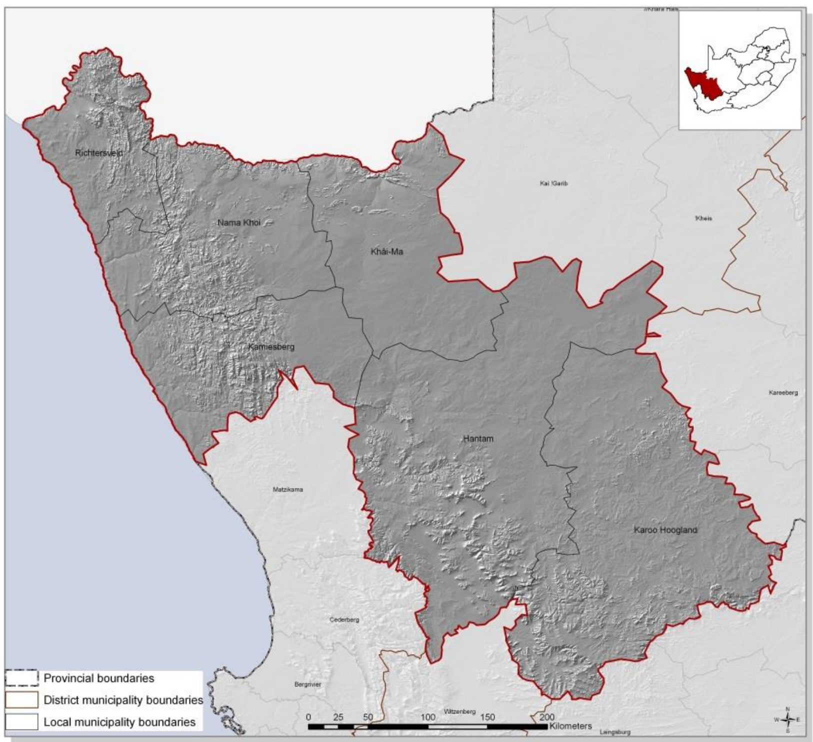

Figure 1: Namakwa District Municipality

The NDM is situated in the Lower Gariep/Lower Orange catchment. The Orange River, with its origins in the Lesotho highlands 2000km away, is the only perennial river in the District and supplies much of the fresh water for the towns in the northern parts of the District. Towns and settlements south of Springbok are reliant on groundwater.

The District's topography is characterised by mountainous escarpment rising to dry grassy plains in the northern interior, and dropping steeply to undulating coastal shrubland towards the west. The northern border, along the banks of the Orange River, is characterised by rocky mountain desert. Mountains rise to just over 1000m above sea level.

Extensive networks of ephemeral wetlands can be found in the high-lying Kamiesberg area.

The NDM is characterised by poor quality sandy soils and granitic outcrops.

2.2 General climate conditions

Climatic conditions in the NDM are semi-arid and influenced by the orographic effect of the escarpment and by west coast frontal systems. Rainfall is low with an average between 100 mm-450mm annually, and is very spatially variable as well as highly variable between years. The northern interior receives predominantly summer rainfall and the coastal and southern parts of the District tend to receive more winter rain. There are also transition zones where rain falls throughout the year, but in small absolute amounts.

In terms of temperatures, the region is characterised by extremes. In summer temperature frequently soar into the 30s and 40s (°C) and winters are cold, characterised by light snow and frequent frost in higher-lying areas.

2.3 Administrative boundaries

There are 6 local municipalities in the NDM – Richtersveld, Nama Khoi, Khai Ma, Kamiesberg, Hantam, and Karoo Hoogland (see **Figure 1**).
The NDM, at 126 860km^2, is geographically the largest District in the country. It is found within the largest Province in the country, the Northern Cape. Despite its large size, the NDM is home to a relatively small population, some 115 842 people (roughly 1 person per km^2), see **Table 1**.

Springbok is the administrative centre of the District, located in the Nama Khoi local municipality. There are a 52 scattered towns and settlements in the District, some of which are very isolated and remote.

Table 1: Population distributions and densities in the NDM

Municipality	Population (2011)	Area	Population density per km^2
Namakwa District	115,841	126,860	0.9
Richtersveld LM	11,982	9,608	1.2
Nama Khoi LM	47,041	14,921	3.2
Khai Ma LM	12,465	19,719	0.6
Kamiesberg LM	10,187	14,210	0.7
Hantam LM	21,578	36,128	0.6
Karoo Hoogland LM	12,588	32,274	0.4
		Average	**1.1**

Table 2: Local municipalities and their administrative centres in the NDM

Local Municipality	Administrative Centre
Richtersveld LM	Port Nolloth
Nama Khoi LM	Springbok
Khai Ma LM	Pofadder
Kamiesberg LM	Garies
Hantam LM	Calvinia
Karoo Hoogland LM	Williston

2.4 Socio-economic context

The NDM is largely a rural municipality with a number of rural and peri-urban settlements scattered around the District. It is characterised overall by low levels of economic activity and a high dependence on government employment and social grants.

The largest land use is for agriculture activities, with extensive private and communal farmers farming with small stock such as sheep and goats. Farming is on the margins of economic viability, with very large areas of land needed to sustain relatively few animals, due to the arid environment. Mining is also a large economic sector in the District and seasonal eco-tourism also brings in some investment.

Large numbers of people are unemployed with 40 – 75% of the District's residents recorded as unemployed in the 2011 Census (very variable across the LMs). There are high levels of poverty and more than 50% of the population is classified as poor.

The distance from larger South African economic centres limits the potential of the tourism industry, restricts access to markets, and results in higher prices paid for goods and services, entrenching poverty. The NDM is always looking into ways of addressing economic stumbling blocks and encouraging growth in local business.

Low income levels directly affect service provision, however, as the municipality is often unable to collect revenue on services provided.

2.5 Institutional and policy context

South Africa has developed a powerful and coherent environmental legislation with the country's constitution containing the bill of rights which promotes a sustainable human-environment relationship. Section 24 of the constitution sets up an enabling environment for the enforcement of environmental legislation. South Africa is also in the process of developing a comprehensive set of Long Term Adaptation Scenarios for the country. Information from these scenarios has been used in particular for the **Vulnerability Index** in Chapter 10.

There are, however, significant challenges regarding resource availability, capacity, and varied stresses that impact on institutional functions and the ability to implement, or to enforce these sustainability goals and environmental laws.

Please see **Annex 1** for a comprehensive overview of national, provincial and local environmental management legislation. This is also summarised in **Table 3** below.

Table 3: A summary of the policy and planning enabling environment for coordinated climate change response in the NDM

International Conventions	United Nations Framework Convention on Climate Change (United Nations) Convention on Biological Diversity United Nations Convention to Combat Desertification
National Acts and Policies	The Constitution of the Republic of South Africa 1996 National Climate Change Response Policy (White Paper) (NCCRP) 2011 National Long Term Adaptation Scenarios (LTAS) 2014 National Environmental Management Act (NEMA) 1998 National Environmental Management: Biodiversity Act (NEMBA) 2004 National Environmental Management: Air Quality Act (NEMAQA) 2004 National Environmental Management: Protected Areas Act (NEMPAA) 2004 Mountain Catchment Areas Act (MCAA) 1970 National Environmental Management: Integrated Coastal Management Act (NEMCMA) 2008 National Environment Management: Waste act (NEMWA) 2008 National Water Act (NWA) 1998 National Forest Act (NFA) 1998
National Plans and Strategies	National Development Plan (Vision 2030) National Water Resource Strategy (NWRS 2) 2013 Environmental Protection and Infrastructure Programme (EPIP) National Framework for Disaster Risk Management 2005 National Strategy for Sustainable Development and action plan (NSSD) 2011-2014

Provincial Plans and Strategies	Northern Cape Provincial Growth and Development Strategy 2014 Northern Cape Provincial Spatial Development Framework 2012 Northern Cape Rural Development Strategy 2010
District Plans and Strategies	Namakwa District Integrated Development Plan 2015 Namakwa District Environmental Management Framework and Strategic Environmental Management Plan 2011 Namakwa Bioregional Plan 2010 Namakwa Biodiversity Sector Plan 2008
Town and Community Level Governance	Ward committees Community-based development organisations Non-governmental organisations Traditional leaders Farmers unions Mineworkers unions Commonage committees

Chapter 3: Temperature and Rainfall Change

3.1 Introduction

In this chapter we present regionally downscaled climate change projections for the NDM, including rainfall and temperature projections for the medium (2040-2059) and longer term (2081-2100). These projections indicate how rainfall and temperature are likely to change by approximately 2050 (medium term: 2040-2059) and by approximately 2100 (longer-term: 2081-2100) compared with current climatic conditions.

3.2 Methods

3.2.1 Temperature and rainfall projections

We used the results from three Global Climate Models (GCMs), dynamically downscaled to Southern Africa, to represent three plausible scenarios of temperature and rainfall change over the medium and longer term for the NDM (see **Box 4** for a statement on interpreting these models and using the outputs for decision-making).

The dynamic regional climate model applied to downscale the GCMs is a variable-resolution global atmospheric model known as the conformal-cubic atmospheric model (**CCAM**). The names of the three GCMs that were dynamically downscaled are listed below:

- Model for Interdisciplinary Research on Climate, medium resolution (**MIROC**3.2-medres);
- Max Planck Institute for Meteorology (ECHAM5/**MPI**); and
- **CSIRO** Mark3.5

The GCMs were downscaled using the **SRES A2** emissions scenario which is a relatively high end, or 'unmitigated', emission scenario. The outputs are for the medium term (2050), which correlates to models for the period 2040-2059, and the longer term (2100), which correlates to models run for the period 2081-2100.

Box 4: Uncertainty in climate change modeling

Although climate science has evolved rapidly over the last few years, there is nevertheless considerable uncertainty about the specific evolution of climate over the shorter term and at fine scales (e.g. at the municipal rather than global scale). While confidence in global climate models is growing, there is greater appreciation of the uncertainties involved in downscaling the global models to produce climate projections at the regional and local scales.

It is quite possible that the projections presented here, particularly rainfall projections, could differ substantially were different Global Climate Models and/or a different downscaling approach used.

Additionally, climate change science is a rapidly advancing discipline and refinements to modelling approaches are continuously being made. It is therefore necessary to periodically update this analysis as climate assessments improve. For example, the latest climate scenarios for South Africa, comparing results from two different downscaling approaches, are available from CSAG and CSIR, and have been captured by the Department of Environmental Affairs' South African Long Term Adaptation Scenarios .

3.2.2 Current climate conditions

The present day climate values used for this analysis are based on agro-hydrology data for rainfall and temperature. Temperature and precipitation data as an annual average and for the seasons DJF (Dec, Jan, Feb), MAM (Mar, Apr, May), JJA (Jun, July, Aug) and SON (Sept, Oct, Nov) were used as the base climate variables. The climate scenario data used were based on the difference between future and current values for each of the three Global Circulation Models (i.e. future predicted value – control values produced by the model for present conditions), with the present being (1960-1999), the medium term being (2040-2059), and the longer term (2081-2100).

3.3 Results: Temperature and rainfall change

Table 4 and **Table 5** summarise the projected medium (2040-2059) and longer term (2081-2100) temperature and rainfall change for the NDM and each of its local municipalities. Rainfall is presented as median area-weighted data, and not as the mean.

The tables include a summary of:

- present day temperature and rainfall for the NDM (**current climate**);
- projected temperature and rainfall for 2040-2059 and 2081-2100 presented for the three regionally downscaled Global Climate Models (**CSIRO, MPI** and **MIROC**);
- an average of the projected temperature and rainfall for 2040-2059 and 2081-2100 across the three models (**average model**); and
- an average change in temperature and rainfall that may be expected for 2040-2059 and 2081-2100. This is calculated by subtracting the projected temperature and rainfall for 2014-2059 and for 2081-2100 from the present day conditions (**average change, future – current**).

Maps of projected seasonal temperature and rainfall changes (i.e. increase or decrease in comparison to current climate) are also presented below. Annual average change maps are shown for the medium term timeframe only, and as a composite of model outputs (**Figure 2** and **Figure 5**). For the seasonal temperature data, maps for the **CSIRO** model are shown (see **Figure 3 and 4**). As there was little variation between the models on temperature projections we only present the outputs of one model as representative (**CSIRO**). For the seasonal rainfall data, maps for the 'wet' **CSIRO** and the 'dry' **Miroc** models are shown (see **Figure 6 to Figure 9)**, to highlight the variation in model projections. Both seasonal temperature and seasonal rainfall data are presented at the medium and longer term time scales. Modelled temperature and rainfall projections for each of the three models can be found in **Table 4** and **Table 5.**

3.3.1 Results: Temperature change

Results from the three models are extremely similar in terms of temperature for both the medium and longer term, although the **MPI** model does consistently show slightly lower temperatures than the other two models. For practical purposes, given small difference, we have treated the outputs of the models as roughly identical.

In the medium term, average temperatures can be expected to rise by 1.8°C across the District. As is the common pattern across South Africa, coastal areas (Richtersveld, Nama Khoi, and Kamiesberg Municipalities) tend to have slightly smaller predicted increases in temperatures than do inland areas (Khai Ma, Hantam, and Karoo Hoogland Municipalities). It should be noted, however, that the differences in the District are relatively small in absolute terms, at a maximum of 0.5°C.

In the longer term, average temperatures can be expected to rise by around 3.9°C above current conditions, for the District as a whole. The coastal versus inland difference is more pronounced in the longer term, with the Richtersveld increasing in temperature by an average of 3.1°C, while Khai Ma looks set to increase in temperature by an average of 4.2°C.

Changes in seasonal patterns are not very marked, but it is notable that for the medium and longer term (with 1.9°C and 4.2°C increases respectively), the greatest increases in temperatures are modelled for the autumn months MAM. Consistently, the smallest increases in temperature are predicted for spring, with temperatures rising by 1.7°C in the medium term and 3.5°C in the longer term. Overall, the temperature change projections for the District are very representative of coastal and midland areas across South Africa.

Major temperature related impacts are likely to be:

- Increased water stress. Even if rainfall remains relatively constant, increased evapotranspiration as a result of higher temperatures will dry out soils. This main have significant consequences for crop and forage production, fresh water quality and availability, and runoff and erosion control;
- Increased magnitude of storm events. Higher summer energy levels may be linked to more intense storms, which have implications for flooding.

3.3.2 Results: Rainfall change

As the NDM is already severely water stressed, reductions in rainfall are of critical significance. Even small changes in annual rainfall totals or the timing of rainfall are likely to have significant impacts. However, the models are divergent in that **Miroc** is a relatively dry model (and hence is likely to represent a worst case model for the water stressed Namakwa District), while the **CSIRO** is a relatively wet model for the best case scenario.

There is, however, very little divergence in terms of the direction of change predicted, with the only exception to the overall dominant drying trend being that the **CSIRO** model appears to indicate the possibility of some increase in autumn rain in the interior in the longer term.

The best case scenario suggests that the NDM may maintain its current rainfall over the longer term (after a small short term dip). It must be noted, however, that the other models suggest that areas currently receiving relatively higher rainfall areas such as in the Kamiesberg and Hantam LMs may experience fairly large decreases in overall rainfall, particularly in autumn when the annual winter rains start.

In the medium term, small decreases in rainfall are predicted across most of the NDM. However, it must be emphasized that the predicted changes are so small that they are well within current levels of normal annual variability. In the longer term, the average reduction in median rainfall is predicted to be 20mm, but it is important to emphasize that the range in the models is large, with the **CSIRO** model suggesting minimal change while the **Miroc** model shows up to a 43% drop overall. The areas potentially worst impacted are the Khai-Ma, Nama Khoi and Hantam LMs. Overall precipitation shows little change in seasonal pattern.

Although their identification is beyond the scope of the current project, there may be important changes in the variability of rainfall between years, and increases in short term variability are also likely.

Table 4 and **Table 5** show temperature in °C and rainfall in mm per year. The value given for rainfall seems low, but this is because the median (midpoint) rather than the mean (average) of the data has been used. In the more arid parts of the country, where annual rainfall totals are very variable, the median is very much lower than the mean, about half. Also rainfall is taken as an area-based average at the local municipal scale. Therefore, in places like the Kamiesberg, where there are pockets of relatively high rainfall in the high-lying areas, the mean, and particularly median, rainfall across much of the municipality is very low, bringing rainfall totals down on average.

Table 4: Current and modelled seasonal and annual temperature and precipitation for the NDM and its local municipalities for the medium term 2040-2059 time period

	Area	Spring Rain (mm)	Spring Temperature (°C)	Summer Rain (mm)	Summer Temperature (°C)	Autumn Rain (mm)	Autumn Temperature (°C)	Winter Rain (mm)	Winter Temperature (°C)	Annual Rain (mm)	Annual Temperature (°C)
Current Climate	Richtersveld	3.8	19.7	0.1	24.7	10.8	20.3	19.7	13.8	34.4	19.6
	Nama Khoi	9.2	18.9	1.4	23.9	21.0	19.8	38.2	13.2	69.8	19.0
	Kamiesberg	17.3	17.6	1.1	22.3	27.5	19.1	58.8	13.2	104.8	18.0
	Hantam	15.2	17.6	9.2	23.4	37.7	18.0	39.9	11.1	101.9	17.5
	Karoo Hoogland	15.8	15.6	17.8	21.9	43.5	15.7	21.6	8.9	98.7	15.5
	Khâi-Ma	2.4	19.2	8.7	25.0	20.8	19.5	4.5	12.1	36.4	19.0
	Namaqua District	12.2	17.6	8.6	23.3	31.5	18.2	31.0	11.4	83.3	17.6
CSIRO 50 years	Richtersveld	3.3	21.1	0.1	26.0	10.5	21.9	20.5	15.8	34.4	21.2
	Nama Khoi	7.8	20.5	1.0	25.6	20.9	21.7	38.8	15.5	68.5	20.8
	Kamiesberg	15.5	19.1	0.8	23.9	27.2	20.8	60.1	15.3	103.6	19.8
	Hantam	12.6	19.4	7.1	25.5	35.8	20.1	39.3	13.4	94.7	19.6
	Karoo Hoogland	13.5	17.3	13.4	24.0	37.7	18.0	20.3	11.3	84.9	17.6
	Khâi-Ma	1.9	21.1	6.2	27.1	18.7	21.7	4.0	14.6	30.9	21.1
	Namaqua District	10.4	19.3	6.5	25.2	29.1	20.2	30.7	13.7	76.6	19.6
Miroc 50 years	Richtersveld	2.4	21.4	0.1	26.3	6.1	21.8	17.5	15.6	26.1	21.3
	Nama Khoi	6.4	20.8	1.4	25.7	13.1	21.6	34.7	15.1	55.6	20.8
	Kamiesberg	11.4	19.4	1.2	24.3	17.1	20.8	56.9	15.0	86.5	19.9
	Hantam	11.0	19.6	8.8	25.5	25.7	20.1	38.2	13.1	83.7	19.6
	Karoo Hoogland	12.8	17.5	17.8	23.8	32.0	17.7	20.8	10.9	83.4	17.5
	Khâi-Ma	1.6	21.3	8.1	27.0	13.5	21.6	4.3	14.2	27.5	21.0
	Namaqua District	9.0	19.6	8.4	25.2	21.5	20.1	29.4	13.4	68.3	19.6
Mpi 50 years	Richtersveld	3.7	21.0	0.1	25.8	9.8	21.6	16.8	14.9	30.4	20.8
	Nama Khoi	8.6	20.4	1.3	25.2	19.6	21.3	33.8	14.4	63.2	20.3
	Kamiesberg	15.7	19.0	1.0	23.5	24.4	20.4	52.2	14.3	93.2	19.3
	Hantam	13.8	19.1	8.7	24.9	34.6	19.8	36.7	12.3	93.7	19.0
	Karoo Hoogland	14.1	17.1	16.5	23.4	39.1	17.5	21.2	10.2	90.9	17.0
	Khâi-Ma	2.2	20.9	8.0	26.5	20.0	21.3	4.3	13.5	34.4	20.6
	Namaqua District	11.1	19.1	8.0	24.7	28.7	19.8	28.3	12.6	76.1	19.1
Average 50 years (Models)	Richtersveld	3.1	21.2	0.1	26.0	8.8	21.8	18.3	15.4	30.3	21.1
	Nama Khoi	7.6	20.5	1.2	25.5	17.8	21.5	35.8	15.0	62.4	20.6
	Kamiesberg	14.2	19.1	1.0	23.9	22.9	20.7	56.4	14.9	94.4	19.6
	Hantam	12.4	19.4	8.2	25.3	32.0	20.0	38.0	12.9	90.7	19.4
	Karoo Hoogland	13.5	17.3	15.9	23.7	36.3	17.7	20.8	10.8	86.4	17.4
	Khâi-Ma	1.9	21.1	7.4	26.9	17.4	21.6	4.2	14.1	30.9	20.9
	Namaqua District	10.1	19.3	7.7	25.0	26.4	20.1	29.5	13.2	73.7	19.4
Average Change (50 year - current)	Richtersveld	-0.7	1.5	0.0	1.4	-2.0	1.5	-1.4	1.6	-4.1	1.5
	Nama Khoi	-1.6	1.7	-0.2	1.6	-3.2	1.7	-2.4	1.8	-7.3	1.7
	Kamiesberg	-3.1	1.6	-0.1	1.6	-4.6	1.6	-2.4	1.7	-10.3	1.6
	Hantam	-2.7	1.8	-1.0	1.9	-5.7	2.0	-1.8	1.9	-11.3	1.9
	Karoo Hoogland	-2.4	1.7	-1.9	1.8	-7.2	2.0	-0.9	1.8	-12.3	1.9
	Khâi-Ma	-0.5	1.9	-1.2	1.9	-3.5	2.0	-0.3	2.0	-5.4	2.0
	Namaqua District	-2.1	1.7	-1.0	1.8	-5.0	1.9	-1.5	1.8	-9.6	1.8

Table 5: Current and modelled seasonal and annual temperature and precipitation for the NDM and its local municipalities for the long term 2081-2100 time period

	Area	Spring Rain (mm)	Spring Temperature (°C)	Summer Rain (mm)	Summer Temperature (°C)	Autumn Rain (mm)	Autumn Temperature (°C)	Winter Rain (mm)	Winter Temperature (°C)	Annual Rain (mm)	Annual Temperature (°C)
Current Climate	Richtersveld	3.8	19.7	0.1	24.7	10.8	20.3	19.7	13.8	34.4	19.6
	Nama Khoi	9.2	18.9	1.4	23.9	21.0	19.8	38.2	13.2	69.8	19.0
	Kamiesberg	17.3	17.6	1.1	22.3	27.5	19.1	58.8	13.2	104.8	18.0
	Hantam	15.2	17.6	9.2	23.4	37.7	18.0	39.9	11.1	101.9	17.5
	Karoo Hoogland	15.8	15.6	17.8	21.9	43.5	15.7	21.6	8.9	98.7	15.5
	Khâi-Ma	2.4	19.2	8.7	25.0	20.8	19.5	4.5	12.1	36.4	19.0
	Namaqua District	12.2	17.6	8.6	23.3	31.5	18.2	31.0	11.4	83.3	17.6
CSIRO 100 years	Richtersveld	2.4	22.7	0.1	27.9	12.4	23.9	17.9	17.4	32.8	23.0
	Nama Khoi	6.2	22.2	1.2	27.7	25.5	23.9	35.4	17.2	68.3	22.8
	Kamiesberg	12.6	20.8	1.0	26.0	32.5	22.9	52.9	17.0	99.1	21.7
	Hantam	12.9	21.2	8.4	27.8	44.0	22.4	38.6	15.3	103.9	21.7
	Karoo Hoogland	13.3	19.2	16.6	26.2	48.0	20.1	21.2	13.2	99.0	19.7
	Khâi-Ma	1.9	23.0	7.6	29.4	25.4	24.1	4.3	16.6	39.2	23.3
	Namaqua District	9.8	21.2	7.9	27.4	36.3	22.4	29.3	15.6	83.3	21.6
Miroc 100 years	Richtersveld	1.5	22.8	0.0	27.7	3.4	23.6	11.8	17.2	16.8	22.8
	Nama Khoi	4.3	22.4	0.8	27.4	7.3	23.7	24.5	16.9	37.0	22.6
	Kamiesberg	8.7	20.9	0.8	26.0	10.5	22.9	40.9	16.6	60.9	21.6
	Hantam	7.5	21.5	6.3	27.7	16.3	22.7	27.6	14.9	57.8	21.7
	Karoo Hoogland	8.9	19.3	13.8	25.7	22.9	20.3	16.1	12.6	61.7	19.5
	Khâi-Ma	1.1	23.2	5.1	29.1	6.7	24.2	3.2	16.1	16.1	23.1
	Namaqua District	6.2	21.3	6.2	27.1	13.9	22.5	21.3	15.1	47.7	21.5
Mpi 100 years	Richtersveld	4.0	22.4	0.0	27.3	5.3	23.2	13.1	17.2	22.4	22.5
	Nama Khoi	9.7	22.0	0.8	27.2	10.7	23.3	28.3	17.1	49.5	22.4
	Kamiesberg	17.8	20.5	0.6	25.4	13.4	22.2	42.0	16.7	73.8	21.2
	Hantam	14.3	21.0	6.2	27.6	19.5	22.2	32.7	15.1	72.7	21.5
	Karoo Hoogland	14.1	18.9	13.1	25.9	25.0	20.0	19.0	12.9	71.2	19.4
	Khâi-Ma	2.4	22.7	4.9	29.1	10.2	23.8	3.7	16.5	21.2	23.0
	Namaqua District	11.7	20.9	5.9	27.0	16.7	22.1	24.4	15.3	58.7	21.3
Average 100 years (Models)	Richtersveld	2.6	22.6	0.0	27.6	7.1	23.6	14.3	17.2	24.0	22.8
	Nama Khoi	6.8	22.2	0.9	27.4	14.5	23.6	29.4	17.1	51.6	22.6
	Kamiesberg	13.0	20.7	0.8	25.8	18.8	22.7	45.3	16.8	77.9	21.5
	Hantam	11.6	21.2	7.0	27.7	26.6	22.5	33.0	15.1	78.1	21.6
	Karoo Hoogland	12.1	19.1	14.5	25.9	32.0	20.1	18.8	12.9	77.3	19.5
	Khâi-Ma	1.8	22.9	5.9	29.2	14.1	24.0	3.7	16.4	25.5	23.1
	Namaqua District	9.2	21.1	6.7	27.2	22.3	22.3	25.0	15.3	63.2	21.5
Average Change (100 year - current)	Richtersveld	-1.2	2.9	0.0	3.0	-3.8	3.3	-5.4	3.4	-10.4	3.1
	Nama Khoi	-2.5	3.3	-0.5	3.6	-6.5	3.8	-8.8	3.8	-18.1	3.6
	Kamiesberg	-4.3	3.2	-0.3	3.5	-8.7	3.6	-13.5	3.6	-26.8	3.4
	Hantam	-3.6	3.7	-2.2	4.2	-11.1	4.4	-6.9	4.1	-23.8	4.1
	Karoo Hoogland	-3.7	3.6	-3.3	4.1	-11.5	4.4	-2.9	3.9	-21.4	4.0
	Khâi-Ma	-0.6	3.7	-2.8	4.2	-6.7	4.5	-0.8	4.3	-10.9	4.2
	Namaqua District	-3.0	3.5	-1.9	3.9	-9.2	4.2	-6.0	3.9	-20.0	3.9

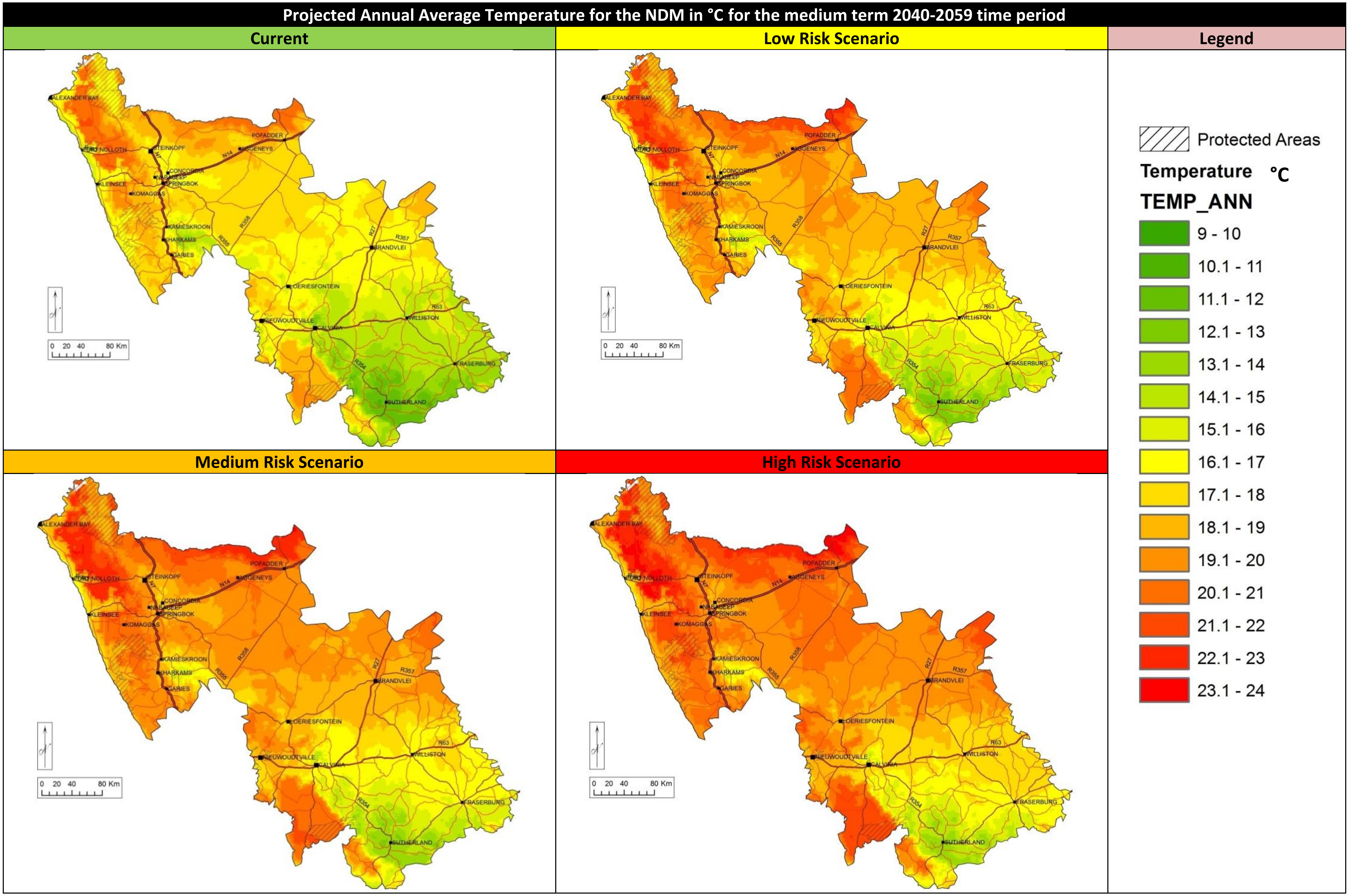

Figure 2: Annual average temperature projection maps for the NDM, in °C, clockwise from top left. 1) Current annual average temperature in the NDM, 2) a low risk scenario for temperature in the medium term presenting the 10th percentile of the data, 3) a medium risk scenario for temperature in the medium term presenting median data, and 4) a high risk scenario for temperature in the medium term presenting the 90th percentile of the data. Temperatures are projected to increase under all scenarios for most of the region.

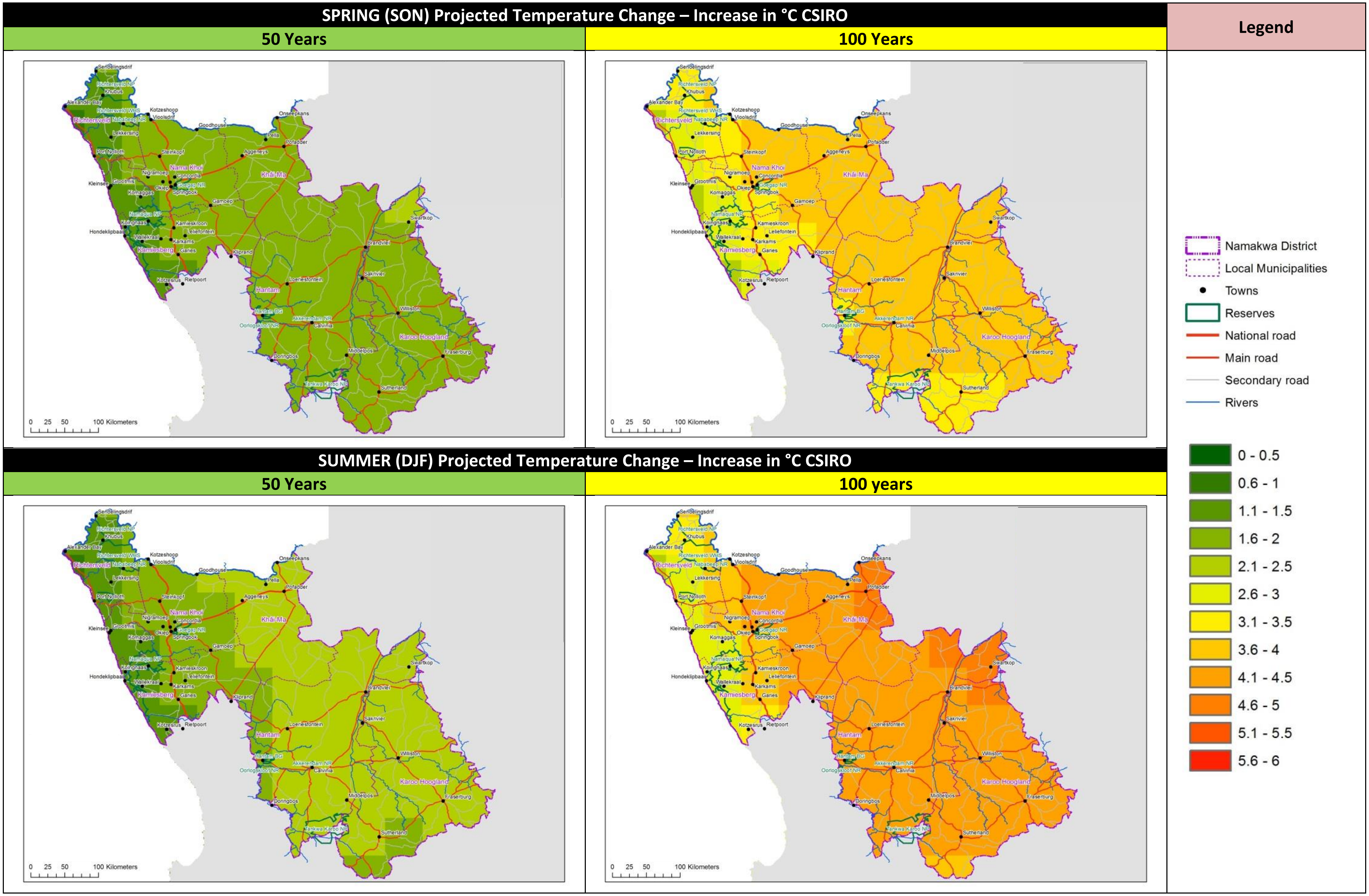

Figure 3: Spring and summer season average temperature projection maps for the NDM, shown as increase in °C relative to current temperatures using the CSIRO model, clockwise from top left. 1) Medium term projected spring average temperatures, 2) long term projected spring average temperatures, 3) medium term projected summer average temperatures, and 4) long term projected summer average temperatures. Temperatures are projected to increase dramatically in the longer term in both spring and summer.

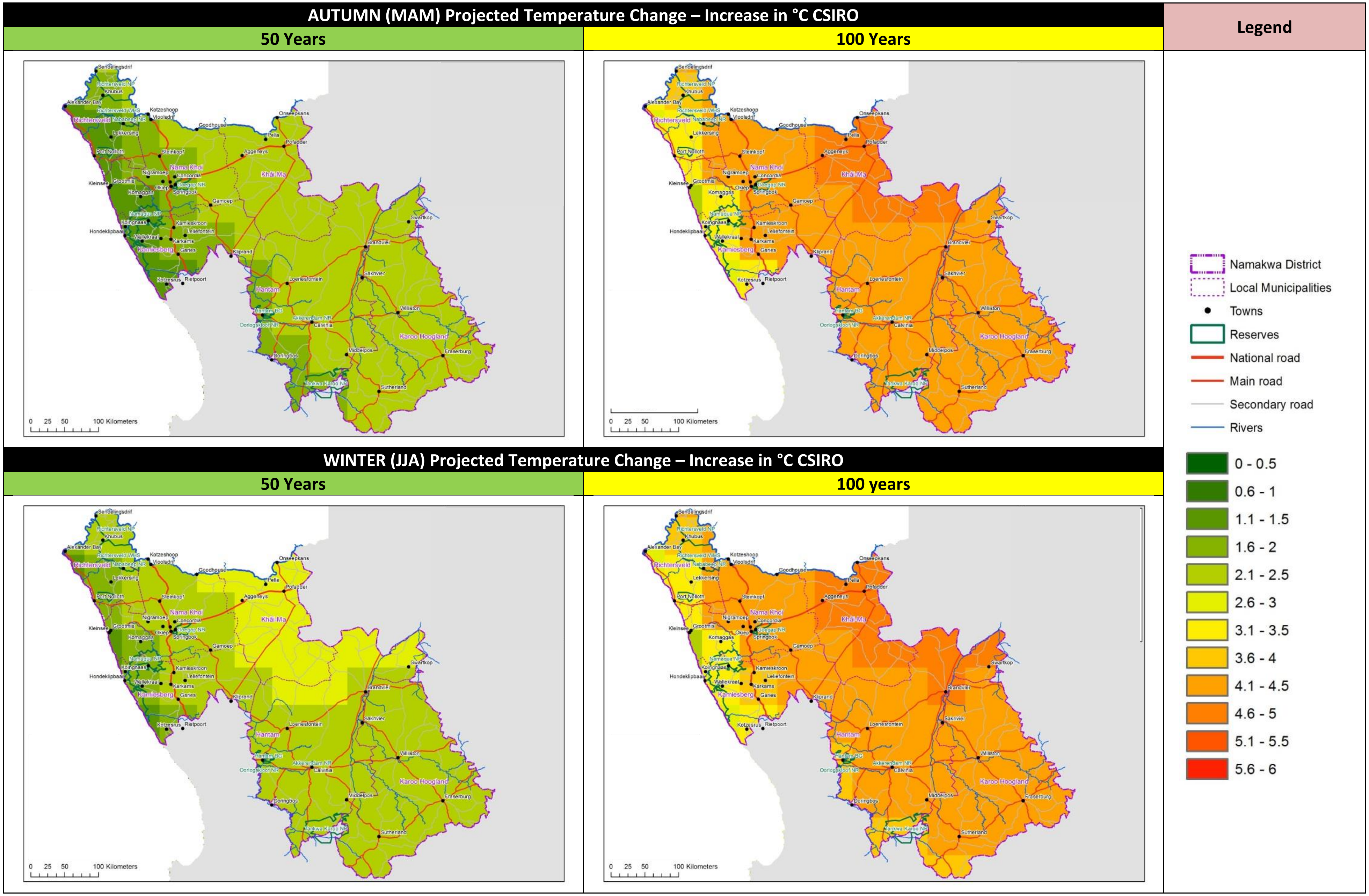

Figure 4: Autumn and winter season average temperature projection maps for the NDM, shown as increase in °C relative to current temperatures using the CSIRO model, clockwise from top left. 1) Medium term projected autumn average temperatures, 2) long term projected autumn average temperatures, 3) medium term projected winter average temperatures, and 4) long term projected winter average temperatures. Temperatures are projected to increase dramatically in the longer term in both autumn and winter.

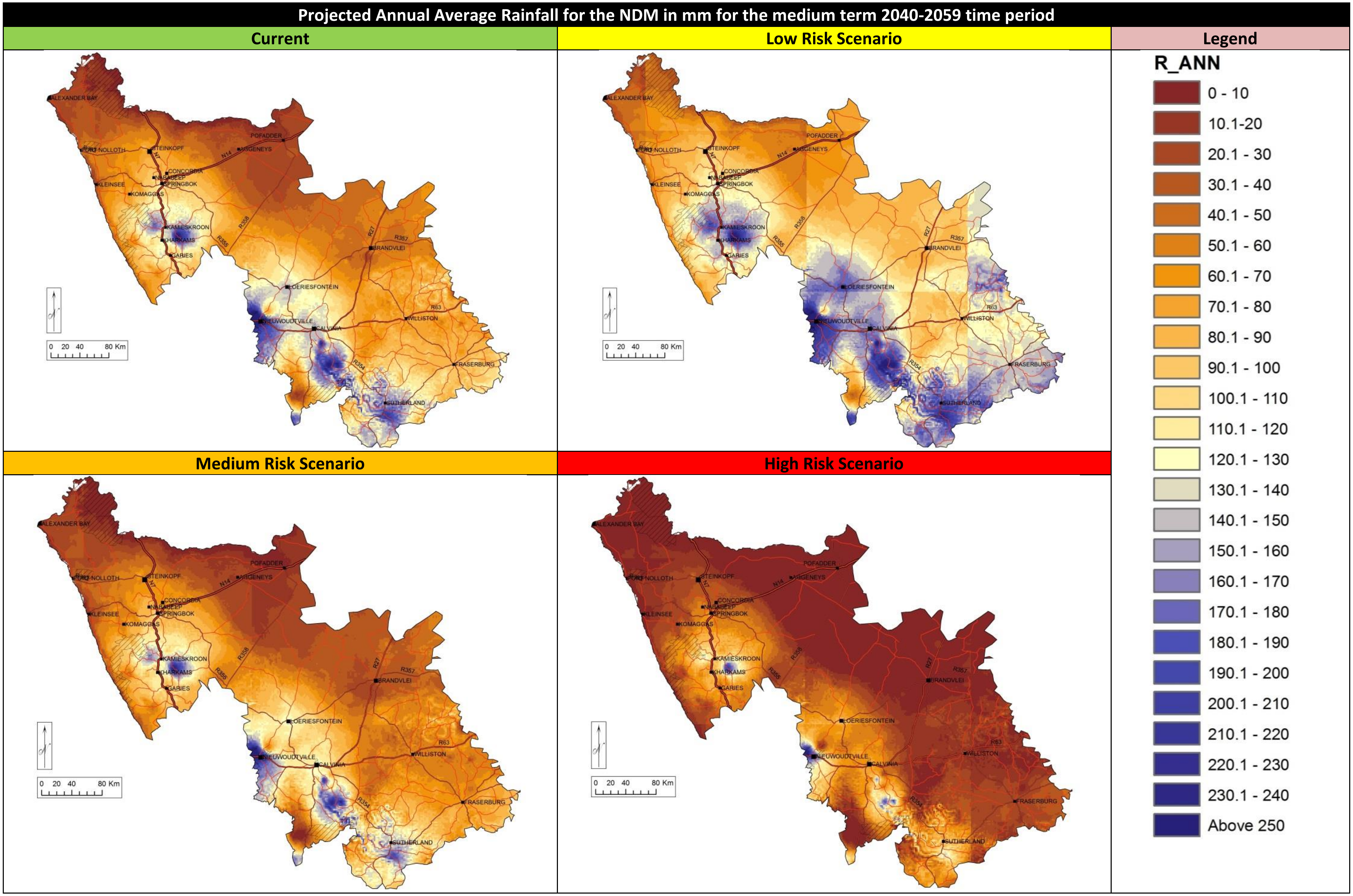

Figure 5: Annual average rainfall projection maps for the NDM, in mm, clockwise from top left. 1) Current annual average rainfall in the NDM, 2) a low risk scenario for rainfall change in the medium term presenting the 10th percentile of the data, 3) a medium risk scenario for rainfall change in the medium term presenting median data, and 4) a high risk scenario for rainfall change in the medium term presenting the 90th percentile of the data. Rainfall projections are quite variable, with some models projecting wetting and others significant drying.

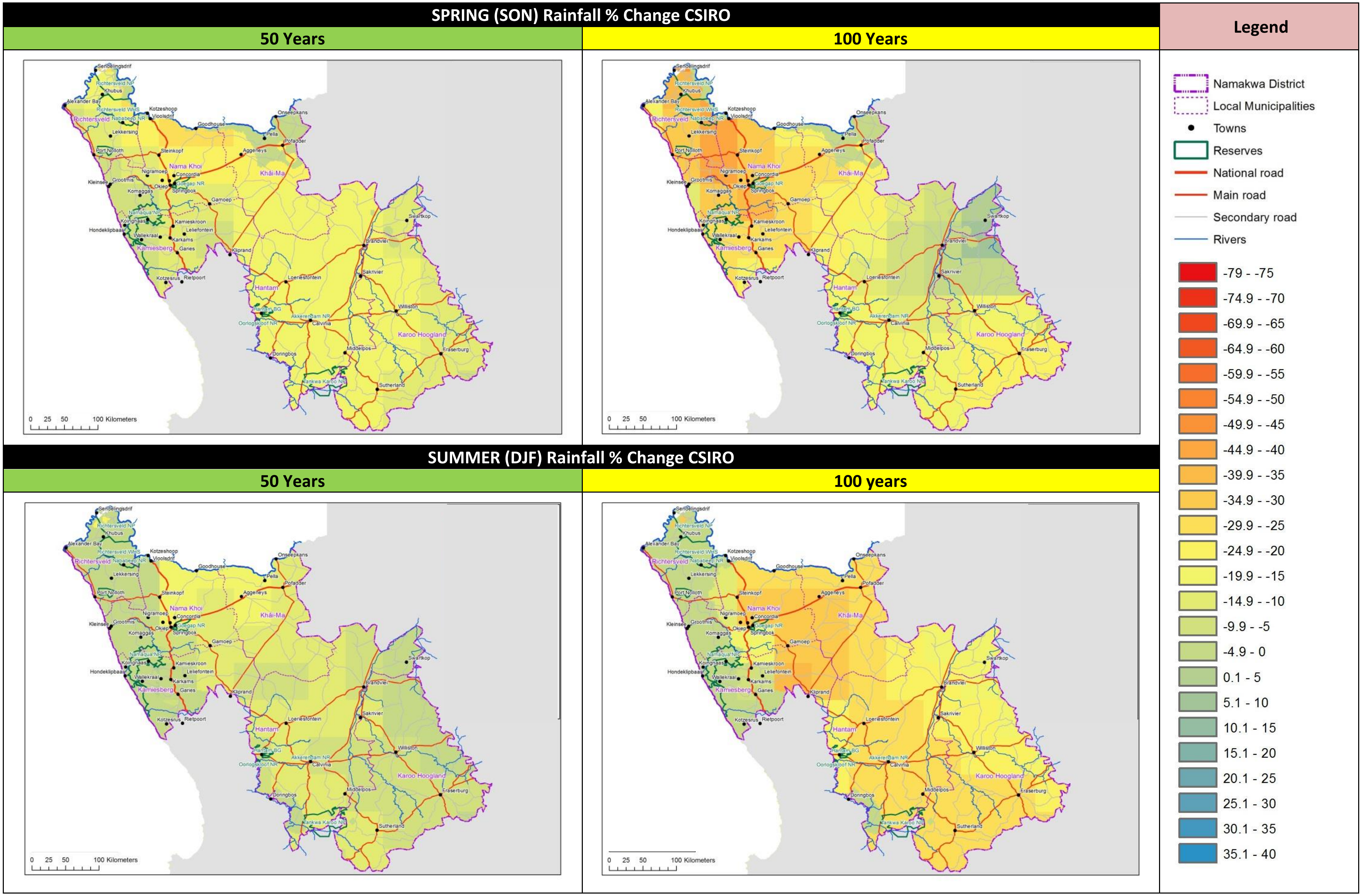

Figure 6: Spring and summer season rainfall change projection maps for the NDM, shown as a % change relative to current annual median rainfall using the CSIRO model, clockwise from top left. 1) Medium term projected rainfall change in spring, 2) long term projected rainfall change in spring, 3) medium term projected rainfall change in summer, and 4) long term projected rainfall change in summer. Rainfall is projected to decrease by up to 40% in the longer term for spring and summer.

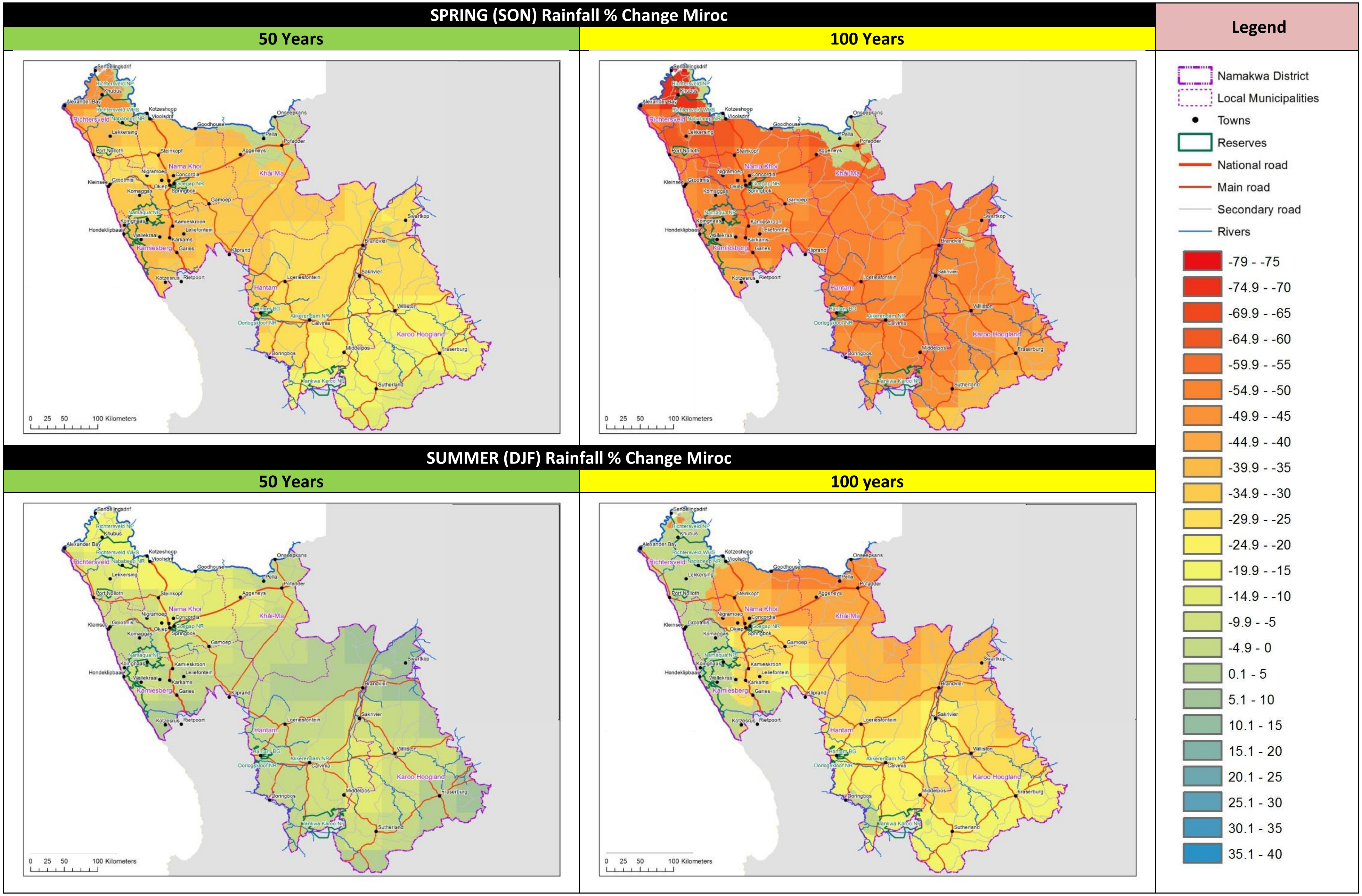

Figure 7: Spring and summer season rainfall change projection maps for the NDM, shown as a % change relative to current annual median rainfall using the Miroc model, clockwise from top left. 1) Medium term projected rainfall change in spring, 2) long term projected rainfall change in spring, 3) medium term projected rainfall change in summer, and 4) long term projected rainfall change in summer. Rainfall is projected to decrease by up to 65% in the longer term for spring and summer.

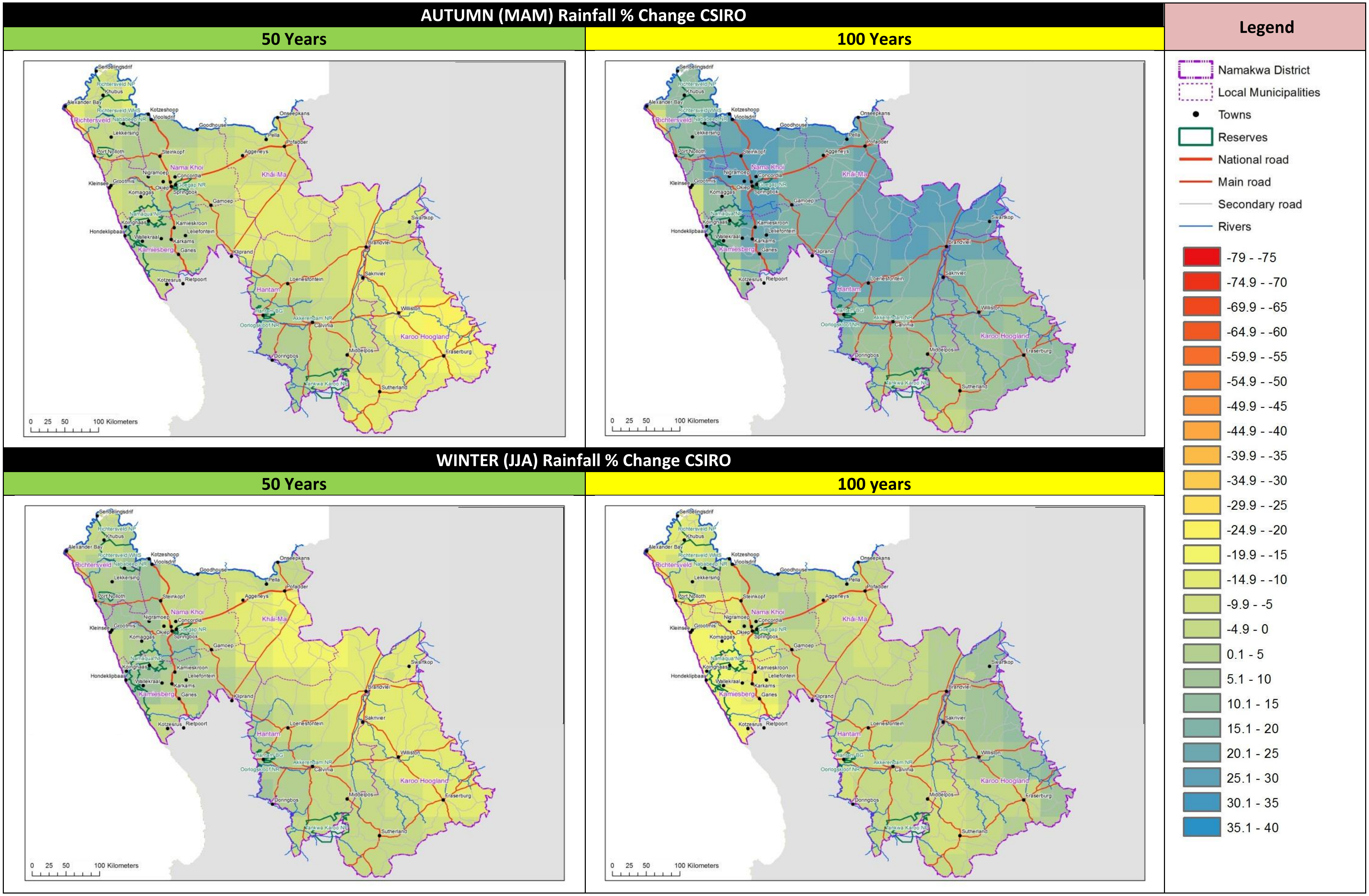

Figure 8: Autumn and winter season rainfall change projection maps for the NDM, shown as a % change relative to current annual median rainfall using the CSIRO model, clockwise from top left. 1) Medium term projected rainfall change in autumn, 2) long term projected rainfall change in autumn, 3) medium term projected rainfall change in winter, and 4) long term projected rainfall change in winter. The CSIRO model predicts long term wetting in the future for the NDM in the autumn months.

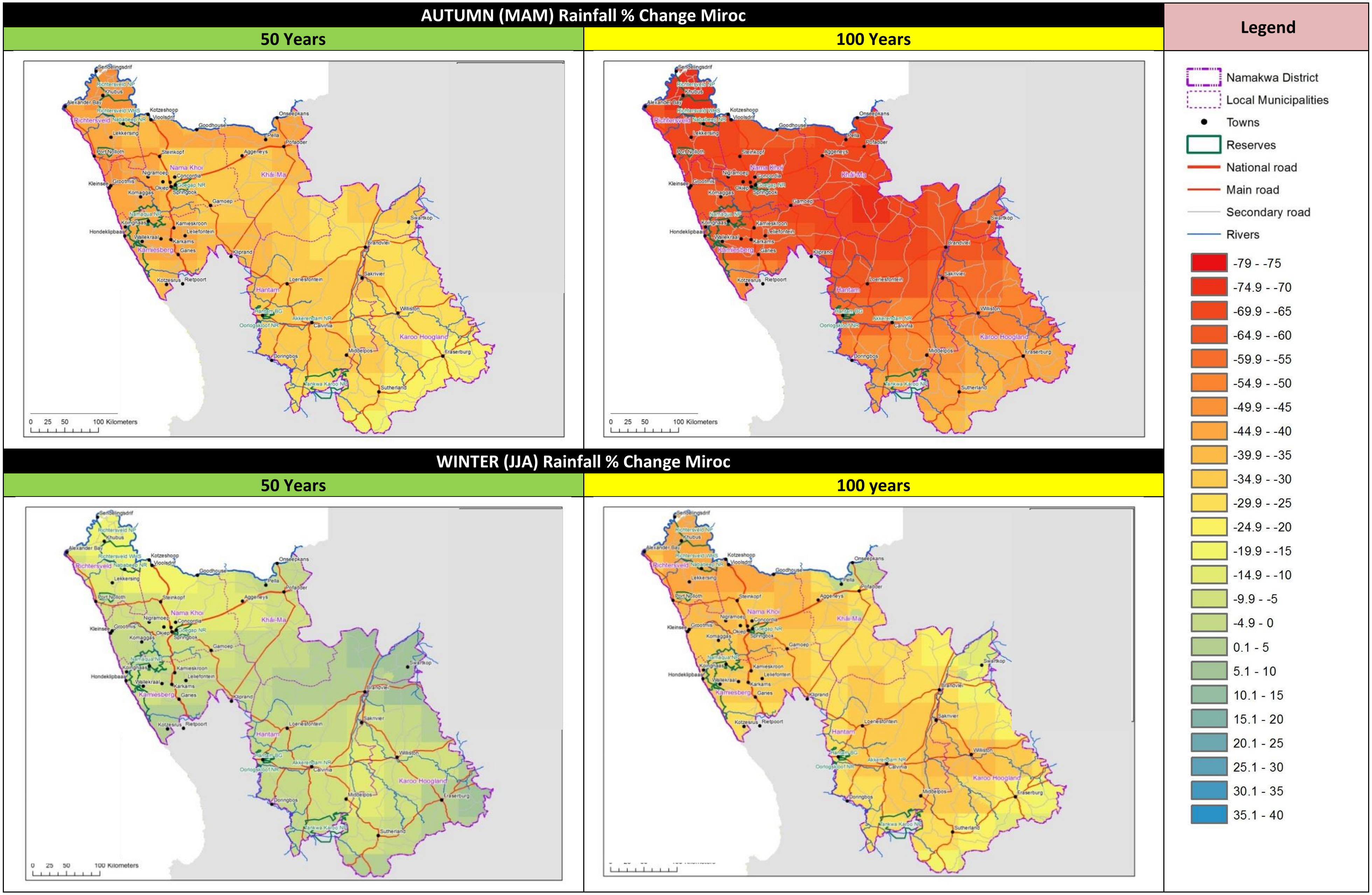

Figure 9: Autumn and winter season rainfall change projection maps for the NDM, shown as a % change relative to current annual median rainfall using the Miroc model, clockwise from top left. 1) Medium term projected rainfall change in autumn, 2) long term projected rainfall change in autumn, 3) medium term projected rainfall change in winter, and 4) long term projected rainfall change in winter. The Miroc model predicts significant long term drying in the future for the NDM in the autumn months.

Chapter 4: Climate change risk and climate envelope stability at the biome scale

4.1 Introduction

South Africa has nine biomes, four of which occur in the NDM. These four are Succulent Karoo, Desert, Nama Karoo, and Fynbos (**Figure 8**). Each biome has a characteristic climate envelope – a range and pattern of temperature and rainfall values – within which it occurs. In this chapter, we identify areas of climate change risk and stability for vegetation biomes occurring in the NDM.

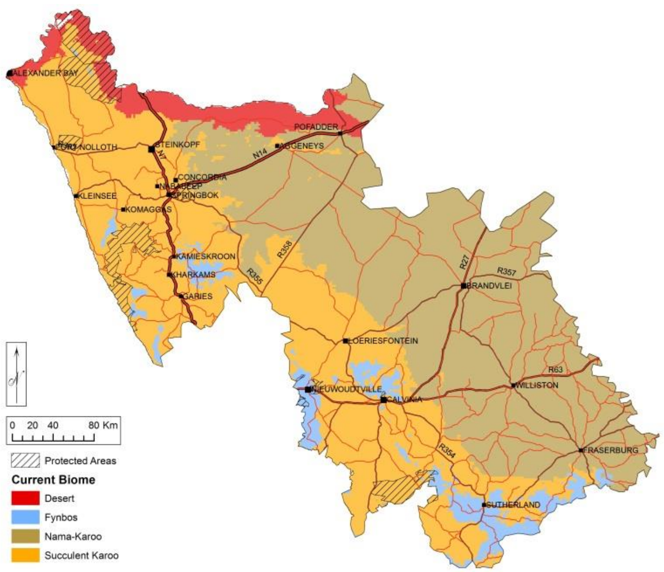

Figure 10: Current distribution of biomes in the NDM

According to our understanding of climate control of vegetation types, as the climate changes, an area that is currently climatically suited to one biome might become more climatically suited to another different biome, inducing climate-related stress in components of the biome. If such changes were to occur over a long period of time (many thousands of years), and if natural habitat were predominantly intact, the ecosystems and species that make up the biome may well be able to undergo adaptation and/or spatial shifts in response. However, with changes in climate happening over relatively short periods (decades) and with much natural habitat lost, degraded or fragmented, it is more likely that disruptive change (such as population declines and even extinctions) will occur alongside shifts in biome climatic suitability.

4.2 Methods

A maximum entropy model (using the industry standard software MaxEnt) was used to develop a biome distribution model in order to predict the distribution of biomes in the NDM based on climatic variables. In other words, this model was used to determine how the distribution of climate envelopes associated with the NDM's four biomes are likely to change based on the projected changes in temperature and rainfall presented in Chapter 3.

The ability of the model to predict the future potential distributions of biomes was tested by using it to model the current distribution of biomes. The model was very accurate at modelling the current distribution of biomes, producing a map that matched the actual distribution of biomes very closely. The biome modelling results from the three different climate models are extremely consistent for each period. To reduce confusion, we only present the biome model results for the **Miroc** model here.

It is important to note that the results presented below show which biome climate envelope the future climate in an area is likely to resemble most closely. This is often different from the current biome in that area. However, this does not necessarily mean that vegetation in the area will change to that of a different biome. We do not yet know precisely how biomes, and the ecosystems and species that they consist of, will respond to these new climatic conditions in practice.

4.3 Results: Biome scale risk and stability

Figure 11 provides maps that show where biomes in the NDM are likely to be most sensitive to climate change in the medium (50 year) and longer (100 year) term. It also shows areas of biome stability in the face of climate change. The darkest areas represent areas of high stability, where the current biome is expected to persist in the medium (50 years) and longer term (100 years). These are areas, which are most likely to maintain a stable ecological composition and structure as climate change progresses.

The following is a summary of projected changes in the climate envelopes associated with NDM's four biomes.

- Conditions associated with the Desert Biome gradually push southwards in the short term and continue with this trend in the longer term. The Desert Biome envelope replaces much of the northern sections of what is currently Nama Karoo;
- Areas with a climate envelope characteristic of Fynbos persist in the medium term, but are largely displaced by Succulent Karoo in the longer term; and
- Areas with a climate envelope characteristic of the Succulent Karoo Biome are largely retained over both the short and longer term.

It is importantly to note that some biomes, such as the Succulent Karoo, encompass a fairly broad range of climatic conditions. Therefore, a specific site could experience fairly large changes in precipitation and temperature while still remaining within the broad envelope of climate conditions currently associated with that biome. An area which is currently in the coolest and moistest portions of the biome may end up with a climate more similar to the hottest and driest parts of the biome currently. Additionally, the Succulent Karoo with its temperature extremes, aridity, and winter rainfall patterns, is unique and so even if conditions have changed significantly, new climate conditions are still likely to be closer to the Succulent Karoo climate envelope than to that of another biome. This likely explains the apparent stability in the Succulent Karoo biome reflected here.

For particular species, such changes may well result in local extinction. However, as the site is still within the envelope of conditions associated with that specific biome, the area as a whole is likely to remain structurally similar and retain a suite of biome specific species. This does not imply that the change will not be extremely serious for a very large number of species and therefore results presented here must be treated with caution and without complacency.

In areas where biomes are most at risk of ecological composition and structural change, it is particularly important to retain natural features in the landscape that will allow ecosystems and species to adapt as naturally as possible. An example of such a feature is corridors of natural habitat that enable species to move along an altitudinal gradient. Corridors have been used extensively in past conservation planning. Additional landscape features are discussed in Chapter 7.

Areas where biomes are most likely to be stable in the face of climate change present good opportunities for the location of new or expanded protected areas. These areas are more likely to retain their current composition and structure and thus to effectively represent the ecosystems concerned.

It should be noted that we have used a relatively coarse modelling method, and that more sophisticated models which incorporate other influences, such as rising CO^2 effects on plant growth and productivity, are necessary for a full picture of potential biome change. Nevertheless, as the modelled outcome is so clear-cut in the NDM, it is unlikely that major changes would result from more nuanced modelling in this environment.

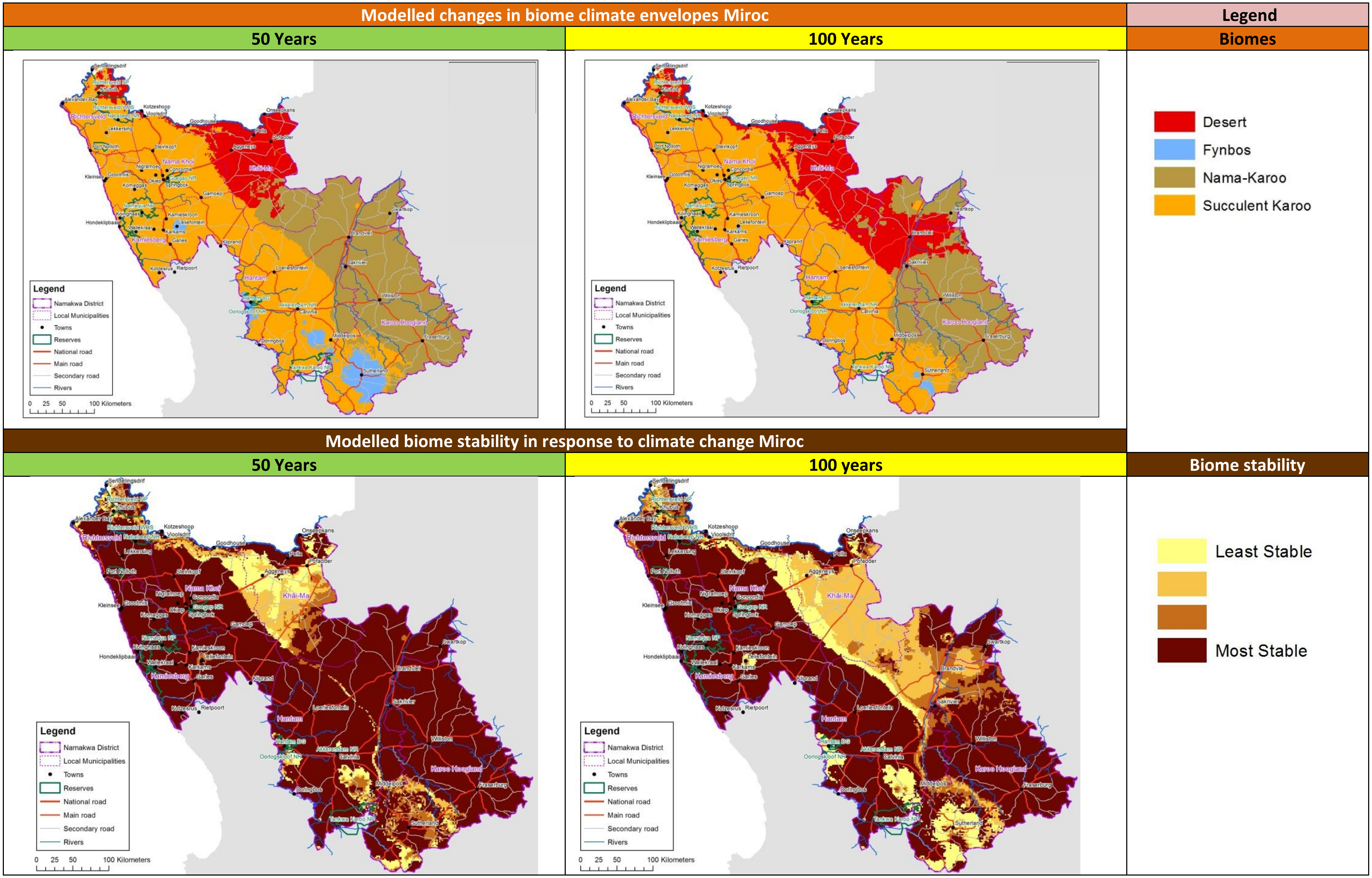

Figure 11: Maps of biome impacts, clockwise from top left. 1) Projected changes in climatic suitability for the biomes in the NDM, medium term, 2) projected changes in climatic suitability for the biomes on the NDM, long term, 3) areas of biome stability in response to climate change, medium term, and 4) areas of biome stability in response to climate change, long term.

Chapter 5: Water-related Ecological Infrastructure in the NDM

5.1 Introduction

A community's vulnerability is determined by their exposure to external pressures such as climate change as well as their capacity to adapt to such pressures. Ecological Infrastructure (EI) provides ecosystem services that underpin and support a community's adaptive capacity (see Box 5).

This chapter identifies and maps EI that delivers valuable water-related ecosystem services to the people living in the NDM.

Five maps are presented:

- **water production and stream flow augmentation**: natural areas with high water yield and portions of the landscape required to support flow during the dry season. Protecting or improving these areas of EI would reduce requirements for additional water storage and would ensure water supply to people directly dependent on water from streams, springs and pools;
- **erosion control**: areas located in erosion prone sites that need to be kept intact or rehabilitated. Protecting or improving these areas of EI would improve capacity of storage schemes and reduce water treatment costs that result from sedimentation;
- **maintaining and enhancing water quality**: areas important for sediment trapping, and reducing levels of phosphates, nitrates and toxicants. Protecting or improving these areas of EI would reduce water treatment costs;
- **flood attenuation**: areas containing particular wetland types which are important for delaying flood peaks and reducing flood intensity. Protecting or improving these areas of EI would reduce risk to water supply and other infrastructure during extreme flood events; and
- an **overall integrated map** of all water related EI.

The following categories are used to describe the value and condition of the EI in the above five maps:

1. NATURAL CRITICAL Ecological Infrastructure: Areas in a natural condition which are critical for the delivery of ecosystem services

- These are areas which are very likely to be critical to the delivery of services, and priority should be given to maintaining these areas in a natural state
- These areas should be the focus for proactive conservation efforts such as stewardship. Appropriate land management should be incentivised, and emerging threats such as alien vegetation should be carefully managed through natural resource management projects.

2. NATURAL ADDITIONAL Ecological Infrastructure: Areas in a natural condition that provide a supporting role in ecosystem service delivery

- These are areas which are likely to be delivering fewer services, or only fulfil a supporting role in service delivery
- Nevertheless, in the context of a water stressed catchment, these areas should also be maintained in a natural state, and should be appropriately managed.

3. DEGRADED CRITICAL Ecological Infrastructure: Areas in a degraded condition but critical to the delivery of ecosystem services

- These areas are currently in a poor or degraded condition, but could be rehabilitated to improve ecological service delivery
- These areas are a logical focus area for natural resource management projects aimed at rehabilitation, and could result in significant improvements in water delivery from more resilient system of EI.
- Investment in these areas, or appropriate incentives to improve sustainable land management practices, should be investigated.

4. D**EGRADED ADDITIONAL Ecological Infrastructure**: Areas in a degraded condition but provide a supporting role in ecosystem service delivery

- As with the previous category, these areas should also be considered for natural resource management projects and improved management
- However, they are likely to be of lower value than the previous categories

5. TRANSFORMED[2] **Ecological Infrastructure**: Areas where Ecological Infrastructure has been lost

- These are areas where there may be opportunities to mitigate/reduce negative impacts through improved management practices and interventions with the production sectors active in these areas
- At a finer scale, it may be possible to identify areas important for delivering ecosystem services, such as wetland buffers in wattle plantation areas, and secure appropriate management of these areas through sector based interventions
- In the long term it may be worthwhile to consider the full cost-benefit of activities and sectors which heavily impact on ecosystem service delivery, and make appropriate decisions on the continuation or withdrawal of activities from those areas where restoration could improve ecosystem service delivery.

Please see **Annex 2** for a detailed discussion of methods and data sources for this section of the report.

5.2 Methods

The South African conceptual framework on EI formed the basis for mapping water related EI in the NDM. The most important specific sources of data and methods were the ProEcoServe and the Wet-EcoServices projects.

Box 5: Ecological Infrastructure (EI)

Most people are aware of the concept of built infrastructure, which refers to the roads, rail, power lines, water reticulation systems, and so on which support and surround human societies.

Related to this concept of built infrastructure is that of Ecological Infrastructure, which refers to the functioning ecosystems that deliver valuable services to people, such as freshwater, climate regulation, soil formation and disaster risk reduction.

Ecological infrastructure includes healthy mountain catchments, rivers, wetlands, coastal dunes, nodes and corridors of natural habitat, all of which form a network of interconnected structural and functional elements in the landscape.

- The ProEcoServ project (implemented by CSIR and SANBI: http://www.proecoserv.org/) provided useful national analyses and concepts which we refined at a local scale for the NDM[3];
- The Wet-EcoServices[4] project provided a technique for rapidly assessing ecosystem services supplied by wetlands in the area. In particular, it formed the conceptual basis for identifying water-related benefits likely to be provided by a wetland based on its particular landform type i.e. the level of ecosystem services provided by a specific wetland type.

[2] Note that in terms of the SANBI/SANBI Grasslands/CSIR/ProEcoServ summary of Ecological Infrastructure concepts only “natural” and “degraded” areas can be defined as ‘Ecological Infrastructure’. We include transformed areas here because of their relevance for managing ecosystem services.

[3] This is best articulated in the SANBI/SANBI Grasslands/CSIR/ProEcoServ summary of Ecological Infrastructure concepts (http://www.grasslands.org.za/); and the proceedings of the November 2012 SANBI Grasslands Dialogue on Ecological Infrastructure (http://www.grasslands.org.za/).

[4] WetEcoServices – a technique for rapidly assessing ecosystem services supplied by wetlands (2005) developed by Donovan Kotze, Gary Marneweck, Allan Batchelor, David Lindley and Nacelle Collins – later also published by the Water Research Commission in 2008 as WRC Report TT 339/08:

A range of additional data sources were used for identifying and mapping water-related EI for the NDM and are summarised in the discussions below.

5.3 Results: Water Ecological Infrastructure Maps

5.3.1 Water production and streamflow

High water yield areas in the district were mapped using the logic of the ProEcoServe project i.e. a slightly adjusted and downscaled process of the methodology used to identify and map Strategic Water Source Areas at a national level for South Africa[5]. In addition to this, various features important for delivering water production and stream flow ecosystem services were identified across the district using:

- i) the categorisation of wetlands table provided by the WetEcoServices project;
- ii) the National Wetland Inventory;
- iii) river data in the National Freshwater Ecosystem Priority Areas database;
- iv) rivers as mapped in the 1:50 000 topocadastral data.

Scores and categories were determined by overlaying high water yield areas, specific features important for providing ecosystem services, and land cover transformation data. A detailed description of the features, classification and methods for mapping water production and stream flow can be found in **Annex 2**.

[5] Nel, J.L., O'Farrell, P., Le Maitre, D.C., Smith, J. and Reyers, B. 2013. Spatial mapping of ecosystem services. CSIR Report, 2013.

5.3.2 Erosion control

National gully erosion mapping[6] was used to prioritise erosion gullies in the NDM as **Critical EI**. We then crosschecked the national mapping against satellite imagery. Erosion prone areas within 250m of existing erosion gullies in the area were classified as **additional EI**.

Wetland types specifically important for erosion control were prioritised using the WetEcoServes technique. These included channeled valley-bottom wetlands, floodplain wetlands, seeps, unchannelled valley-bottom wetlands, and valleyhead seeps. Riparian areas were also included.

Erosion gullies, wetland types and riparian areas were all overlaid with land cover transformation to determine overall scores and categories to develop the composite ‘erosion control and sediment retention’ map in **Figure 12**.

5.3.3 Maintaining or enhancing water quality

The WetEcoServices technique was used to prioritise wetlands critical for water quality enhancement, including floodplain wetland, seep, unchannelled valley bottom and valley head seep (**Critical EI**). Wetlands playing a role in water quality but not considered as critical were included as **additional EI** – channeled valley bottom wetlands, depression, and flat pans. Riparian areas were also prioritized and scored based on overall proximity to important rivers.

Wetlands important for water quality and riparian buffers were overlaid with land cover transformation maps to generate a composite map displaying critical and additional EI important for maintaining or enhancing water quality (**Figure 12**).

[6] Mararakanye N, Le Roux JJ (2012) Gully location mapping at a national scale for South Africa. *South African Geographical Journal 94: 208–218*

Table 6: Data sources used for mapping EI

Category & Original Source	Description & Use
Wetland & river base data: *Nel et al 2011*[7]	Each wetland and river type was buffered by specific distances - see methods in Annex 2.
Additional minor rivers: *Surveys and mapping 1:50 000 river data*	The FEPA river dataset (Nel et al 2011) only includes major rivers and tributaries. This additional dataset was used to identify minor perennial and non-perennial streams.
Wetland ecosystem services delivery analysis: *Kotze et al 2005*[8]	WetEcoServe technique: Evaluation of delivery of services by different wetland types used to help define wetland value.
Gullies and areas prone to erosion: *Mararakanye and Le Roux 2012*[9]	Gully dataset was used directly.
Runoff: *ProEcoServ: Nel et al 2013*[10]	Gridded 1 minute layer developed by ProEcoServ project was converted to a point layer. The top 50% of values (115.5mm/yr runoff) were then buffered by 2km to an area which was designated as high water yield.
Landcover: landcover 2000 with additional data from ESKOM on households was used.	The landcover types were categorized into Natural, Degraded and Transformed. They were a primary determinant in categorizing the condition of features.

5.3.4 Flood attenuation

Areas important for delaying flood peaks and reducing flood intensity were prioritised using the WetEcoServe technique. Specifically, this included prioritising floodplain wetlands (+100m buffer) as these are the most important wetland type for flood attenuation. Wetland types of secondary importance for flood attenuation were included (+50 m buffer) as **additional EI**.

These included channeled valley bottom wetlands, depressions and flat pans, seeps, unchannelled valley-bottom wetlands and valleyhead seeps. Large rivers (+250 m buffer) and smaller rivers (+100 m) were also included as **additional EI**.

Wetland types and rivers important for water quality were overlaid with the land cover transformation data to develop scores and final categories. This resulted in a final composite map.

5.3.5 Overall integration map of water related EI in the NDM

The four maps described above (5.2.1-5.2.4) were integrated into one map (**Figure 13**) that shows water-related EI priorities for the NDM. Essentially this process involved overlaying all four maps as well as the land cover transformation data and using the highest score possible for determining categories for the specific areas.

[7] Nel JL, Driver A, Strydom W, Maherry A, Petersen C, et al. (2011) Atlas of Freshwater Ecosystem Priority Areas in South Africa: Maps to support sustainable development of water resources. Atlas and accompanying data available from CSIR or WRC.
8 Kotze DC, Marneweck GC, Batchelor AL, Lindley DS, Collins NB (2005) Wet-EcoServices. A technique for rapidly assessing ecosystem services supplied by wetlands.
9 Mararakanye N, Le Roux JJ (2012) Gully location mapping at a national scale for South Africa. South African Geographical Journal 94: 208–218. doi:10.1080/03736245.2012.742786
[10] Nel, J.L., O'Farrell, P., Le Maitre, D.C., Smith, J. and Reyers, B. 2013. Spatial mapping of ecosystem services. CSIR Report, 2013.

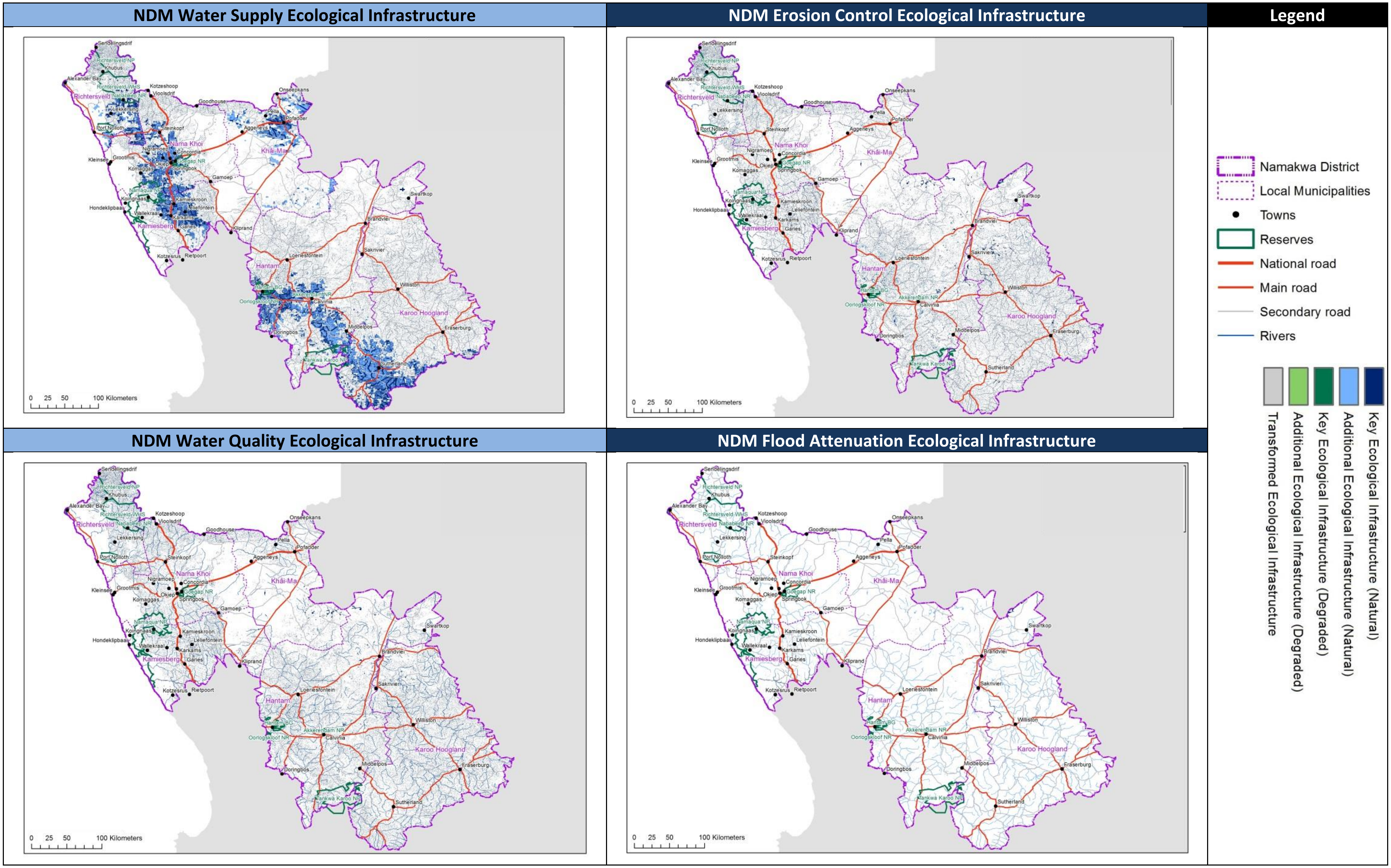

Figure 12: Clockwise from top left, areas of Ecological Infrastructure important in the NDM for 1) water production and stream flow augmentation, 2) sediment retention and erosion control, 3) maintaining or enhancing water quality, and 4) flood regulation.

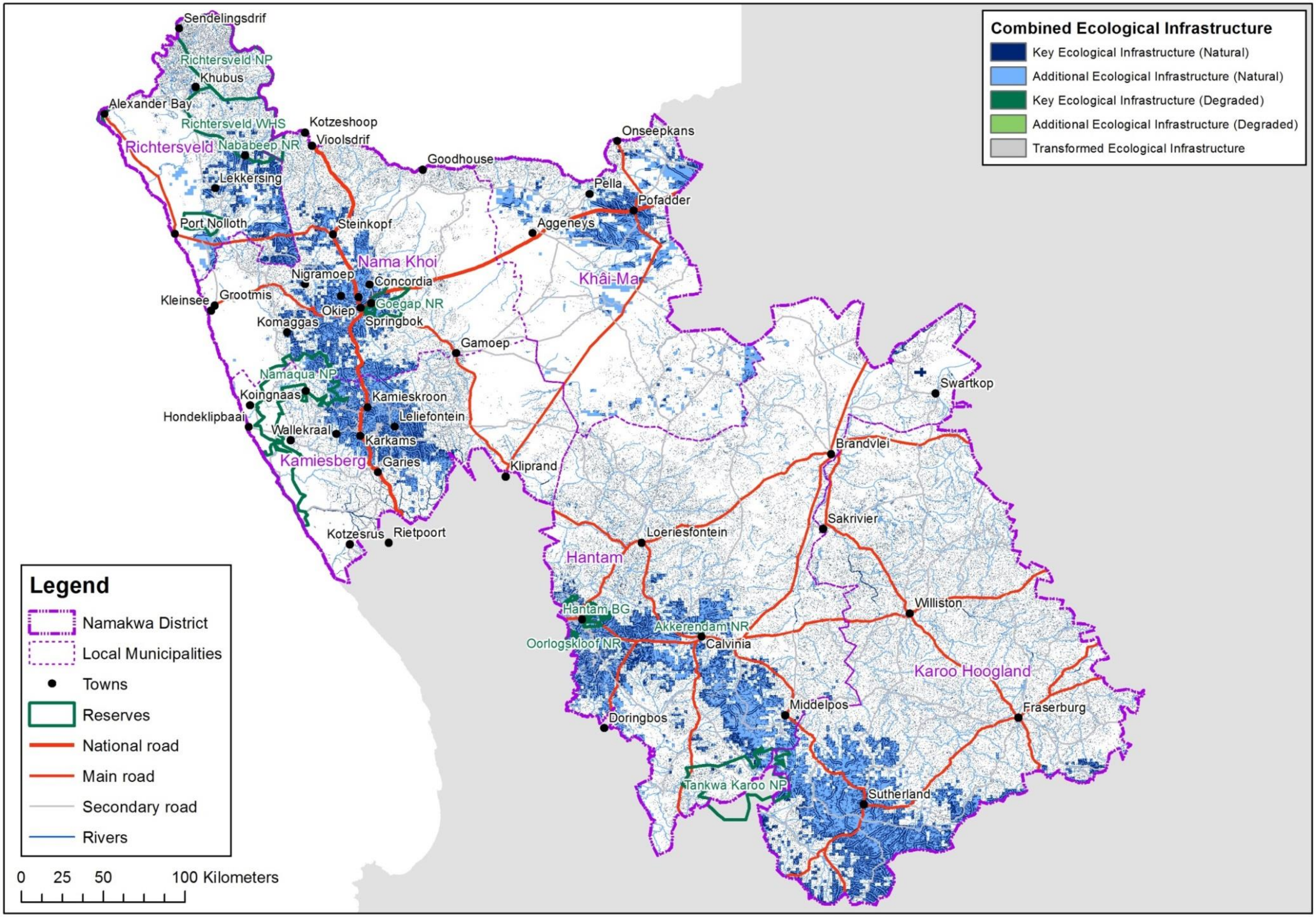

Figure 13: Integrated map of Ecological Infrastructure important for the NDM

Chapter 6: Biodiversity Priorities

6.1 Introduction

In addition to water related EI, there are other types of EI which consist of biodiversity assets. These also underpin a range of ecosystem services across the NDM. Biodiversity is crucial to ecosystem health, and healthy ecosystems are central to human well-being. All South Africans depend on healthy ecosystems for economic and livelihood activities, including agriculture, tourism and a number of income generating and subsistence level activities.

This chapter focuses on mapping priority areas for biodiversity, reasoning that intact, healthy, and well-functioning landscapes are critical for supporting species, ecosystems, and society as a whole.

Six maps are presented, representing the following spatial biodiversity priorities for the district:

- Aquatic biodiversity priorities;
- Critical biodiversity areas and other priorities identified at a national and provincial level;
- Threatened ecosystems;
- Ecosystem protection levels;
- Protected area expansion priorities; and
- Biodiversity priorities identified from local level and other planning processes.

An overall integrated map of conservation priorities consolidates all the above maps into a single map which shows conservation priorities on a scale from lowest to highest priority for the NDM.

6.2 Methods

Spatial biodiversity priorities were identified and mapped using the following main data sources:

- National Biodiversity Assessment 2012[11] (NBA)
- National Estuary Biodiversity Plan 2011[12] (NEBP)
- National Freshwater Ecosystem Priority Areas 2011[13](NFEPA)
- Namakwa District Biodiversity Sector Plan[14] (including the Critical Biodiversity Area Map) (NBSP)
- National[15] protected area expansion priorities

For a detailed description of the methods and data sources please see **Annex 3**.

6.3 Results: Biodiversity Priority Maps

6.3.1 Aquatic biodiversity priorities

A single integrated layer of aquatic priorities was developed drawing on the following national datasets listed above – NBA, NEBP, and NFEPA. The aquatic features mapped here include rivers, wetlands, estuaries, and

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[11] Nel, J.L., Driver, A. & Swartz, E.R. 2012. National Biodiversity Assessment 2011: Technical Report. Volume 2: Freshwater Component. CSIR Report Number CSIR/NRE/ECO/IR/2012/0022/A. Council for Scientific and Industrial Research, Stellenbosch.

[12] Turpie, J.K., Wilson, G. & Van Niekerk, L. 2012. National Biodiversity Assessment 2011: National Estuary Biodiversity Plan for South Africa. Anchor Environmental Consulting, Cape Town. Report produced for the Council for Scientific and Industrial Research and the South African National Biodiversity Institute.

[13] Nel, J.L., Driver, A., Strydom, W.F., Maherry, A., Petersen, C., Hill, L., Roux, D.J., Nienaber, S., Van Deventer, H., Swartz, S. & Smith-Adao, L.B. 2011. Atlas of Freshwater Ecosystem Priority Areas in South Africa. WRC Report No. TT 500/11. Water Research Commission, Pretoria.

[14] Available at http://bgis.sanbi.org/namakwa/project.asp

[15] Holness, S., 2008. Focus areas identified in the National Protected Area Expansion Strategy conservation assessment.

catchments. These features were scored from low to high priority and a composite map of all aquatic features was generated (**Figure 14**). All transformed and degraded areas were classified as heavily impacted land and removed from the priority scoring.

6.3.2 Critical Biodiversity Areas

Critical Biodiversity Areas (CBA) and equivalent priorities form part of the provincial conservation plan as well as the NBSP. The NBSP was created to guide land-use planning, environmental assessments and authorisations, and natural resource management in order to promote sustainable development locally. It remains a key input into spatial prioritisation in the NDM.

The product was used directly in this analysis, scored as follows:

- **Protected Areas:** An updated Protected Area layer was used. All areas were given a score of 10
- **Critical Biodiversity Area One:** All intact areas were given a score of 10
- **Critical Biodiversity Areas Two:** All intact areas were given a score of 5
- **Ecological Support Areas:** All intact areas were given a score of 2

A final map was generated combining all of these (**Figure 14**). Transformed and degraded areas were removed to highlight the value of remaining intact Critical Biodiversity. These areas represent parts of the landscape in the NDM which should be kept and managed to stay within a 'natural' state.

6.3.3 Protected Area Expansion Priorities

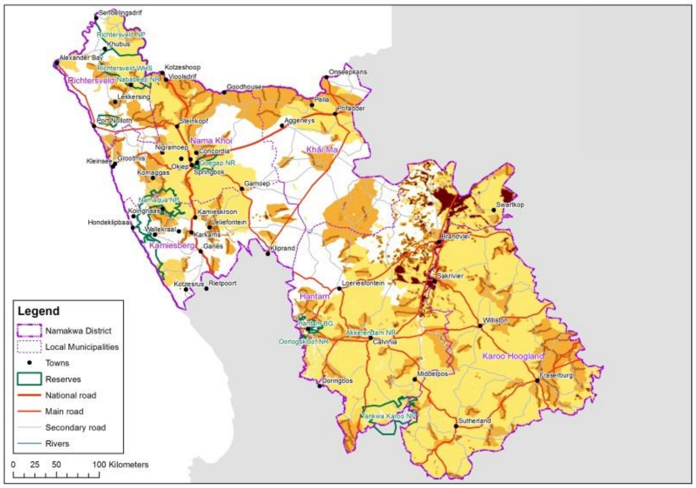
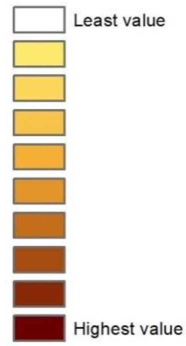
National protected area expansion priorities, indicating areas that should be prioritised for expanding the formal protected areas system, were used. The spatial assessment of the National Protected Area Expansion Strategy used a systematic conservation planning process to identify focus areas for land-based protected area expansion which are large, intact and unfragmented areas of high importance for biodiversity representation and ecological persistence, suitable for the creation or expansion of large protected areas.

Although available for similar assessments in other parts of South Africa, no finer scale provincial protected area expansion areas have been identified for the Northern Cape.

These areas were given a score of 10 and mapped, as shown in **Figure 14**.

6.3.4 Overall integration

The individual input layers were integrated into a single map displaying overall conservation priorities for the NDM. The outputs are shown in **Figure 15Figure 108**. This map provides an integrated overview of overall biodiversity priorities in the NDM. The map complements the water related EI map presented in chapter 5. It consolidates and provides an overall rating of priority (ranging from low to high priority) for biodiversity EI.

<table>
<tr><th>NDM Aquatic Priorities</th><th>Legend</th></tr>
<tr><td>
</td><td>
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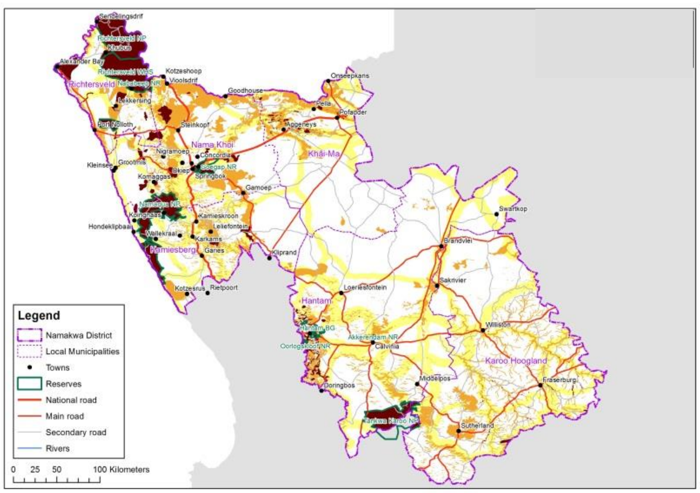
<tr><th>NDM Critical Biodiversity Areas</th><th>Legend</th></tr>
<tr><td>
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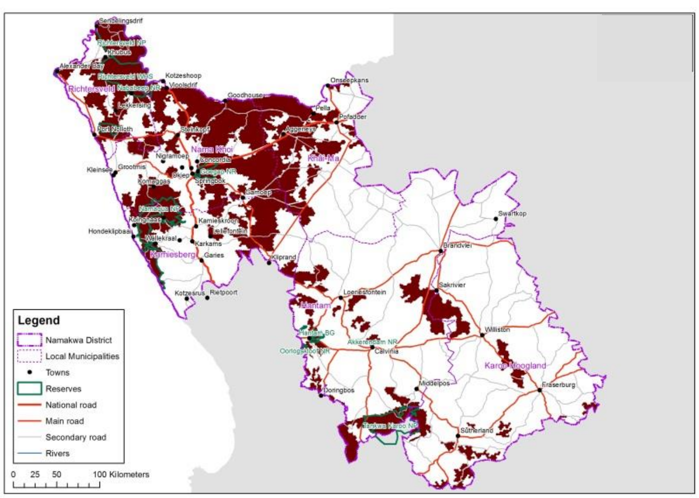
<tr><th>NDM Protected Area Expansion Priorities</th><th>Legend</th></tr>
<tr><td>
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Figure 14: Maps of Biodiversity Priority Areas in the NDM, from the top. 1) Priority aquatic features in the NDM, 2) critical biodiversity areas and ecological support areas in the NDM, and 3) protected area expansion priorities in the NDM.

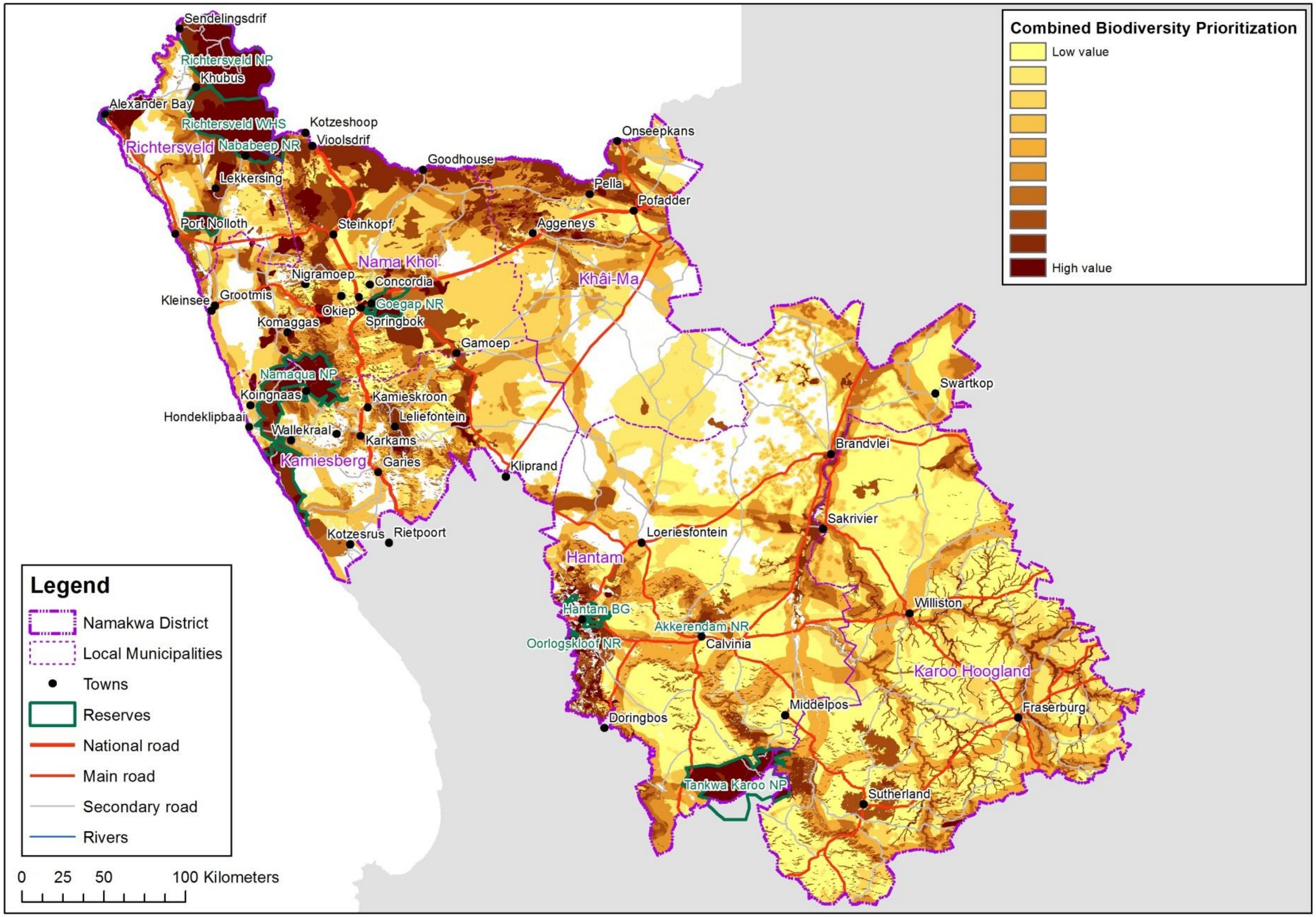


Figure 15: Integrated map of biodiversity priorities in the NDM

Chapter 7: Areas important for supporting climate change resilient ecosystems

7.1 Introduction

Some features in the landscape are more likely to support the resilience of biodiversity to climate change than other features. These features include riparian corridors and buffers, coastal corridors, areas with temperature, rainfall and altitudinal gradients, areas of high diversity, areas of high plant endemism, refuge sites including south-facing slopes and kloofs, and priority large unfragmented landscapes.

In this chapter, we map all of these features separately, and then combine them to provide a single map of areas supporting climate change resilience in the NDM. It should be noted that in addition to supporting well-functioning landscapes in the long term, some of these areas important for climate change resilience for biodiversity may also provide more specific, immediate benefits that directly support human liveihoods as well as adaptation to the impacts of climate change.

7.2 Methods

The following is a brief description of the methods for the individual features that were mapped. For a detailed description of the methods and data sources for each feature, and details on the integration method, please see **Annex 4**.

- **Coastal corridors**: 1km inland buffers of coastal features and land types associated with coastal geomorphological processes (e.g. sand dunes) and vegetation[16] were generated.
- **Riparian corridors and buffers**: A corridor layer was created based on the 2nd order rivers and larger rivers[17]. Corridor width varied between ~1km and 10km depending on the level and pattern of transformation.
- **Temperature, rainfall and altitudinal gradients**: Topographic and climatic indices describing altitudinal heterogeneity, precipitation gradients and temperature gradients were mapped and combined into a summary layer showing areas with high climate and landscape heterogeneity and gradients.
- **Areas with high biotic diversity**: Areas with high levels of biodiversity heterogeneity were identified using the South African Vegetation Map[18] at three scales: biome, vegetation group and vegetation type. Areas were considered to have high habitat heterogeneity if they contained three or more biomes, three or more vegetation groups, or four or more vegetation types. Layers were combined to provide a summary maps of all areas with high habitat heterogeneity.
- **Centres of floral endemism**: The floristic centres of endemism summarised in Regions of Floristic Endemism in Southern Africa [19] were clipped to the remaining extent of natural habitat. Transformed, degraded and fragmented areas were excluded from the dataset[20].
- **Local speciesrefugia**: The local refugia layer was derived by spatially combining areas that have south-facing slopes and kloofs present, as these are considered important shorter term refugia

[16] Mucina, L. & Rutherford, M.C., 2006: The vegetation of South Africa, Lesotho and Swaziland.

[17] Department of Water Affairs 1 in 500 000 river layer developed by Resource Quality Services.

[18] Mucina, L. & Rutherford, M.C., 2006: The vegetation of South Africa, Lesotho and Swaziland.

[19] Van Wyk, A. & Smith, G., 2001: Regions of floristic endemism in Southern Africa, Umdaus Press, Hatfield, 199pp.

[20] Transformation and fragmentation layer developed by Stephen Holness for the National Protected Areas Expansion Strategy Conservation Assessment 2008.

enabling species persistence. A subset of steep south facing slopes was developed using a 90m digital elevation model (DEM). All slopes steeper than 10° were included. The DEM was also used to define kloofs as all areas steeper than 15° that are in close proximity to a river.

- **Priority large unfragmented landscapes**: The priority unfragmented areas layer was generated by spatially combining the existing protected areas with a priority large unfragmented landscapes layer derived from the spatial assessment used to develop the National Protected Area Expansion Strategy. This included mapping existing formal protected areas[21], including National Parks, provincial Nature Reserves, proclaimed Mountain Catchment Areas and local authority Nature Reserves, and large areas identified in the National Protected Area Expansion Strategy[22] as priorities for protected area expansion.

The above six maps were combined and refined into one single integrated map showing areas most important for supporting ecosystem resilience to climate change, as shown in **Figure 16**.

7.3 Results: Climate Resilient Features Maps

Figure 17 and **Figure 18** show maps of individual natural features in the landscape to support the resilience of biodiversity to climate change. **Figure 19** is a single integrated map combining all of these features. The individual maps and integrated map can be used to assist with identifying areas where activities supporting resilience of biodiversity to climate change can be implemented.

[21] Available from http://planet.uwc.ac.za/ BGISdownloads/ protectedareasNPAES_Formal.zip

[22] Jackelman, J., Holness, S. & Lechmere-Oertel, R. 2008: The national protected area expansion strategy 2008-2012. A framework for implementation. Report for the South African National Biodiversity Institute and National department of Environment Affairs and Tourism.

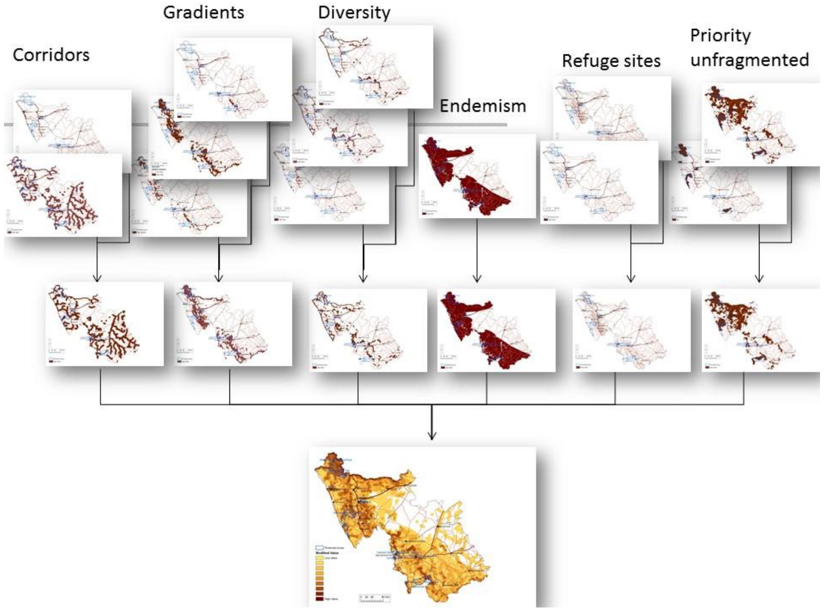


Figure 16: Diagram illustrating the integration method used to identify areas most important for supporting resilience to climate change impacts at a landscape scale in the NDM.

Areas important for climate resilient biodiversity could be managed and conserved through a range of mechanisms including land-use planning, environmental impact assessments, protected area expansion, and working with industry sectors to minimise their spatial footprint and other impacts.

Keeping the areas identified as high value in a natural or near-natural state will allow ecosystems and species to adapt naturally to climate change, thus supporting healthy landscapes and the ability of ecosystems to continue to provide ecosystem services. Appropriate management of these areas should be a crucial part of the NDM's response to climate change.

Note that **Figure 19** represents an overall summary of areas important for supporting resilience to climate change impacts. When focussing on a particular issue, such as riparian corridors or threatened species, it may be more appropriate to prioritise based on that issue alone. Specific recommendations and information per feature type is provided below and can be used in conjunction with the maps for project planning and implementation.

7.3.1 Coastal and riparian corridors and buffers

Corridors provide critical ecological linkages between large core areas of intact habitat that exist as patches within a matrix of heavily modified habitat. In the **short-term**, corridors are seen to be critical for the movement of animal species, such as pollinators and predators, from source to sink areas.

In the **medium term**, they provide for genetic interchange between spatially separate populations of animals. In the **long term** they are seen to be important for the migration of plant and other species under conditions of global climate change.

One of the most clearly defined corridors, especially in heavily modified arable agriculture landscapes, are those associated with rivers. River corridors also provide upland-lowland linkages on the landscape scale.

7.3.2 Temperature, rainfall and altitudinal gradients

Maintaining these areas is important to support species and ecosystems to rapidly adapt to a changing climate. These areas represent the shortest routes for an animal or plant species to move along between the uplands and lowlands and between climatic gradients in order to still remain within acceptable climate envelopes.

These areas are particularly important for species which are not able to move rapidly in response to climate change. These areas also have high levels of climate and landscape heterogeneity, and hence are likely to contain a range of important micro-climates which may act as local refugia for certain species.

7.3.3 Areas with high biodiversity

These areas contain an extremely diverse set of habitats, landscapes and microclimates. They are likely to be very important for supporting the adaptive capacity of biodiversity. High levels of floristic diversity, likely to represent areas of high levels of speciation, are found in these places.

7.3.4 Centres of floral endemism

Southern Africa has extremely high levels of floristic diversity and endemism. The region only represents 2.5% of the world's surface areas but is home to 10% of the world's ~30 000 terrestrial plant species. 60% of these species are endemic to the region[23]. Most of these endemic species are concentrated in a few relatively small and clearly defined centres of endemism.

At a national scale, centres of endemism represent areas of concentrated unique biodiversity pattern. Concentrations of endemic plant species occur there that are not found elsewhere. These are areas where a particular combination of ecological processes has resulted in high levels of biodiversity and endemism. Those characteristics that allow high levels of diversity to develop and persist are often found in areas where species have survived previous eras of climate change. Hence, these are likely to be very important for supporting biodiversity adaptation capacity in the future.

[23] Van Wyk, A. & Smith, G., 2001: Regions of floristic endemism in Southern Africa, Umdaus Press, Hatfield, 199pp.

7.3.5 Local species refugia- south-facing slopes and kloofs

Refuge sites for species include south-facing slopes and kloofs. Kloofs are defined here as steeply sloping areas in close proximity to rivers or streams. These sites tend to be wetter and cooler than the surrounding landscape, and represent key shorter term refugia which allow species to persist in these landscapes. These areas provide a 'safe zone' for species.

7.3.6 Priority large unfragmented landscapes

The ecological processes which support climate change adaptation are more likely to remain functional in unfragmented landscapes than in fragmented ones. Intact natural habitats found in protected areas and other large, intact and unfragmented areas of high importance for biodiversity representation and ecological persistence are likely to play an important role in supporting landscape scale biodiversity and ecosystem resilience to climate change through:

- acting as refuge areas for ecosystems and species which are likely to be under more pressure in production landscapes;
- supporting the ecological processes required for long term adaptation to climate change; and
- the provision of ecosystem services.

It is important to note that these areas were identified and mapped from a formal protected areas expansion perspective, and therefore do not sufficiently address all conservation priorities. For example, nationally, threatened species and habitats in highly fragmented landscapes such as the Chrissiesmeer area are poorly incorporated. Nevertheless, this analysis represents the best available summary of intact landscapes in South Africa, with functioning ecological processes which are likely to play a significant role in long term climate change adaptation for both biodiversity and people.

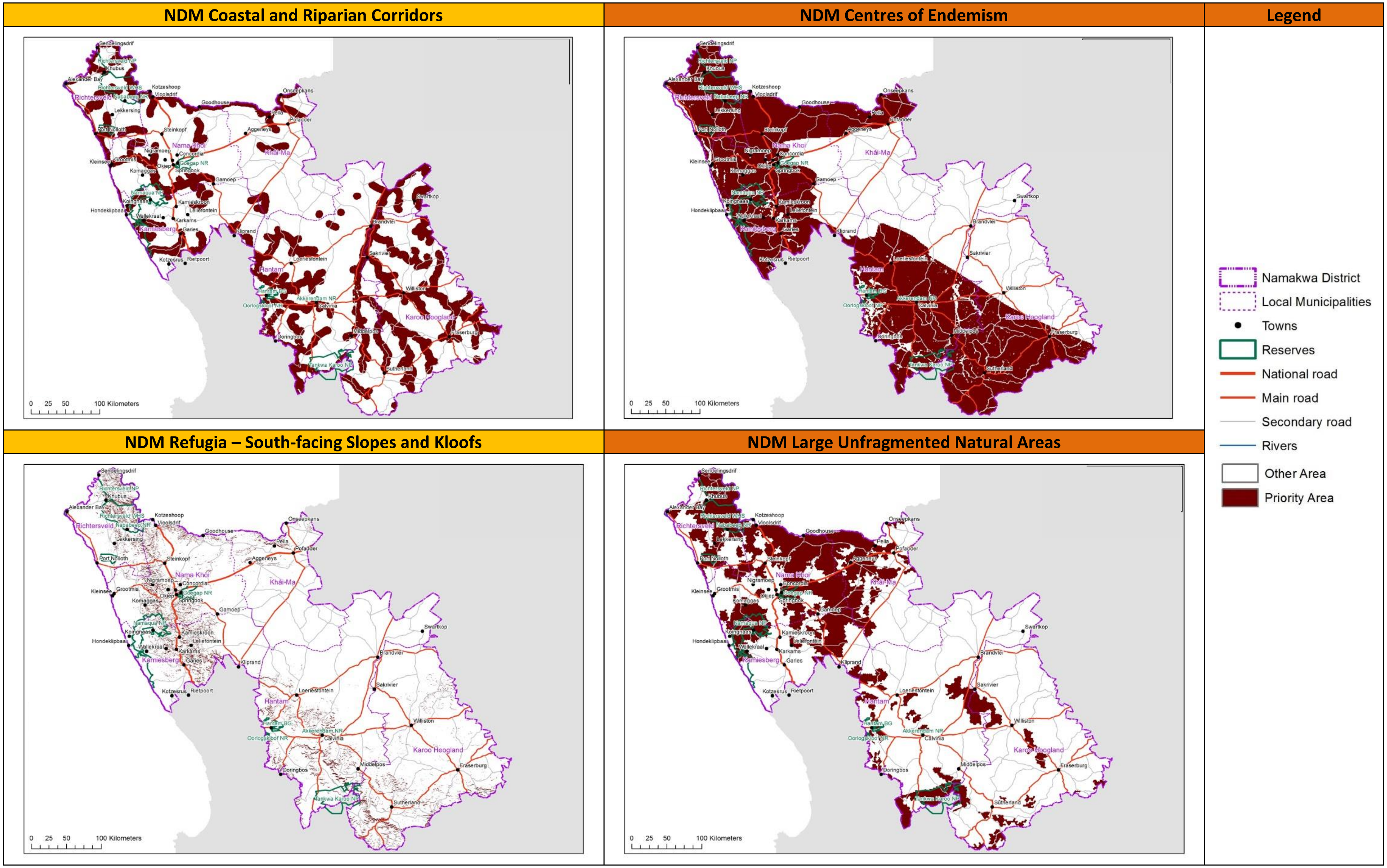


Figure 17: A series of maps of natural features in the NDM contributing to climate resilience in local biodiversity, clockwise from top left. 1) Coastal and riparian corridors in the NDM, 2) remaining centres of endemism in the NDM, 3) local refugia consisting of a combination of gorges and south facing slopes in the NDM, and 4) priority large unfragmented areas in the NDM

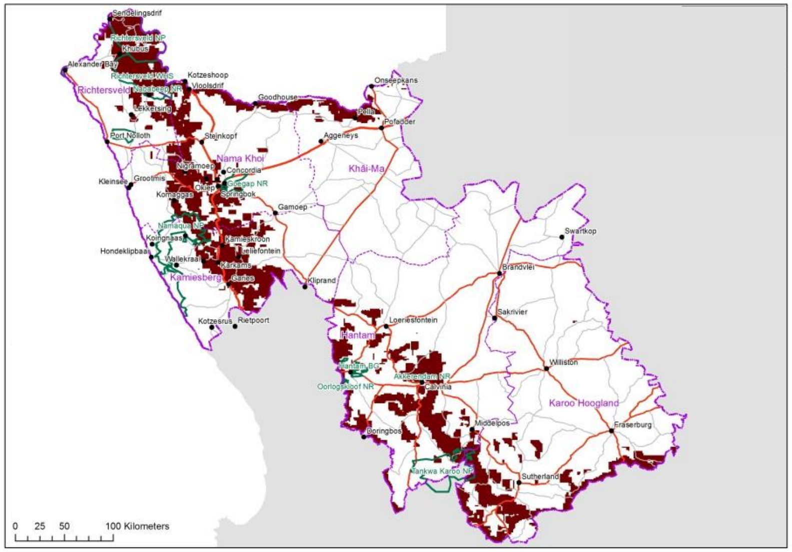
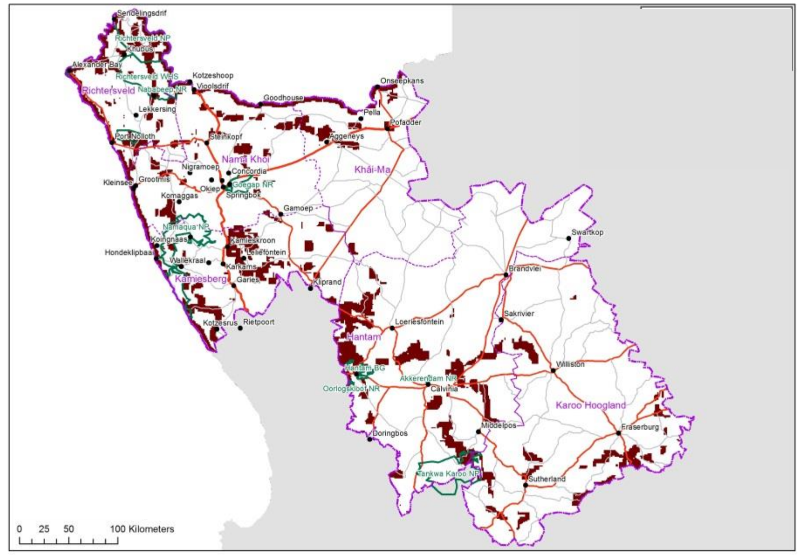
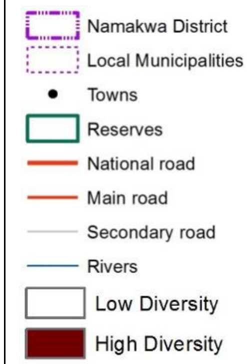
NDM Altitude, Temperature, and Rainfall Gradients	NDM High Biodiversity Habitats	Legend
		

Figure 18: A series of maps of natural features in the NDM contributing to climate resilience in local biodiversity, from left. 1) Combined areas of steep altitudinal, temperature, and precipitation gradients in the NDM, and 2) combined areas of high habitat diversity in the NDM

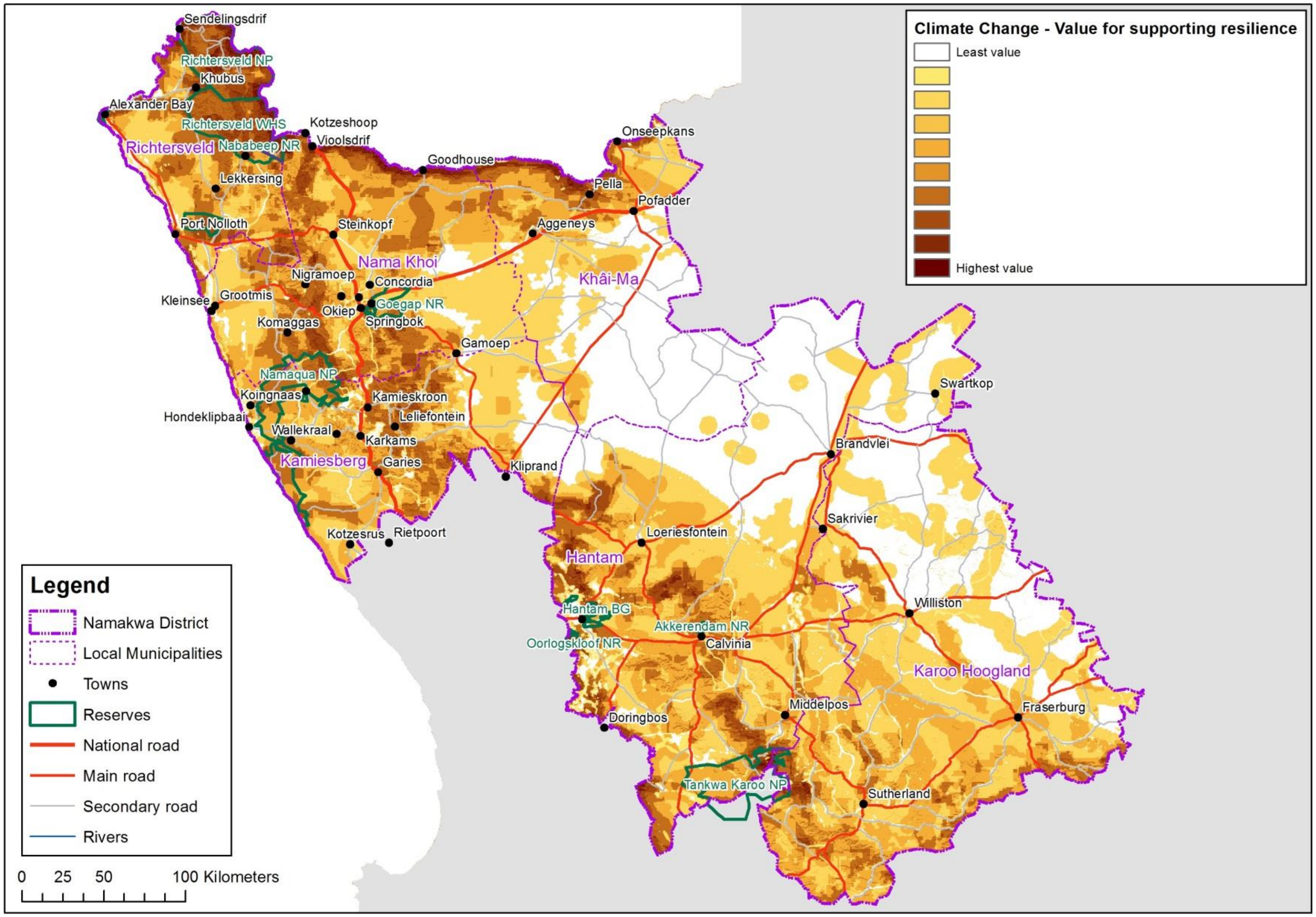


Figure 19: Integrated map of priority areas for climate resilient ecosystems in the NDM

Chapter 8: Socio-economic vulnerability in the NDM

8.1 Introduction

The distribution and the level of access to resources, such as wealth, municipal services, infrastructure, education and natural resources, influences a community's vulnerability to potential risks and hazards. This chapter identifies social priority areas for adaptation, where people have high levels of general poverty and where they are most directly dependent on the environment for the delivery of ecosystem services.

8.2 Methods

Information from National Census data collected in 2011 and collated by StatsSA at the local level (called 'small-place' data), data on the location of buildings from Eskom, and additional inputs based on local expert knowledge were used to develop three summary indices describing general poverty and environmental dependency that were then integrated into an overall **Social Demand Index**. The **Social Demand Index** essentially reflects adaptation priorities based on socio-economic information, in natural and semi-natural areas where people rely directly and heavily on ecosystem services as well as where general poverty is high.

For the social demand analysis, we developed three summary indices:

- **Population densities and location** – this examined where households are located within the district;
- A **General Poverty Index** – this is based on proportions of households which meet specific poverty criteria for four components:
  - proportions of low income households,
  - a dependency ratio,
  - an access to services measure of poverty, and
  - a consumption measure of poverty;
- A **Specific Environmental Dependency Indicators** – these focussed on groundwater dependency and communal grazing.

Each component of the three summary indices has been mapped separately (**Figure 20, Figure 21**, and **Figure 23**), as well as in an integrated **General Poverty Index** map (**Figure 22**). These three summary indices were then combined with the landcover maps to identify the natural and semi-natural areas in these high demand areas and produce a single **Social Demand Index (Figure 24)**. These are the areas in which natural resources need to be most carefully managed to ensure the ongoing supply of good quality environmental goods and adaptation services for people.

For a detailed description of the methods and data sources for each of the above social indices, please see **Annex 5**.

8.3 Results: Socio-economic Priorities Maps

Figure 20 to **Figure 23** gives an overall picture of which areas in the NDM have:

- the highest overall relative population density (**Figure 20**)
- the highest proportions of households with incomes of R9,600/year or less (**Figure 21**)
- the highest dependency ratio as the ratio of employed people to unemployed people, discouraged work seekers, people who are not economically active, and those who are under 15 years old and therefore not legally permitted to work (**Figure 21**)
- the highest levels of poverty in terms of a relative lack of access to services in the NDM. This is a measure of households with no access to sanitation, no piped water within 200m, no collection of refuse, and no access to electricity for lighting. Although the NDM performs well against national average service delivery, this relative measure highlights those areas in the NDM with relatively less access to services than other parts of the NDM (**Figure 21**)

- the highest levels of poverty in terms of ability to consume goods, measured as the lack of ownership of a range of goods including a car, cell phone, computer, DVD player, refrigerator, radio, satellite television, electric/gas stove, television, vacuum cleaner and washing machine. Again this is a relative measure comparing consumption levels in the NDM against itself, and not against the national average (**Figure 21**).

The poverty measures shown in **Figure 21** were then all consolidated into a **General Poverty Index** displayed in **Figure 22**. The consolidated map consists of an equally weighted summary of values derived from the proportion of low income households, the dependency ratio, the lack of access to services and the lack of access to goods.

Figure 23 highlights specific areas where households are directly dependent on the environment. For the NDM, this analysis focussed on two critical environmental dependencies – groundwater dependency and reliance on communal grazing resources. The two maps in **Figure 23** show where people that are highly dependent on the natural environment for their livelihoods are located. Specifically the map presents an index which ranges from zero or low (0) to high (10) to describe the density of households dependent on the environment in the NDM.

The final integrated **Social Demand Index** map shows natural and semi-natural high social demand areas in the NDM. The map consolidates the **Population Density Index**, **General Poverty Index** and the **Specific Environmental Dependency Indicators** into an overall **Social Demand Index** incorporating available natural resources. All irreversibly modified land has been removed from the analysis. Natural and semi-natural high social demand areas contributing to adaptation and highlighted in the **Social Demand Index** map need to be most carefully managed to ensure the ongoing supply of quality environmental goods and services to vulnerable communities.

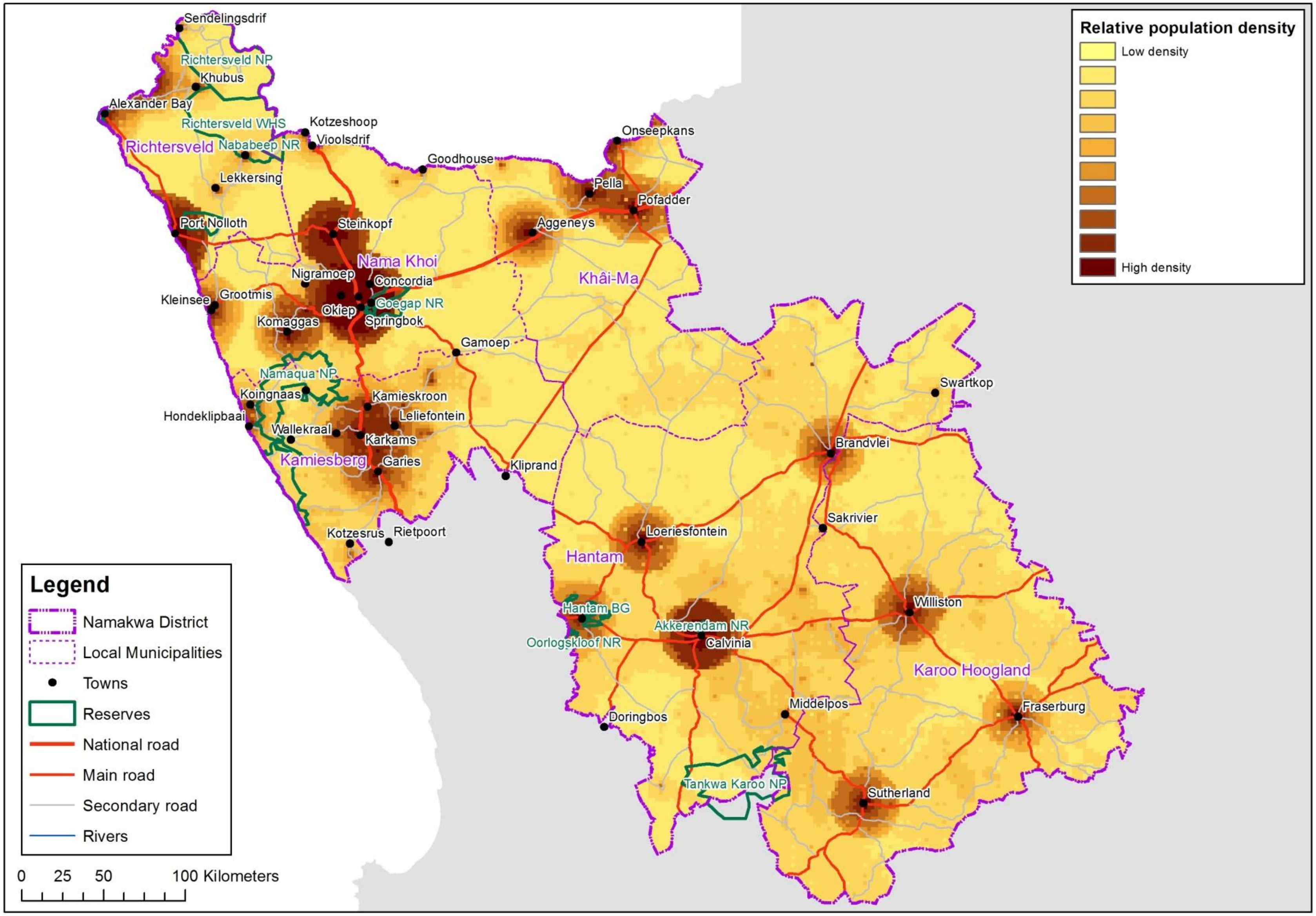


Figure 20: Map showing relative population density in the NDM based on an analysis of the distribution of buildings from the Eskom data (see Annex 5 for details).

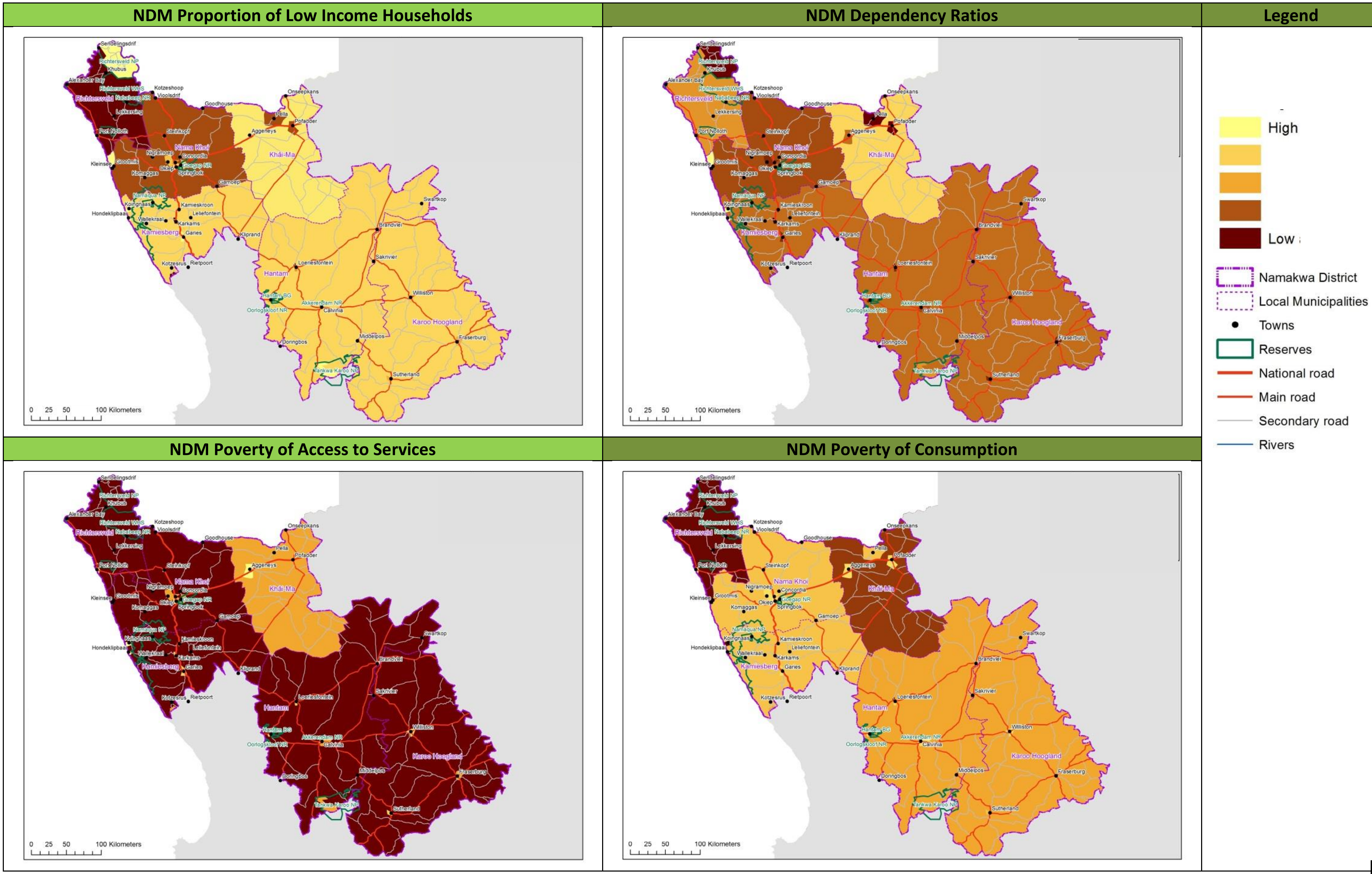


Figure 21: Maps of socio-economic indicators in the NDM contributing to poverty and thus to vulnerability, clockwise from top left. 1) Household income for the NDM as the proportion of households with incomes under R9600/year, 2) ratio of employed people to people who are unemployed, discouraged work-seekers, not economically active or under 15 for the NDM, 3) poverty measured by a lack of access to services such as sanitation, electricity, and piped water in the NDM, and 4) poverty measured by the lack of ownership of all goods in the NDM. Data derived from Census 2011. See Annex 5 for details. The darker the mapped area, the lower income, employment, and access to goods and services occurs in that area.

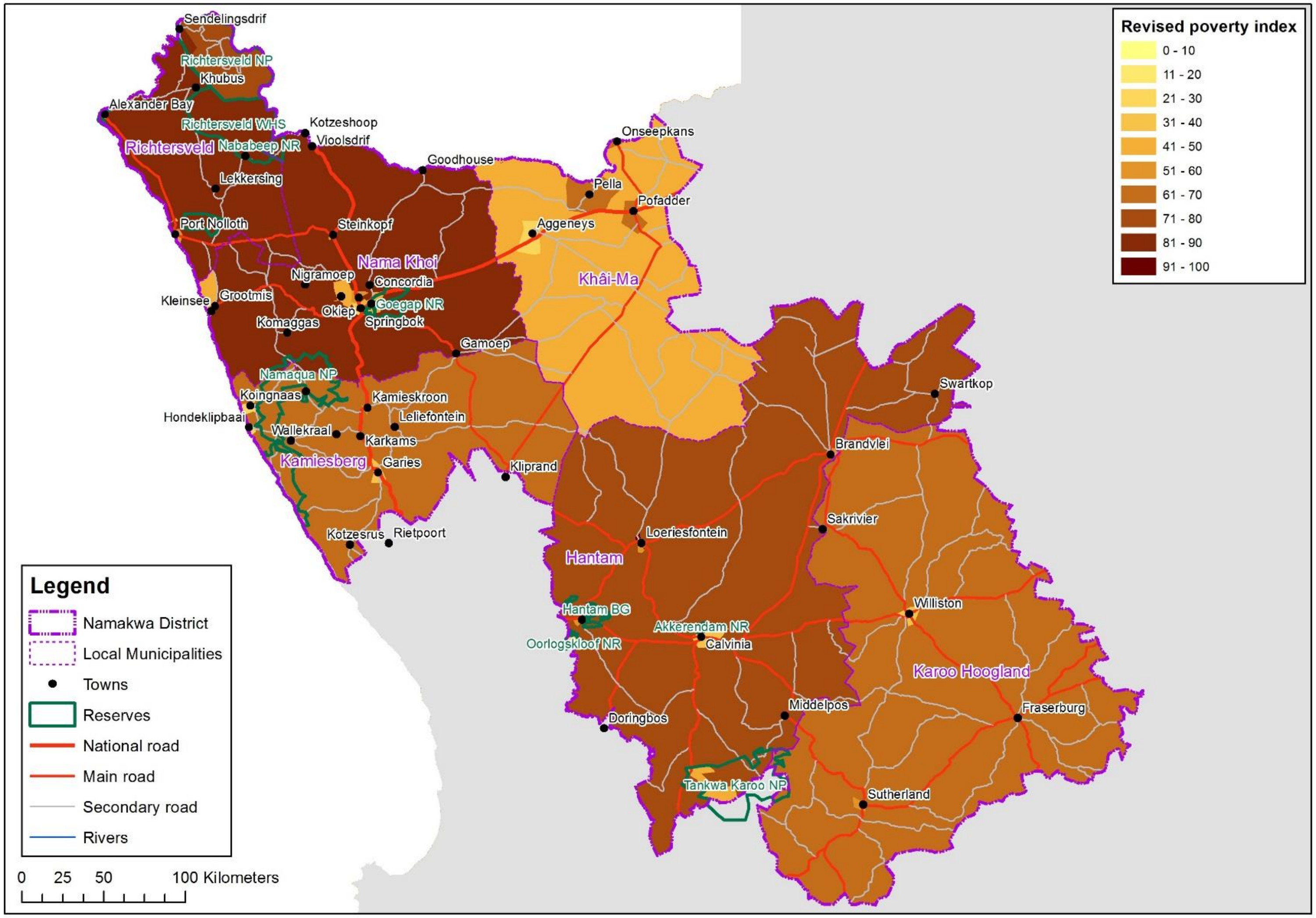


Figure 22: Integrated map summarizing the General Poverty Index for the NDM. This consists of an equal weighted summary of values derived from the proportion of low income households, the dependency ratio, the lack of access to services and the lack of access to goods.

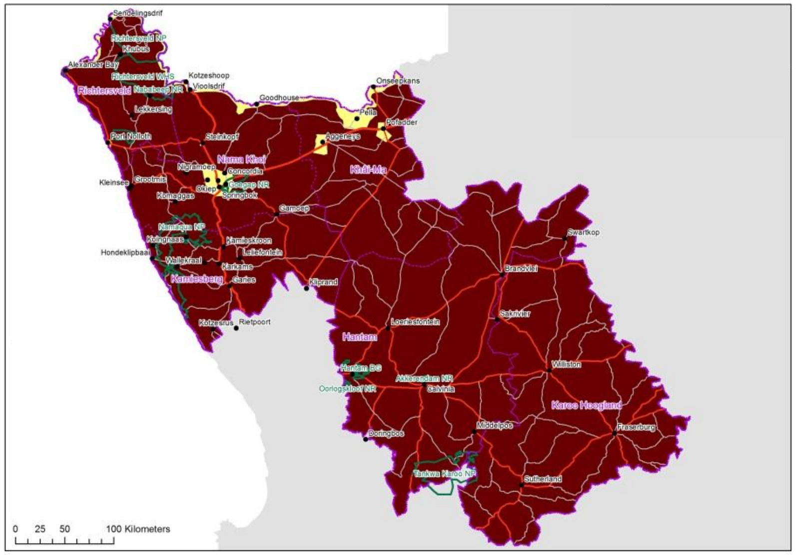
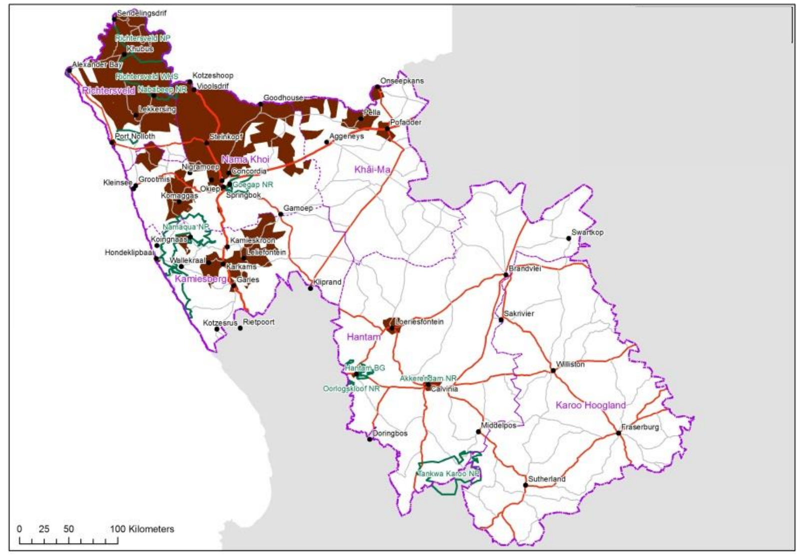
NDM Levels of Groundwater Dependency	NDM Communal Lands	Legend
		Namakwa District Local Municipalities Towns Reserves National road Main road Secondary road Rivers
Levels of Groundwater Dependency Low groundwater dependency Partial groundwater dependency High groundwater dependency	**Namakwa District Commonage** Commonage	

Figure 23: Specific Environmental Dependency maps for the NDM, from left. 1) Levels of dependence on groundwater for freshwater in the NDM, and 2) areas in the NDM that are under communal land tenure

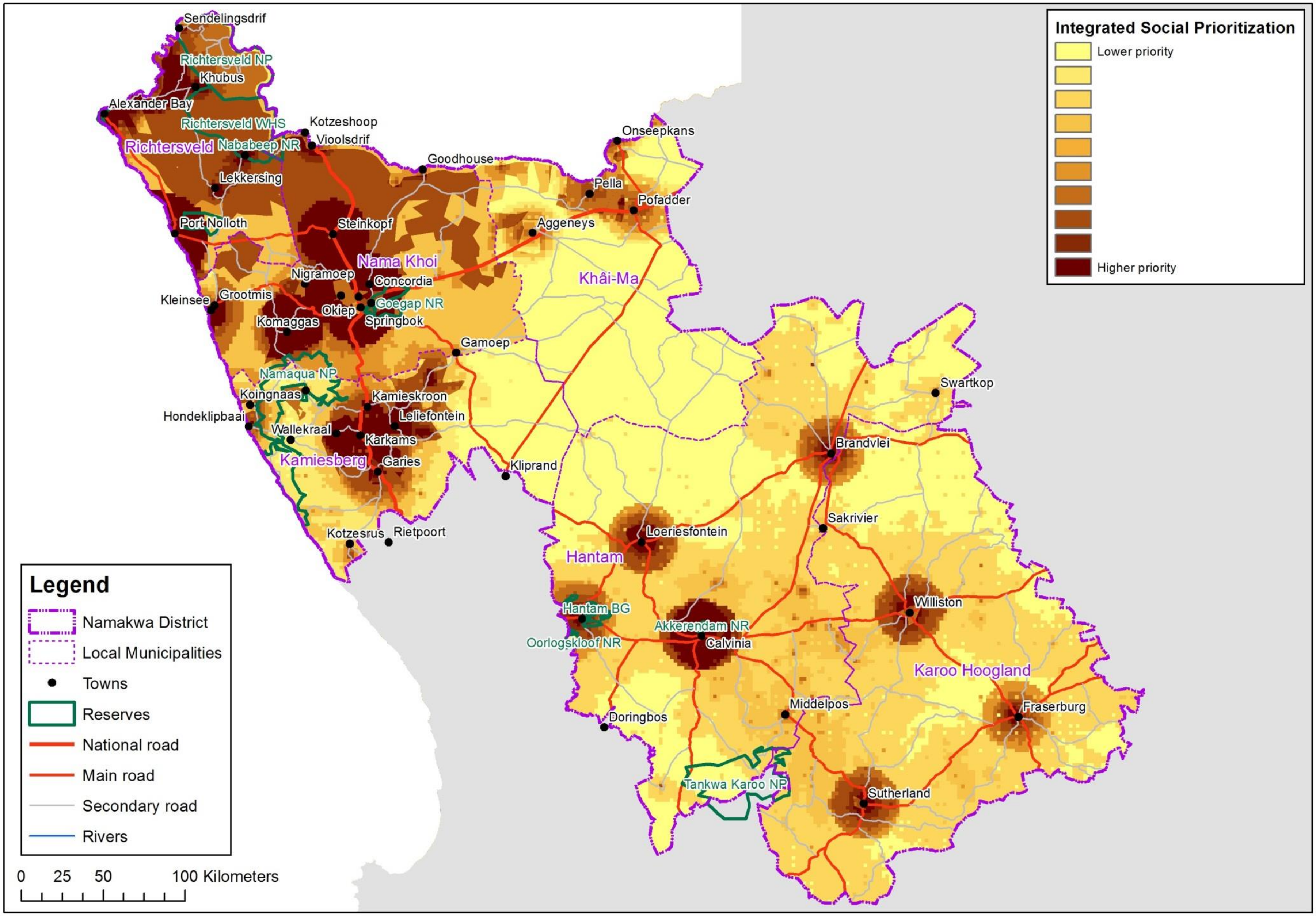


Figure 24: Map showing social demand priorities overlaying Population Density, General Poverty, and Specific Environmental Dependency indicators with natural and semi-natural areas data. High priority areas can be described as natural and semi-natural areas with high social demand on the environment. These are the areas which need to be most carefully managed to ensure the ongoing supply of good quality environmental goods and adaptation services for people in the NDM.

Chapter 9: Ecosystem-based Adaptation Priority Areas

9.1 Introduction

Improving access to natural resources and basic services is an essential component of reducing a community's vulnerability to climate change. Well-functioning ecosystems provide natural solutions that build resilience and help society adapt to the adverse impacts of climate change.

Ecosystem services provided by natural and semi-natural environments are critical for supporting climate change resilient communities and can contribute directly to climate change adaptation. This includes, for example buffering communities from extreme weather events such as flood and drought, reducing erosion and trapping sediments, increasing natural resources for diversifying local livelihoods, providing food and fibre, and providing habitats for animals and plants. Sustainably managed and/or restored ecosystems help in adapting to climate change at the local or landscape level.

Ecosystem-based Adaptation (also see box 3 in Chapter 1) requires investing in maintaining and restoring important ecological infrastructure, as well as priority areas for biodiversity and ecosystems. This frequently has the added benefit of creating jobs and contributing to livelihoods, especially in rural economies most at risk from adverse climate change impacts. In some cases EbA requires simply that healthy natural ecosystems are left alone to do what they already do best, and ensuring that they are not converted to other land uses. In other cases it requires the rehabilitation of impacted ecosystems – for example clearing invasive alien plants in ephemeral wetlands systems to increase water supply rather than building desalination plants or dams.

EbA is well suited to rural landscapes, and implementation efforts can be easily aligned with job creation and other projects with significant social benefits.

This chapter identifies areas important for Ecosystem-based Adaptation in the NDM. It uses information and data presented in chapters 3-8 to prioritise areas for the planning and implementation of EbA for building the climate resilience of local communities and the environment.

9.2 Methods

Summary layers described and presented in chapters 5, 6, 7 and 8 were produced in a compatible format – comprehensive coverage across at the NDM District scale – and scored in a consistent format with lowest value areas scoring 0 and highest value areas scoring 10 to allow for later integration. The individual layers used to create and integrates map of EbA priority areas in the NDM were:

- Water related Ecological Infrastructure (see chapter 5 **Figure 13**)
- Biodiversity Priority Areas (see chapter 6, **Figure 15**)
- Climate Resilient Ecosystem Priority Areas (see chapter 7, **Figure 19**)
- Socio-economic Adaptation Priority Areas (see chapter 8, **Figure 24**)

To generate the integrated EBA priority areas map, all of the above individual layers were equally weighted and combined. Then, specific natural and semi-natural portions of these areas were identified by removing irreversibly modified landscapes. The approach described here is shown in **Figure 25** below and represented in an integrated map in **Figure 26.**

9.3 Results: Integrated Ecosystem-based Adaptation Priority Areas Map

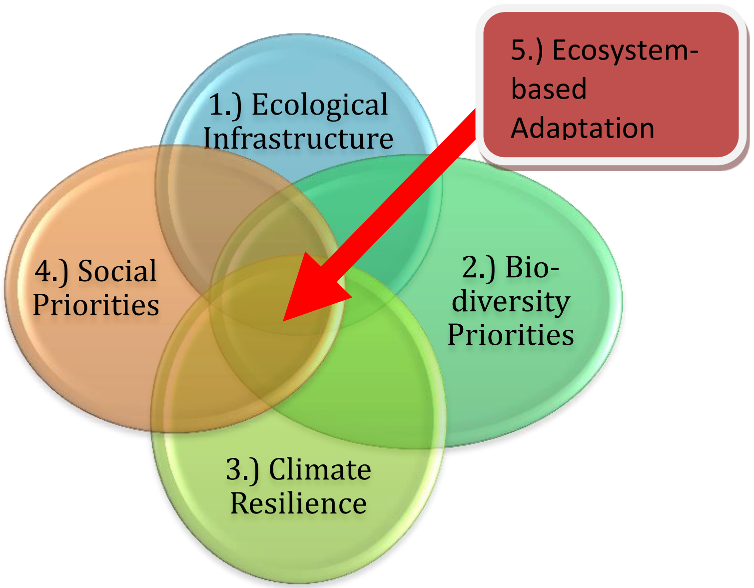


Figure 25: Summary of the analysis process

The outcome of the above analysis is shown in **Figure 25**. This map highlights areas in the landscape that are:

- Critical for delivering Ecosystem Services;
- Helpful for ecosystems adapting to climate change impacts, and hence support the overall socio-ecological system;
- Important for a range of other environmental reasons, including supporting viable and robust ecological systems. It is these systems on which we will depend for ecosystem services and climate change adaptation in the future; and
- Most important for supporting people who are directly dependent on the natural environment for their livelihoods.

The analysis identified where these areas overlap most strongly, and it is these priority areas where we should focus our (Ecosystem-based) climate change adaptation activities.

Activities that should be prioritised in these areas include:

- The sufficient inclusion of these areas into spatial planning instruments such as Spatial Development Frameworks and other appropriate planning tools, such as Integrated Development Plans. Avoiding inappropriate development of these areas will be critical to the long term ability of the NDM to adapt to climate change impacts;
- The full integration of these areas into relevant climate adaptation policy relating to the district, including national, provincial, district and local municipal climate change response strategies;
- The full integration of these areas into disaster risk management strategies for the NDM and its 6 local municipalities;
- The inclusion of these areas as the focus for Natural Resource Management (NRM) Programmes and other projects securing water services, both for water availability and water quality, restoring and maintaining livestock grazing services as a safety net for the poor, and controlling soil erosion as a way of avoiding infrastructure costs from damage to roads and dams;
- The restoration and protection of resource integrity in the region’s water catchments, wetlands, and rivers, and other priority areas; and
- The implementation of activities aimed at conserving landscapes, such as community based stewardship projects.

These areas are designed to serve to prioritise CSA's work and the work of CSA and the NDM’s partners towards the restoration and conservation of scientifically prioritised landscapes to ensure ecosystem function as a foundation for climate resilience and the development of the regional green economy.

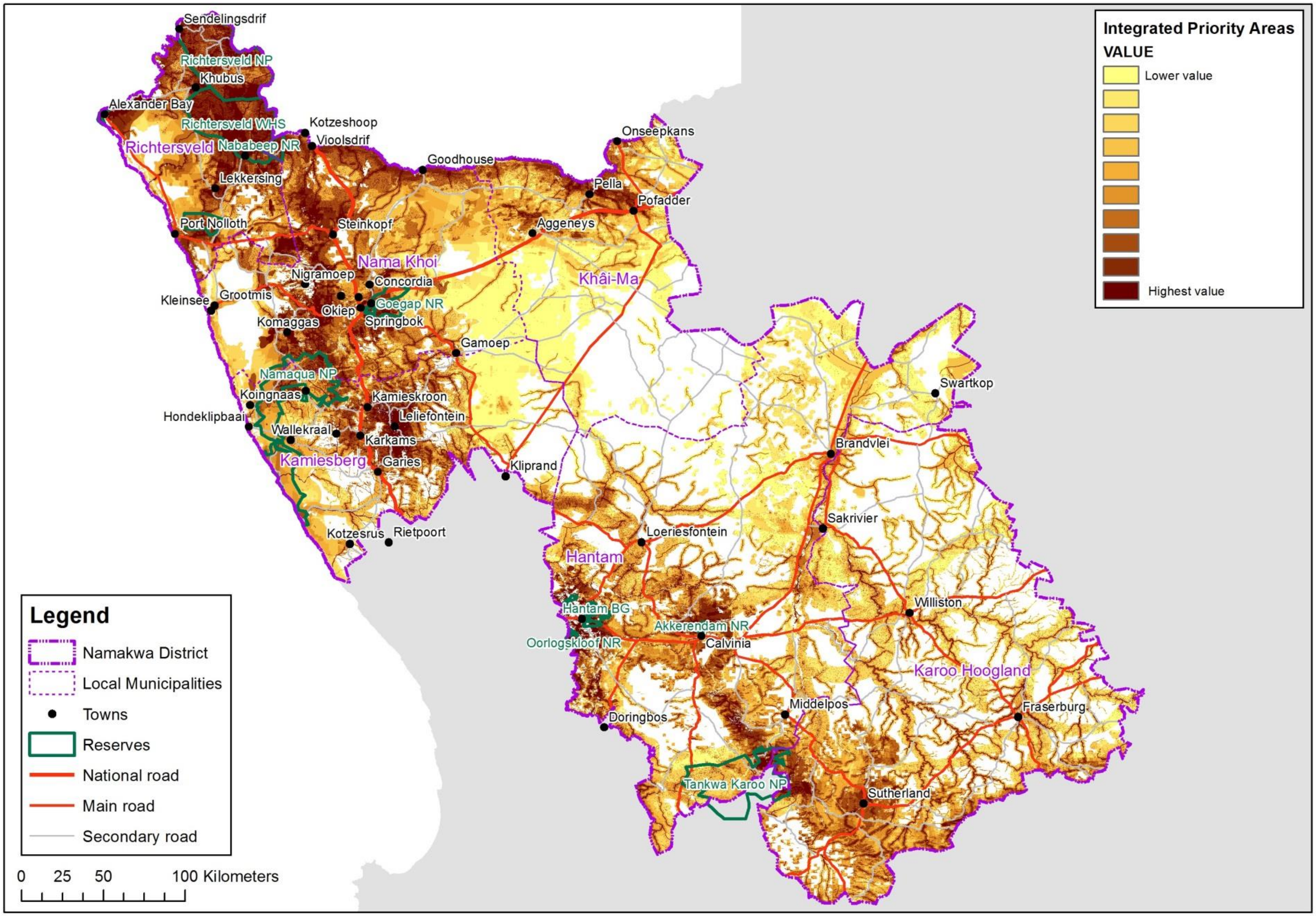


Figure 26: Integrated map of priority areas for Ecosystem-based Adaptation to climate change impacts in the NDM

Chapter 10: A Vulnerability Index for Namakwa District Municipality – *tracking adaptation progress at a local level*

10.1 Introduction

This chapter presents a Vulnerability Index for the NDM which aims to assist local decision makers and managers in the rapid evaluation of climate change vulnerability for the District. The index has been specifically designed to track change over time for the NDM and essentially can be used for any District across South Africa as it is primarily based on national datasets. The assessment can be seen as a repeatable exercise that provides a snapshot of vulnerability that can be tracked over time.

10.2 Methods

The conceptual framework for understanding vulnerability is based on the perception that vulnerability is an outcome of the interaction between social and ecological vulnerabilities and environmental risks and stresses arising from climate change.

Two main categories of climate change vulnerability have been considered to represent the overall climate change vulnerability for the district:

- Ecological vulnerability
- Socio-economic vulnerability

} Overall climate change vulnerability for NDM

Within these two categories a number of sub-indicators were used as proxies to represent parameters of **exposure**, **sensitivity** and **adaptive capacity**.

Each of these ecological and socio-economic sub-indicators was scored using a 1-5 sliding scale where **1** represents the **most desirable** condition (low vulnerability) and **5** represents the **least desirable** state (high vulnerability) in terms of climate change vulnerability. Scores for each of these sub-indicators were then equally weighted and combined to score the NDM's overall vulnerability to the impacts of climate change, also using a sliding scale of 1-5.

The data used for determining scores for the sub-indicators were largely drawn from publically available national datasets such as the Long Term Adaptation Scenarios and the National Census 2011. Some draw directly on the data presented here as part of the vulnerability assessment. One of the indicators relies on primary data collected through structured interviews using a national questionnaire template.

The following sections in this chapter present individual sliding scales, methods, data sources, and the NDM scores for Ecological (Section 10.3) and Socio-economic (Section 10.4) Vulnerability as well as the overall Vulnerability Index for NDM (Section 10.5).

10.3 Results: Ecological Vulnerability Index

10.3.1 Exposure

Sub-indicator 1 (change in temperature and rainfall)

Sliding scale 1-5

- 1 No temperature increase, no change or wetting
- 2 Low temperature increases (below 3°), no change or wetting
- 3 Low temperature increases (below 3°), drying
- 4 High temperature increases (more than 3°); no change or wetting
- 5 High temperature increase (more than 3°), drying

Method: Temperature increases of above and below 3° were used to summarise high and low temperature increase scenarios respectively. This is based on the standard determined for South Africa by the Long Term Adaptation Scenarios Flagship Research Programme.

Table 7: The sub-indicators for ecological and socio-economic vulnerability that were used as proxies for exposure, sensitivity and adaptive capacity. Each sub-indicator was scored out of 5 (with 1 being the least desirable and 5 being the most desirable.

Parameter	Ecological vulnerability	Socio-economic vulnerability
Exposure	Sub-indicator 1: Change in temperature and rainfall	Sub-indicator 1: % population living in the least stable areas according to the climatic envelope stability maps
	Sub-indicator 2: Increase in frequency and magnitude of extreme events – drought and flood	
	Sub-indicator 3: Increase in frequency and magnitude of extreme events –sea level rise	
Sensitivity	Sub-indicator 1: Change in stability of climatic envelopes associated with particular biomes	Sub-indicator 1: Total direct dependence on natural resources as a % of the population
Adaptive Capacity	Sub-indicator 1: % area of natural features supporting landscape resilience to climate change	Sub-indicator 1: Household adaptive capacity measured through a composite general poverty index, as a % of households
		Sub-indicator 2: Local Institutions supporting climate resilience (effectiveness of service delivery)
		Sub-indicator 3: Local government officials' perception of their current capacity to respond to climate change

Given the context of South Africa as a water-stressed country overall, it is assumed here that significant projected reductions in annual average rainfall will have stronger negative consequences than projected increases, which we take to represent opportunities[24].

Therefore, where rainfall projected by the models indicates no change in rainfall or at least 50% of the models indicate a wetting trend this is considered neutral and described below as 'no change or wetting'. Where rainfall projected by at least 50% of the models indicates a drying trend this is considered an 'undesirable' result and is described below as 'drying'.

This sub-indicator does not account for extreme events, which are dealt with separately in sub-indicator 2 and 3.

Data source: Namakwa District Vulnerability Assessment

NDM Score: Namakwa District scores a 3 in the medium term and a 5 in the long term, with both medium and long term projections showing progressively higher temperature increases alongside projected drying.

Description: Temperature under medium and long term scenarios is predicted to increase. In the medium term, temperature increases in the district are predicted to be at 1.8°C with slight variations between coastal and inland municipalities. In the long term an increase of 3.9°C is projected on average for the District, with significant differences in warming between the coastal municipalities, at 3.4°C, and the inland municipalities at 4.1°C.

Rainfall patterns suggest (although inconsistently) show slight drying, with a reduction by about 20mm per year (or 10% of current annual average rainfall) by 2100. Seasonal changes show some potentially interesting patterns, with the largest rainfall reductions projected in the winter in the coastal, largely winter rainfall municipalities and in the late summer in the inland, largely summer rainfall municipalities.

[24] DEA (Department of Environmental Affairs). 2013. Long Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Climate Trends and Scenarios for South Africa. Pretoria, South Africa.

Sub-indicator 2 (increase in frequency and magnitude of extreme events – drought and flood)

Sliding scale 1-5

- ❖ 1 No specific increase in drought/flood disaster risk profile (status quo or ideal)
- ❖ 2 Low exposure to a single climate related disaster risk
- ❖ 3 Low exposure to multiple climate related disaster risks
- ❖ 4 High exposure to a single climate related disaster risk
- ❖ 5 High exposure to multiple climate related disaster risks

Method: In this indicator, disaster-type events and high magnitude flood and drought events that are likely to be the result of climate change in the future are considered. These are estimated from the Long Term Adaptation Scenarios[25] disaster modelling reports. Data from quaternary catchments **D8, E3, and F1-6 were used to estimate impacts for Namakwa District** for the flood risk, and data from quaternary catchment **G1 was used to estimate impacts for Namakwa District** for drought risk.

Data source: Long Term Adaptation Scenarios Climate Trends and Scenarios Report and Disaster Modelling Report[24, 25].

NDM Score: Namakwa District scores a 4, with high exposure to a single climate related disaster risk, drought

Description: Large changes to drought frequency and severity are predicted for the representative catchment used to estimate disaster risk in the NDM, G1 Berg (Figure 7 in that report). Decreasing rainfall and increasing temperatures leave the closest representative catchment in a state on nearly perpetual drought, relative to current conditions, from 2045 onwards

[25] DEA (Department of Environment) 2015. Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Draft Report: Climate Change Adaptation: Disaster Risk Reduction and Management: Provisional modelling of drought, flood and sea level rise impacts and a description of adaptation responses, Pretoria, South Africa

No change in flood risk is projected for the catchments in the Namakwa District. Based on the LTAS Disaster Modelling Report (Figure 13 in that report), change in 1 in 10 year maximum daily flows are projected to decrease very slightly in most areas and increase very slightly in other areas, staying well within current normal ranges.

Sub-indicator 3 (increase in frequency and magnitude of extreme events –sea level rise)

Sliding scale 1-5

- ❖ 1. No coastal LMs or no land below 5.5m
- ❖ 2. <2% of land below 5.5m
- ❖ 3. >2-4% of land below 5.5m
- ❖ 4. >4-6% of land below 5.5m
- ❖ 5. >6% of land below 5.5m

Method: This indicator refers to the percentage area of the coastal LMs in the District that lie below the 'safe zone' for sea level rise recommended in LTAS, 5.5m above sea level.

Data source: Long Term Adaptation Scenarios Disaster Modelling Reports[26]

NDM Score: Namakwa District scores a 2, with less than 1% of land in the District's coastal LMs lying below 5.5m above sea level

Description: The NDM has three coastal local municipalities with about 300km of coastline. This is, however, a steep, rocky, and sparsely populated coastline, with less than 2% of the land area lying below 5.5m above sea level. Although there have been impacts of storm surge on coastal infrastructure in the past, and this needs to be carefully managed, the District can be classed overall as a low risk municipality in terms of coastal impacts of sea level rise.

[26] Draft disaster modelling report versions out for public comment in 2014

10.3.2 Sensitivity

Sub-indicator 1 (change in stability of climatic envelopes associated with particular biomes)

Sliding scale 1-5

- 1 No Change (or change in stability of less than 20%)
- 2 Small Change (or a change in stability of >20-40%)
- 3 Some Change (or a change in stability of >40-60%)
- 4 Much Change (or a change in stability of >60-80%)
- 5 Total Change (or a change in stability of more than 80%)

Method: This indicator is based on the identification of areas in the landscape where we can confidently predict that structural changes in the ecological systems will occur as a result of shifting climatic envelopes associated with biomes. Moving to a different climate envelope as a result of the changes in climate will likely lead to measurable change in the fundamental characteristics of the area.

Data Source: Namakwa District Vulnerability Assessment

NDM Score: Namakwa District scores a 1 in the medium term and 2 in the longer term, with relatively small structural changes in climatic conditions, and thus biome stability overall. This is largely because the large and spatially dominant Succulent Karoo biome broadly holds relatively stable under both scenarios. On closer inspection, the Fynbos and Nama Karoo biomes are extremely negatively affected.

Description: Climate change impacts are projected to have a significantly negative impact on Fynbos biome structure and distribution in the District. As shown in the NDM vulnerability assessment, an almost total disappearance of climate envelope suitability for the Fynbos biome occurs under the projected temperature and rainfall changes in the long term.

In the medium term, conditions suitable for the desert biome (higher temperatures and reduced late summer rainfall) are expected to expand into the Nama Karoo areas for a roughly 25% change. In the longer term, a more than 50% loss of stability is to be expected, with conditions suitable for desert displacing large areas of those currently suitable for Nama Karoo.

The Succulent Karoo biome holds relatively stable under the climate scenarios produced because it has a very broad climate envelope. It is also quite unique and distinctive in its characteristics, overall dry, hot summer, cold winter, but with autumn and winter rain, which do not really resemble other biomes. Therefore, large changes in temperature and rainfall are possible without shifting from general biome climate envelope. Since Succulent Karoo in the Richtersveld is quite different to Succulent Karoo in the Robertson area, large on the ground changes may not be picked up in these models.

10.3.3 Adaptive capacity

Sub-indicator 1 (% area of natural features supporting landscape resilience to climate change)

Sliding scale 1-5

- 1 More than 80%
- 2 >60-80%
- 3 >40-60%
- 4 >20-40%
- 5 Less than 20%

Methods: This indicator refers to the % area of the maps showing natural features in the landscape that contribute to climate resilience that has some identified value (i.e. its contribution to climate resilience is not 0)

Data source: Namakwa District Vulnerability Assessment

NDM Score: Namakwa District scores a 2, with a moderately high % area of natural features in the landscape that support climate resilience.

10.4 Results: Socio-economic Vulnerability Index

10.4.1 Exposure

Sub-indicator 1 (% population living in the least stable areas according to the climatic envelope stability maps)

Sliding scale 1-5

- 1 No exposure (<20% of the population)
- 2 Small exposure (>20-40% of the population)
- 3 Medium exposure (>40-60% of the population)
- 4 High exposure (>60-80% of the population)
- 5 Full exposure (>80% of the population)

Methods: Change in climate envelopes will introduce uncertainty, change, and risk. The closer a population or the natural environment is to a particular threshold, the more disruptive shifting climatic envelopes are likely to be. This indicator highlights the proportion of the population who live in the least stable areas identified in ecological vulnerability sensitivity sub-indicator 1.

Data source: NDM Vulnerability Assessment for least stable areas; National Census 2011 for spatial population distribution.

NDM Score: Namakwa District scores a 1 in the medium term, with a very small % of the population living in areas that look likely to be affected by biome instability early on, and a 2 in the longer term, with 21.6% of the population living in the least stable areas.

Description: As shown above in the ecological vulnerability section of the vulnerability assessment there are likely to be very high levels of instability and uncertainty in the Fynbos and Nama Karoo biomes of the Namakwa District, particularly as the climatic suitability for desert expands southwards inland. However, in these models, the Succulent Karoo holds relatively stable, and only a around 20% of the population lives in those highly vulnerable areas in the Khai Local Municipality, and near the high-lying towns of Leliefontein, Calvinia, Nieuwoudtville, and Sutherland, where the largest Fynbos nodes are currently located.

10.4.2 Sensitivity

Sub-indicator 1 (total direct dependence on natural resources as a % of the population)

Sliding scale 1-5

- 1 No Direct Dependency (<20% of the population)
- 2 Low Direct Dependency (>20-40% of the population)
- 3 Medium Direct Dependency (>40-60% of the population)
- 4 High Direct Dependency (>60-80% of the population)
- 5 Full Direct Dependency (>80% of the population)

Methods: This indicator considers the average number of households in area with direct dependency on the natural environment as % of total number of households.

Data source: National Census 2011 for dependency on each variable, NDM Vulnerability Assessment, Municipal records.

NDM Score: Namakwa District scores a 4, with 67% total direct dependence on natural resources that could be affected by future climate change (considering groundwater dependence and/or dependence on communal grazing resources).

Description: The NDM has a high score in sensitivity with the proportion of the population directly dependent on the natural resources investigated at 67%. Excluding those who live in the major towns in and around Springbok, as well as Aggenys and Pofadder, who all draw their water from the Orange River and do not depend directly on communal grazing land for livelihoods, the vast majority of people in the Namakwa District are directly dependent on either, or both, of groundwater and communal grazing resources, which are sensitive to the impacts of climate change.

Due to the rural nature of the NDM, a large proportion of the population is directly dependent on their surrounding environment for water and fodder. This is illustrated by **Figure 23** in chapter 8 of this vulnerability assessment.

10.4.3 Adaptive Capacity

Sub-indicator 1 (household adaptive capacity measured through a composite general poverty index, as a % of households)

Sliding scale 1-5

- 1 No exposure (<20% of the population)
- 2 Small exposure (>20-40% of the population)
- 3 Medium exposure (>40-60% of the population)
- 4 High exposure (>60-80% of the population)
- 5 Full exposure (>80% of the population)

Method: This indicator consists of a composite general poverty index that is a measure of population density, percentage ownership of assets, proportion of low income households, access to services, and a dependency ratio based on the proportion of not employed people including unemployed, discouraged work-seekers, and other not economically active groups such as children and the elderly.

This combination accounts for the fact that many elderly, disabled, and child members of the population qualify for government grants and these are often the sole source of income for a household.

Data source: National Census 2011 and NDM Vulnerability Assessment, Chapter 8

NDM Score: Namakwa District scores a 4.

Description: Although poverty indicators are very variable across the District and between poverty indicators, the NDM has an average General Poverty Index of about 65%. With a large proportion of the population in a poor position regards the general poverty index, their likely adaptive capacity is decreased.

Sub-indicator 2 (local Institutions supporting climate resilience – effectiveness of service delivery)

Sliding scale 1-5

- 1 More than 80% service delivery averaged across 5 sectors
- 2 60-80% service delivery averaged across 5 sectors
- 3 40-60% service delivery averaged across 5 sectors
- 4 20-40% service delivery averaged across 5 sectors
- 5 Less than 20% service delivery averaged across 5 sectors

Method: Services contributing to climate change adaptation were broken down into measurable components, sanitation (flush toilet connected to sewage), water (piped, inside dwelling), electricity (for lighting at the household level), and weekly refuse removal, which can be accessed from the National Census, for the NDM http://www.localgovernment.co.za/districts/demographics/36/Namakwa-District-Municipality. Each of the components received a District level percentage delivery score that was then averaged.

This indicator is designed to be a measure of how good the municipality is at delivering on their mandate as an indicator of their effectiveness overall, and a proxy indicator of their likely ability to be able to respond to new needs and challenges. The average of the four service delivery sector scores determines the score for local government institutions on this measure.

Service delivery is recorded as a proportion of the population in the District with access to the listed services.

Data source: National Census 2011

NDM Score: Namakwa District scores a 2.

Description: The Namakwa District has very high rates of service delivery, particularly in the larger towns and settlements, compared to the national average. Electricity and refuse collection services are particularly comprehensively delivered, with water and sanitation services lagging behind.

Table 8: Service delivery in the NDM, from Census 2011 data

Basic Services	Percentage delivered
Sanitation (flush)	57.9%
Piped water	63.3%
Household electricity for lighting	86.5%
Refuse collection	80.1%
Average	*71.95%*

Sub-indicator 3 (local government officials' perception of their current capacity to respond to climate change)

Sliding scale 1-5

- 1 All 'Yes' answers (> 80% of answers are 'yes' on average)
- 2 >60-80% 'Yes' answers on average
- 3 >40-60% 'Yes' answers on average
- 4 >20-40% 'Yes' answers on average
- 5 No 'Yes' answers (<20% of answers are 'yes' on average)

Method: Using the Department of Environmental Affairs Climate Change Adaptation Situational Analysis and Needs Assessment Survey 2014[27], the percentage of' Yes' responses given by interviewed officials were used in a self-assessment of local government officials of their institution's capacity in responding to climate change.

Target questionnaires were distributed amongst local institutional officials to source primary data regarding climate resilience, budgetary support and climate responsive projects within local municipalities.

The structured survey asked interviewed officials to respond on the presence or absence of a number of criteria including but not limited to policies, strategies, funding, dedicated personnel, trained personnel, and knowledge and information.

The 25 question structured survey where respondents have the option to select 'Yes', 'No', and 'Partly' as answers, was administered to all LED/IDP officials in the Namakwa District. The % of 'Yes' answers in each survey is calculated separately for each section of the survey, and the average taken for the District and presented in Table 9.

Data source: Primary data, Department of Environmental Affairs Climate Change Adaptation Situational Analysis and Needs Assessment Survey 2014

NDM score: NDM scores 4

Description:

Table 9: Percentage of Yes answers to SANA Questionnaire in the NDM

Municipality	Number of yes answers	Proportion of yes answers	
Namakwa DM	6	0.24	
Karoo Hoogland LM	7	0.28	
Hantam LM	4	0.16	
Kamiesberg LM	6	0.24	
Nama Khoi LM	8	0.32	
Khai Ma LM	3	0.12	
Richtersveld LM	11	0.44	
Average			***0.26***

27 Draft national situational analysis and needs assessment report out for public comment in 2015

10.5 Results: Summary Overall Vulnerability Index

10.5.1 Overall Ecological Vulnerability Scores

Scores from each individual sub-indicator were equally weighted and averaged to determine an overall average for each parameter: exposure, sensitivity and adaptive capacity. An average of the parameter scores were then used to represent an overall Ecological Vulnerability Index. See **Table 10** below.

Parameters	Sub-Indicators	Score medium term	Score long term
Exposure	1. Temperature and rainfall change (Long term)	3	5
	2. Change in extreme events	4	4
	3. Sea level rise	2	2
	Average	*3*	*3.7*
Sensitivity	1. Change in biome stability	1	2
	Average	*1*	*2*
Adaptive Capacity	1. % of natural features supporting climate resilience	2	2
	Average	*2*	*2*
Ecological Vulnerability Index (average of the average scores)		**2**	**2.7**

10.5.2 Overall Socio-economic Vulnerability Scores

Scores from each individual sub-indicator were equally weighted and averaged to determine an overall average for each parameter: exposure, sensitivity and adaptive capacity. An average of the parameter scores were then used to represent an overall Socio-economic Vulnerability Index. See **Table 11** below.

Table 10: Scores for sub-indicators used in assessing socio-economic vulnerability in NDM (ranging from 1 most desirable to 5 least desirable)

Parameters	Sub-Indicators	Score medium term	Score long term
Exposure	Population in Least Stable area (long term)	1	2
	Average	*1*	*2*
Sensitivity	Dependency on Natural resources	4	4
	Average	*4*	*4*
Adaptive Capacity	General poverty pressure	4	4
	Effectiveness of basic services	2	2
	Official perception of capacity	4	4
	Average	*3.3*	*3.3*
Socio-economic Vulnerability Index (average of the average scores)		**2.8**	**3.1**

10.5.3 Overall Integrated Climate Change Vulnerability Index for the NDM

A graphic summary of the above scores for socio-economic and ecological vulnerability parameters can be viewed in Error! Reference source not ound. to Error! Reference source not found. below.

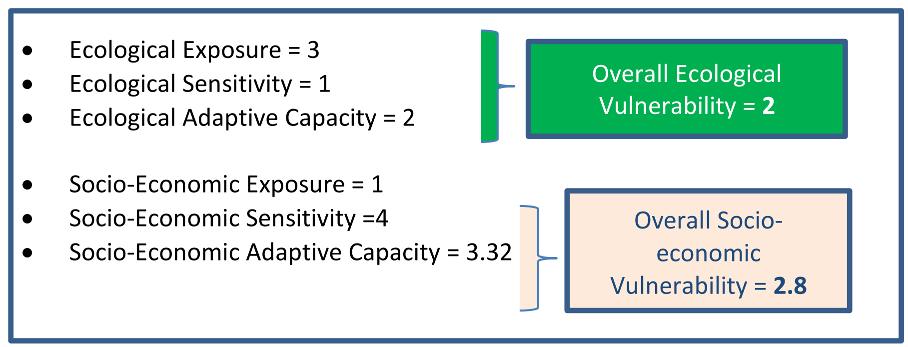


Figure 27: Parameter scores were averaged to represent overall ecological and socio-economic vulnerability indices for the medium term

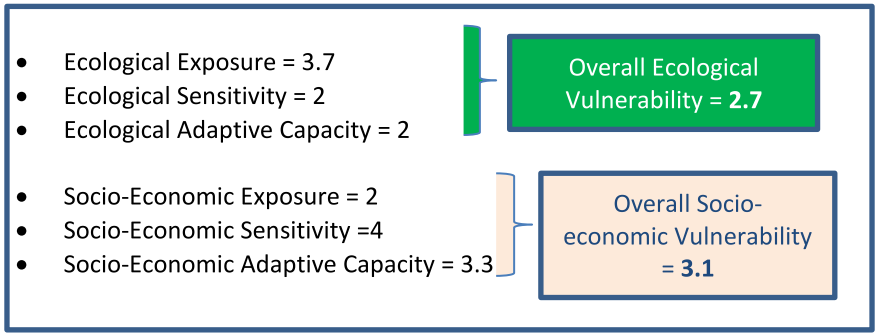


Figure 28: Parameter scores were averaged to represent overall ecological and socio-economic vulnerability indices for the long term

Overall, the Namakwa District exhibits medium vulnerability to climate change, scoring an average across all indicators of 2.4 in the medium term and 2.9 in the longer term.

A radar chart is useful for seeing which components of vulnerability need to be addressed most urgently as vulnerability is not evenly spread across the selected indicators and therefore poorly represented by the average score. Given that each indicator has been scored on a <u>1-5 sliding scale</u> where **1** represents the **most desirable** state and **5** the **least desirable**, it is most desirable for the indicators to cluster towards the centre of the radar chart. As can be seen in **Figure 29** and **Figure 30**, this is rarely the case, and vulnerability is unevenly spread throughout the indicators.

Areas of strength in the NDM are good municipal effectiveness, low numbers of people living in climatically unstable areas, large areas of natural features contributing to climate resilience, low exposure to sea level rise, and reasonably stable biome climatic envelopes. These are areas to maintain and build on for a successful climate response in the NDM in the future. These are shown on the radar chart as points closer to the centre of the chart.

Weaker areas in terms of climate resilience are shown on the radar chart as those points further from the centre of the chart. These include low levels of confidence on climate response capacity amongst municipal officials, high general poverty, high direct dependence on natural resources likely to be affected by climate variability and change, and high exposure to drought risk. These are the aspects of vulnerability in the NDM that need to be prioritised for climate preparedness action. If these can be improved, or better planned for and dealt with in the case of drought risk, the NDM will be in a better position to respond effectively to climate change.

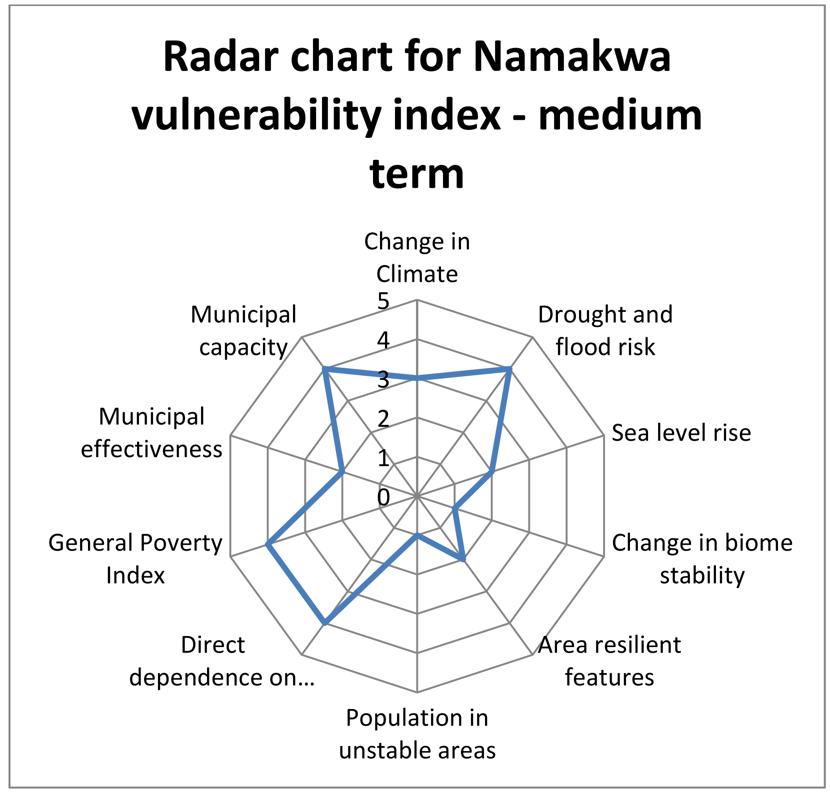


Figure 29: Radar chart for the NDM Vulnerability Index, medium term

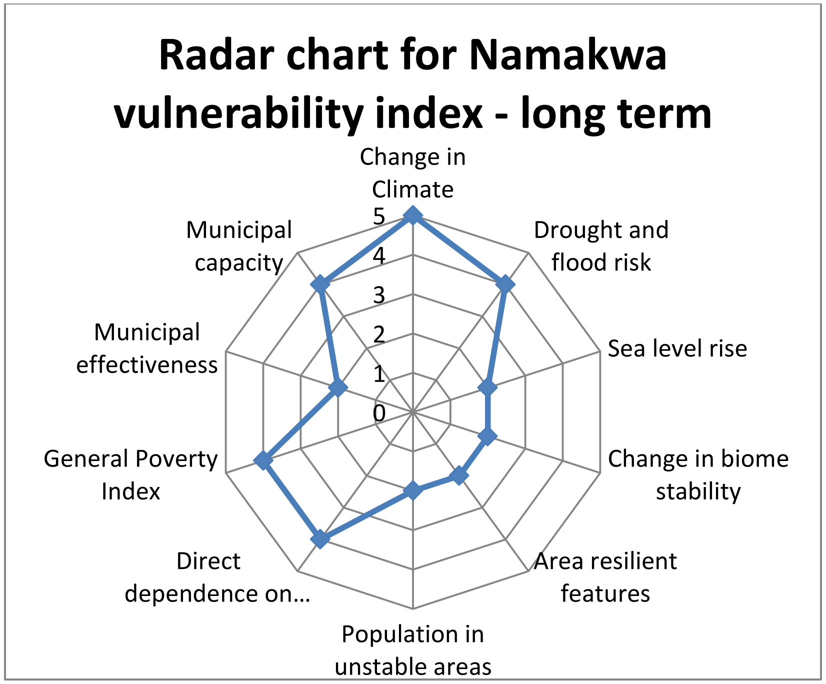


Figure 30: Radar chart for the NDM Vulnerability Index, long term

Figure 30 above shows how climate vulnerability increases across certain indicators over time. Changes in rainfall and temperature become larger and more dangerous in the longer term future. Along with this, the risk of a loss of stability in some of the biome climatic envelopes also increases, leaving greater numbers of the population exposed to climatic instability.

We did not model projected changes in other social indicators, such as general poverty pressure or direct dependence on natural resources, for this report. These, therefore, remain unchanged in the longer term analysis.

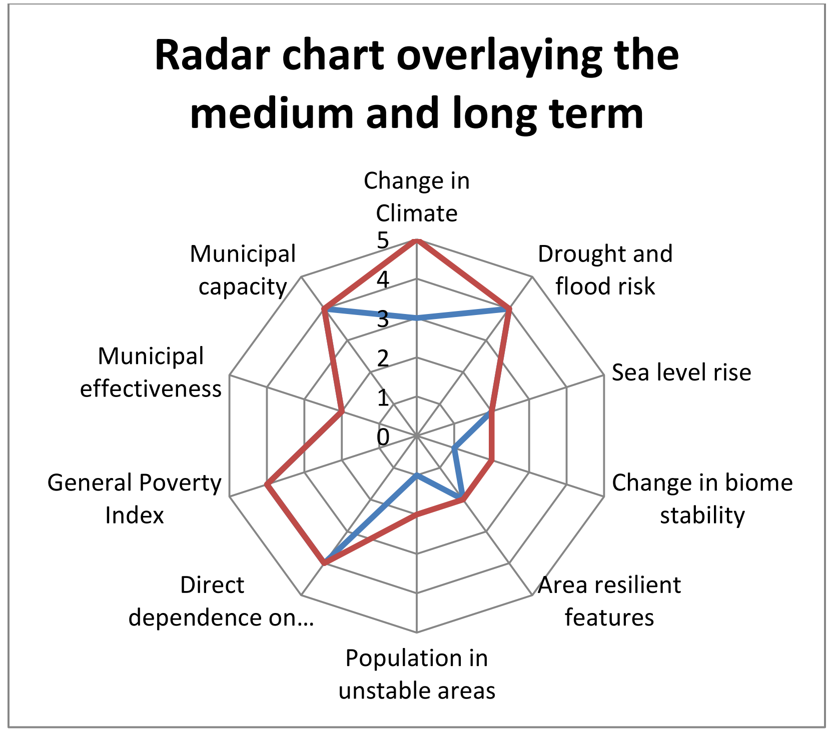


Figure 31: Radar chart overlaying NDM Vulnerability Index results for the medium term and the long term. Medium term is shown in blue and long term in red.

An average of the overall Ecological Vulnerability and Socio-economic Vulnerability indices is used to represent the overall district Vulnerability Index score. The process is illustrated in **Figure 32** and **Figure 33** below.

The overall vulnerability score for the NDM is medium. In the medium term analysis, the NDM scores a 2.4 – close to the middle of the 1-5 sliding scale for vulnerability. In the long term analysis, the NDM scores a 2.9, demonstrating that, according to current climate projections, the situation is due to worsen over time and steps should be taken now to ensure proactive adaptation to expected impacts.

Vulnerability is unevenly spread across the indicators, highlighting those areas where NDM is weaker and stronger in terms of climate resilience. There is particular concern in terms of the increasing risks over time introduced by increasing temperatures, decreasing rainfall, and potentially increased risk if exposure to drought. Shifting biomes under changing climate conditions is likely to affect the population living in least stable areas, and directly dependent on natural resources for their livelihoods.

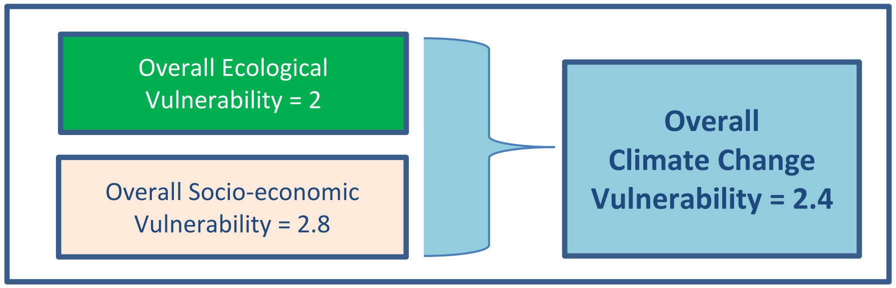


Figure 32: The overall ecological and socio-economic scores were averaged to obtain an overall vulnerability index for the NDM in the medium term

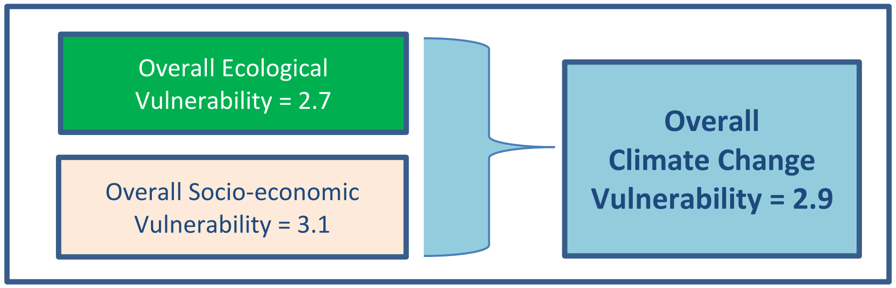


Figure 33: The overall ecological and socio-economic scores were averaged to obtain an overall vulnerability index for the NDM in the long term

Chapter 11: Conclusion

The goal of an assessment of vulnerability to climate change is to highlight priorities and enable actions that will reduce susceptibility to the impacts of climate change.

It is hoped that this vulnerability assessment provides localised site specific analysis, guidance and recommendations to local decision makers and managers in the NDM regarding the possible impacts of climate change in the district as well as the priority areas (both spatial and institutional) in which ecosystem based adaptation efforts should be concentrated.

The impacts of climate change are cross-cutting and thus require a cross-cutting approach which will ensure that communities are able to withstand the impacts of climate change and adapt to the possible futures. The rural nature of the NDM, high levels of direct dependency on local Ecological Infrastructure, and high levels of poverty and unemployment make this region and excellent candidate for specific, targeted Ecosystem-based Adaptation actions, as well as a more general institutional shift towards an increasingly more climate responsive district.

Efforts should be made to reduce socio-economic vulnerabilities and increase institutional capacities. This is important as enhanced capacities will result in an improvement in people's wellbeing, as well as an improved understanding of the importance of ecosystem services and natural resources for the NDM.

Although the current assessment represents a major step forward in our understanding of the climate change related vulnerabilities in the NDM, and our ability to represent these spatially, a number of the analyses require further refinement in order for them to integrate into business as usual planning processes in the NDM.

A specific set of initial highest, and then secondary, priority areas is needed to guide implementation activities. These focus areas need to be described using local place names that make sense to users, and need to be linked to clear site specific implementation activities. It should also be noted that climate change science advances continuously, and it may be necessary to update this analysis as climate assessments improve.

In short, the actionable results of this report are as follows:

From chapter 3, temperature and rainfall projections

- All climate models used predict increases in temperatures over time. The increases in temperature become quite dramatic in the longer term. Proactive adaptation measures to address heat stress on livestock, people, and infrastructure will be no-regrets investments
- There is a lot of variability in the models for predicting future change in rainfall amounts and patterns as a result of climate change. This means that there is greater uncertainty in terms of what we can expect in the NDM from future rainfall. Large and small infrastructure, from houses to roads and dams, must be constructed taking into account the full range of possible rainfall futures.
- Considering expected temperature increases, aridity can be expected to increase regardless of the direction of rainfall change. Agricultural activities, such as watering livestock, dryland cropping for fodder, and irrigated agriculture, must be planned so as to be prepared for a more arid future environment with higher levels of evaporation and transpiration.

From chapter 4, biome stability modelling

- The NDM's unique Fynbos pockets are highly vulnerable to climate change and farmers and residents in these areas need to be engaged to begin monitoring these sites, tracking change, and preparing for biome shifts in these areas
- The Nama Karoo biome seems sensitive to climate change, particularly in the northern parts of the NDM. The areas need to be monitored to track potentially advancing desertification in

these areas, and farmers need to be prepared for increasingly harsh conditions.

- The globally unique Succulent Karoo biome appears to hold relatively stable into the future. This result needs to be treated with caution however, because the Succulent Karoo firstly has a very broad climate envelope - the dry Richtersveld is very different to much less arid Robertson area while still occurring in the same biome. Secondly, the Succulent Karoo climate envelope is also quite distinctive in its characteristics - overall dry, hot summer, cold winter, but with autumn and winter rain - which does not really resemble that of any other biome. Therefore, quite big changes in actual values can occur but wouldn't indicate a pattern shift to a new biome. At any given site, it may be plausible to have huge and disastrous changes but still stay in the same biome climate envelope. This will need to be monitored closely.

From chapter 5, water ecological infrastructure

- Natural critical water related ecological infrastructure should be priorities for conservation action
- Other natural water related ecological infrastructure should be maintained in a natural state, and degraded water related ecological infrastructure rehabilitated and sustainably managed to perform the best possible water ecosystem service delivery in this extremely water stressed area.

From chapter 6, biodiversity priorities

- High priority biodiversity ecological infrastructure should be maintained in a natural or near-natural state through conservation, biodiversity stewardship, and sound management
- Degraded areas important for biodiversity ecological infrastructure should be actively rehabilitated to enhance their ability to deliver climate related ecosystem services for adaptation in the NDM.

From chapter 7, climate resilient ecosystem priorities

- High priority climate resilience ecological infrastructure should be maintained in a natural or near-natural state through conservation, biodiversity stewardship, and sound management
- Degraded areas important for climate resilience ecological infrastructure should be actively rehabilitated to enhance their ability to deliver climate related ecosystem services for adaptation in the NDM.

From chapter 8, socio-economic vulnerability to climate change

- Poverty, measured by access to goods and services, incomes levels, and levels of unemployment and dependency, will undermine the ability of people living in the NDM to respond effectively to climate change. Human development measures focusing on health, education, skills development, and job creation will contribute towards the eradication of poverty and improve overall adaptive capacity
- With only one perennial river in the region, the Orange River, many people in the NDM are entirely dependent on groundwater for their freshwater. Many of these groundwater resources are already oversubscribed. Implementing water supply and demand projects, such as minimising leaks on water reticulation systems, promoting grey water recycling and water harvesting and storage, assisted groundwater recharge, and water saving schemes are necessary and actionable.
- Large numbers of people also depend on commonage rangelands for supplements to their livelihoods. These areas are often overcrowded, overgrazed, and degraded. Restoration, rehabilitation. Agricultural development such as arid-adapted dryland fodder cropping and water saving water infrastructure, as well as sound planned grazing, will assist in building the resilience of these important natural resources.

From chapter 9, ecosystem based adaptation priority areas

- Through the integration of all of the above information, we have identified priority areas in the NDM for ecosystem based adaptation to climate change. These are critical sites for ecosystem services delivery, natural resources, and adaptation services, and are utilised by people in the NDM likely to be hard hit by climate change – the poor, people living in small isolated settlements, and farmers. It is in these areas – around Sutherland, Calvinia, and Nieuwoudtville, along the escarpment and transition zones from Garies to Sendelingsdrift, along the coast, and, particularly, along the length of the Lower Orange river – that adaptation actions can most productively be focused.

From chapter 10, the vulnerability index

- Areas of strength in the NDM are good municipal service delivery effectiveness, low numbers of people living in climatically unstable areas, large areas of natural features contributing to climate resilience, low exposure to sea level rise, and reasonably stable biome climatic envelopes. These are strengths to maintain and build upon by conserving natural areas in the landscape, and continuing to promote good governance and strong service delivery
- Weaker areas include low levels of confidence on climate response capacity amongst municipal officials, high general poverty, high direct dependence on natural resources likely to be affected by climate variability and change, and high exposure to drought risk. Addressing poverty, direct dependence, and drought have been discussed above. Further, the NDM needs to prioritise climate preparedness and climate change capacity building for its own staff and associated institutions, continued and enhanced mainstreaming of climate change information into all development planning and action, and detailed, coordinated, and participatory municipal planning to ensure they are in a better position to respond effectively to climate change.

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Annex 1: An Overview of Institutional policy

INTRODUCTION

South Africa's Institutional arrangement in environmental governance is considered one of the best in the world, with the country being an active participant in international policies which trickle down to national, provincial, municipal and to towns and communities.

International Conventions

United Nations Framework Convention on Climate Change

The UNFCCC recognises that the climate system is a shared resource and thus promotes intergovernmental approach in mitigating GHG emissions. The Kyoto Protocol is linked to the UNFCCC and is, considered an international agreement to reduce GHG emissions. The protocol commits parties to measurable reductions in GHG emissions in the establishment of man-made GHG sinks.

It is available online at

https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf

Convention on Biological Diversity

The CBD promotes the protection of biological diversity, sustainable use and the sharing of benefits derived from the utilisation of those genetic resources.

See http://www.cbd.int/

United Nations Convention to Combat Desertification

The UNCCD has established a thread which links climate change, development and sustainable land management. The convention specifically targeting drylands as these areas fall in the category of being most vulnerable.

See http://www.unccd.int/en/Pages/default.aspx

National Acts and Policies

The Constitution of the Republic of South Africa 1996

Within the bill or rights of the South African constitution, every person has the right to an environment which will not have a detrimental impact and for that environment to be maintained for future generations.

The bill of rights (Chapter 2 of the constitution) which states that everyone has the right (a) to an environment that is not harmful (b) to have the environment protected through legislation which ensure that;

i) Prevent pollution and ecological degradation.
ii) Promote conservation and

iii) Secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

It is available online at

http://www.gov.za/sites/www.gov.za/files/images/a108-96.pdf

National Climate Change Response Policy (White Paper)2011

Climate change has been recognised as a significant factor in the well-being and the provision of services to communities and thus the NCCRP provides a long term vision to combat climate change through, effective management of climate change impacts and how South Africa can contribute to global targets in lowering carbon levels.

It is available online at

http://www.sanbi.org/sites/default/files/documents/documents/national-climate-change-response-white-paper.pdf

National Long Term Adaptation Scenarios

The LTAS is a flagship research programme on climate change adaptation led by the Department of Environmental Affairs. Technical reports on climate change impacts, and sector-based adaptation threats and opportunities for biodiversity, marine fisheries, human health, agriculture, and water have been released.

These reports, and summary factsheets, are available online at http://www.sanbi.org/biodiversity-science/state-biodiversity/climate-change-and-bioadaptation-division/ltas

National Environmental Management Act 1998.

The NEMA forms the basis for all environmental management acts in South Africa and is based on the principles of section 24 of the South African constitution.

It is available online at

http://www.gov.za/sites/www.gov.za/files/a107-98.pdf

National Environmental Management: Biodiversity Act 2004.

The NEMBA is intended to protect biodiversity in South Africa. It specifically protects threatened and endangered ecosystems, species and aids in the regulation of bio-prospecting.

It is available online at http://ship.mrc.ac.za/biodiversity.pdf

National Environmental Management: Air Quality Act 2004.

The NEMAQA recognises the adverse impacts of GHG emissions and thus deals with air quality and air pollution.

It is available online at

http://www.saflii.org/za/legis/consol_act/nemaqa2004454.pdf

National Environmental Management: Protected Areas Act 2003.

The NEMPAA deals with the management and the protection of areas which are important as they provide environmental services, such as wetlands, biologically diverse areas and the establishment of 'safe zones' for plant and animal species.

It is available online at

https://www.environment.gov.za/sites/default/files/gazetted_notices/nempaa_actno57of2003_protectedareas.pdf

Mountain Catchment Areas Act 1970.

The MCAA promotes the protection of mountain catchments and the effective management of areas around river sources, to protect the availability and quality of water.

It is available online at

http://www.saflii.org/za/legis/consol_act/mcaa1970237.pdf

National Environmental Management: Integrated Coastal Management Act 2008.

The NEMICMA allows for the protection of designated coastal protection regions. The NDM has three coastal municipalities and several important estuaries, one of which is the RAMSAR site Orange River estuary at Alexander Bay.

It is available online at

http://www.saflii.org/za/legis/num_act/nemicma2008571.pdf

National Environment Management: Waste Act 2008.

The NEMWA promotes environmentally sound waste disposal methods which are environmentally sound.

It is available online at

http://sawic.environment.gov.za/documents/384.pdf

National Water Act 1998.

The NWA requires the sustainable use of water and the equitable distribution of this scarce resource, and the integrated management of all aspects of water resource.

It is available online at

http://www.energy.gov.za/files/policies/act_nationalwater36of1998.pdf

National Forest Act 1998.

The NFA promotes the protection and sustainable use of forests and trees for the benefit of all.

It is available online at

http://www.forestry.co.za/uploads/File/legislation/forestry/National%20Forest%20Act%20%28regs%2029%20April%202009%29.pdf

National Plans and Strategies

National Development Plan (Vision 2030)

The plan is geared towards the improvement of lives and livelihoods through a variety of development initiatives which place significant importance on climate change. Climate change is seen as a significant hurdle in achieving developmental goals as climate variations will have an impact on food security, migration patterns and political conflicts.

It includes

1. The New Growth Path;

2. A Comprehensive Rural Development Strategy and associated programmes; and

3.The Comprehensive Plan for the development of sustainable human settlements.

It is available online at

http://www.poa.gov.za/news/Documents/NPC%20National%20Development%20Plan%20Vision%202030%20-lo-res.pdf

National Water Resource Strategy 2013.

The NWRS serves to promote sustainable use, manage and control water resources in promoting development in South Africa over a 10 year period. The current NWRS is the second, with the 1st launched in 2004.

It is available online at

https://www.dwa.gov.za/nwrs/LinkClick.aspx?fileticket=ClwWyptzLRk%3D&tabid=91&mid=496

Environmental Protection and Infrastructure Programme

The EPIP aim is the protection of natural assets and conservation of the natural environment. The programme has initiated new methods in the climate change approach with;

I. Working for the coast (WftC).

WftC programme helps deal with challenges experienced in the implementation of the Integrated Coastal Management Act 28 of 2008, by placing greater emphasis on coastal challenges like sedimentation, environmental pollution, distruction of coastal habitats, urbanisation and tourism activities under the vision of

"A healthy and sustainable coastal environment that is equitably maintained and preserved for current and future generations" (https://www.environment.gov.za/projectsprogrammes/workingfor_thecoast)

II. Greening and open space management

The development Restoration and rehabilitation of open spaces which function as sinks and improves climate change adaptation through minimizing biodiversity loss.

III. People and parks

The promotion of local partnerships in the management of parks. The aim of this is to bridge the gap between conservation and communities.

Other EPIP functions fall within the management of land, wildlife and the promotion of skills development in environmental services.

National Framework for Disaster Risk Management 2005.

The framework is geared towards the effective protection of vulnerable communities to natural and anthropogenic risks.

It is available online at

https://www.westerncape.gov.za/text/2013/July/sa-national-disaster-man-framework-2005.pdf

National Strategy for Sustainable Development and Action Plan 2011-2014.

The NSSD promotes sustainable development which places ecosystems and natural resources at the front. Human well-being is hinged on a healthy ecosystem so in order to have a healthy environment ecosystem have to come first.

It is available online at

https://www.environment.gov.za/sites/default/files/docs/sustainabledevelopment_actionplan_strategy.pdf

Provincial Plans and Strategies

Northern Cape Province Growth and Development Plan

The PGDP is a 10year vision for sustainable growth and human development in the province, with set programs which will aid in reaching the "better life for all" target which aims to reduce poverty in the Northern Cape Province.

Northern Cape Provincial Spatial Development Framework

The PSDF is an enabling policy and strategy to ensure that the Northern Cape will remain able to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. It contains the prioritisation of projects within a spatial economic framework that takes due cognisance of environmental realities and the imperative to create a developmental state.

It is available online at http://northerncapepsdf.co.za/wp-content/uploads/Northern_Cape_PSDF_22_August_2012.pdf

Northern Cape Rural Development Strategy

The Northern Cape Province RDS combines 5 strategy papers 1) Reflecting on practice – Lessons from international and South African experiences of rural development, 2) The rural development context in the Northern Cape, 3) Critical success factors for rural development in the Northern Cape, 4) Northern Cape Rural Development Strategy – Activities and Outcomes, and 5) Northern Cape Rural Development Strategy - Institutional Options.

It is available online at

http://www.phuhlisani.com/oid%5Cdownloads%5C20100505NCRDSStrategyPapersV4.1.pdf

District Plans and Strategies

Namakwa District Municipality Integrated Development Plan 2015/2016

IDPs are municipal growth and development plans targeting the provision of basic services by providing direction on land management, municipal budget, institutional transformation and environmental infrastructure related projects at the municipal level.

It is available online at http://www.namakwa-dm.gov.za/wp-content/uploads/2011/08/NDM-Draft-Revised-IDP-Mrt-2015.pdf

Namakwa District Municipality Environmental Management Framework and Strategic Environmental Management Plan 2011

This document is informed by the National Environmental Management Act (NEMA) of 1998 to promote sound environmental management and sustainable land-use practices in the NDM. It provides a picture of the state of the environment and the resources derived from the district for the provision of services in a sustainable manner.

Namakwa Municipality Bioregional Plan 2010

The purpose of this document is to ensure that biodiversity information can be accessed and utilized by local municipalities within the NDM to inform land use planning and development as well as decision making processes within the NDM.

Namakwa Municipality Biodiversity Sector Plan 2008

This product is intended to help guide land-use planning, environmental assessments and authorisations; and, natural resource management in order to promote development which occurs in a sustainable manner. It has been developed to further the awareness of the unique biodiversity in the area, the value this biodiversity represents to people as well as the management mechanisms that can ensure its protection and sustainable utilisation.

It is available online at

http://bgis.sanbi.org/namakwa/Sector_plan.pdf

Town and community level governance

Significant challenges are experienced in the provision of services in more rural municipalities like NDM. The Northern Cape Province is one of the poorest provinces in South Africa and service delivery capacities are low. Fragmented governance structures impact on the provision of services and a lack of coordination leads to duplication of effort in some areas and absence in others. Community based and non-government structures often exist to plug these capacity and delivery gaps and assist with coordination at the local level.

Ward communities, community development initiatives, traditional authorities, non-governmental organisations (NGOs), unions, and many less formal networks form the governance structures at a town and community level.

Ward Committees consist of community members who have been elected to represent the respective areas in a wide range of key areas in the provision of services by the local municipalities. The people who sit in these communities are there as representatives of the communities they come from. At this level of representation there are also government employed community development officers, often members of the local community, who provide a means for local people to participate in local activities and decisions.

Community development initiatives and community-based organisations are community led programs, often small and based on a specific issue or set of issues, which try and help communities.

Non-Governmental Organizations can be of various sizes and have a wide range of focus areas. They are typically donor funded, and work in local areas to promote programmes and projects intended to improve local conditions.

Traditional leaders are the leaders or gate keepers of rural communities. Traditional councils are very similar to the ward committees and traditional leaders are often part or aware of decisions taken at a ward committee level.

As mentioned in the introduction South Africa's Institutional arrangement in environmental governance is considered one of the best in the world, but capacity challenges limit the effectiveness of these institutions at a local level. Greater effort needs to be placed on ensuring an effective and coordinated link between policy, programmes, and the agendas for various actors so that policies and plans reach the ground and are adequately enforced for the good of all.

Annex 2: Water-related Ecological Infrastructure

Methods and Data Sources

Table 1. Rating of the hydrological benefits likely to be provided by a wetland based on its particular hydro-geomorphic type (Kotze et al. 2005).

WETLAND HYDRO-GEOMORPHIC TYPE	HYDROLOGICAL FUNCTIONS POTENTIALLY PERFORMED BY THE WETLAND								
	Flood attenuation		Stream flow augmentation		Erosion control	Enhancement of water quality			
	Early wet season	Late wet season	Early wet season	Late wet season		Sediment trapping	Phos-phates	Nitrates	Toxicants[1]
1. Floodplain	++	+	0	0	++	++	++	+	+
2. Valley bottom – channelled	+	0	0	0	++	+	+	+	+
3. Valley bottom – unchanneled	+	+	+?	+?	++	++	+	+	++
4. Hillslope seepage feeding a stream channel	+	0	+	+	++	0	0	++	++
5. Hillslope seepage not feeding a stream	+	0	0	0	++	0	0	++	+
7. Pan/ Depression	+	+	0	0	0	0	0	+	+

Note: [1]Toxicants are taken to include heavy metals and biocides

Rating:
- 0 Function unlikely to be performed to any significant extent
- \+ Function likely to be present at least to some degree
- ++ Function very likely to be present (and often performed to a high level)

Water production and stream flow augmentation Ecological Infrastructure

The project identified areas important for water production and stream flow regulation using the methods described below and detailed in Table2.

The Proecoserv project (Nel et al 2013) logic used to identify Strategic Water Source Areas was applied to the Alfred Nzo District. However, although in the national context almost all of the catchment is considered to have a high water yield, and falls within the Proecoserv identified Strategic Water Source Areas, this is not helpful when it comes to prioritizing within the catchment.

The top 50th percentile of values (115.5mm/yr runoff) were then buffered by 2km to produce an area which was designated as high water yield.

Various features important for delivering ecosystem services were then identified using the Wet-EcoServices categorization of wetlands and the services provided (Table 1), the National Wetland Inventory, the river data in the National Freshwater Ecosystems Priority Areas project, and rivers in the 1:50 000 topocadastral data. Where possible buffer widths were linked to literature or legislation, but elsewhere these widths were determined using an iterative approach with experts. The features, their classification and their treatment are detailed in Table 2 and summarised here:

- In high water yield areas all areas are considered important to some degree, however all natural wetlands and riparian buffers (which were wider around large rivers and narrower around smaller rivers) were most strongly highlighted. The remaining terrestrial high water yield areas were categorised according to their current condition.

- In lower water yield areas, only wetlands and areas within limited riparian buffers were included (again with narrower buffers for smaller systems and wider buffers for large systems).

- In all areas, wetlands and buffers were include for the specific wetland types which are known to be particularly important for water production and stream flow augmentation.

Scores and categories were determined by overlaying the features and the transformation data. The value at a particular point was determined by the highest value at that point.

Erosion Control

The study also identified areas important for erosion control. These are erosion prone areas which need to be kept intact or rehabilitated. Protecting or improving these areas of Ecological Infrastructure would reduce capacity reduction of storage schemes and reduce water treatment costs. The method (detailed in Table 3) is described below. Erosion prone areas were prioritized.

- Areas with gully erosion were identified from the national gully erosion mapping study by DAFF[28] . All gullied areas were included. Areas identified were cross checked against satellite imagery, which confirmed that the identified areas were both sufficiently accurate and comprehensive.
- Erosion prone areas were defined as sites within 250m of an existing gully. This approach gave a more refined picture of erosion prone areas than other national datasets. The results were checked by evaluating gullies which were missed in the national mapping, with rapid cross checking of imagery suggesting that large portions of these sites were within the 250m buffer of existing erosion sites.
- Wetland types specifically important for erosion control were prioritized. These include channelled valley-bottom wetlands,

[28] Mararakanye N, Le Roux JJ (2012) Gully location mapping at a national scale for South Africa. South African Geographical Journal 94: 208–218

- floodplain wetlands, seeps, unchannelled valley-bottom wetlands and valley head seeps, all with a 100m buffer.
- Riparian buffers were also included, with wider buffers around large rivers and narrow buffers on smaller rivers.

Scores and categories were determined by overlaying the features and the transformation data. The value at a particular point was determined by the highest value at that point, and a composite map was developed.

Water quality

The project identified areas important for enhancement or maintenance of water quality, including areas important for sediment trapping, and reducing levels of phosphates, nitrates and toxicants. Protecting or improving these areas of Ecological Infrastructure would reduce water treatment costs. The method (detailed in Table 4) is described below. Wetlands specifically important for water quality enhancement were prioritized.

- The wetland plus a wide (100m) buffer were used for the wetland types which are most important from a water quality perspective (floodplain wetland, seep, unchannelled valley-bottom wetland, valleyhead seep).
- The wetland plus a narrower 50m buffer included as additional ecological infrastructure for types which play a role in water quality but are not as critical (channelled valley-bottom wetlands and depression and flat pans).
- A two stage buffering of rivers was undertaken:
  - Riparian buffer areas immediately adjacent to key rivers were scored highest (100m on larger rivers).
  - A broader but lower value buffer was then added. A buffer of 250m was used on larger rivers and 32m on all other rivers.

Scores and categories were determined by overlaying the features and the transformation data. The value at a particular point was determined by the highest value at that point, and a composite map was developed.

Flood attenuation

The project identified areas important for flood attenuation e.g. the particular types of wetland which are important for delaying flood peaks and reducing flood intensity. Protecting or improving these areas of Ecological Infrastructure would reduce risk to water supply and other infrastructure during extreme flood events. The method (detailed in Table 5) is described below. Wetlands specifically important for flood attenuation were prioritised.

- The wetland plus a wide (100m) buffer were used for the wetland types which are most important from a flood attenuation perspective (floodplain wetland).
- The wetland plus a narrower 50m buffer were included as additional ecological infrastructure for types which play a secondary role in flood attenuation but are not as critical (channelled valley-bottom wetlands, depression and flat pans, seeps, unchannelled valley-bottom wetlands and valleyhead seeps).
- A single stage buffering of rivers was undertaken and these areas were also included as additional ecological infrastructure:
- A buffer of 250m was used on larger rivers and 100m on smaller perennial rivers.

Scores and categories were determined by overlaying the features and the transformation data. The value at a particular point was determined by the highest value at that point, and a composite map was developed.

Table 2. Methods used to identify key areas of Ecological Infrastructure important for water production and stream flow augmentation.

			Ecological Infrastructure: Intact areas for protection (i.e. Areas that are in good condition)	Potential Ecological Infrastructure: Areas for rehabilitation (i.e. Areas that are in poor condition)	Transformed Ecological Infrastructure (i.e. Areas where value has been lost, but there may be opportunities to reduce negative impacts)
Water production & stream flow augmentation					
In high yield areas (over 115mm runoff)	Rivers	Riparian buffers (100m minimum; 500m larger rivers)	2	2	1
	Terrestrial areas	All natural habitat types (as per landcover)	1		
		Degraded areas (as per landcover)		1	
		Transformed areas (as per landcover)			1
	Wetlands	All natural wetlands	2	2	1
In lower yield areas (under 115mm runoff)	Rivers	Riparian buffers (32m minimum; 500m larger rivers)	2	2	1
	Wetlands	All natural wetlands	2	2	1
All areas	Additional buffers on wetlands specifically important for water production & stream flow	Unchannelled valley-bottom wetland with 50m buffer	1	1	1
		Valleyhead seep with 50m buffer	1	1	1

Values:
2 = Key ecological infrastructure; 1 = Other Ecological Infrastructure

Table 3. Methods used to identify key areas of Ecological Infrastructure important for erosion control.

			Ecological Infrastructure: Intact areas for protection (i.e. Areas that are in good condition)	Potential Ecological Infrastructure: Areas for rehabilitation (i.e. Areas that are in poor condition)	Transformed Ecological Infrastructure (i.e. Areas where value has been lost, but there may be opportunities to reduce negative impacts)
Erosion control					
Wetlands	Wetlands specifically important for erosion control	Channelled valley-bottom wetland with 100m buffer	2	2	1
		Floodplain wetland with 100m buffer	2	2	1
		Seep with 100m buffer	2	2	1
		Unchannelled valley-bottom wetland with 100m buffer	2	2	1
		Valleyhead seep with 100m buffer	2	2	1
Erosion prone areas which need to be kept intact or rehabilitated	Terrestrial areas	Areas with existing erosion gulllies	2	2	1
		Areas within 250m of existing gullies	1	1	1
Rivers	Rivers	Riparian buffers (32m minimum; 100m larger rivers)	2	2	1

Values:
2 = Key ecological infrastructure; 1 = Other Ecological Infrastructure

Table 4. Methods used to identify key areas of Ecological Infrastructure important for water quality.

			Ecological Infrastructure: Intact areas for protection (i.e. Areas that are in good condition)	Potential Ecological Infrastructure: Areas for rehabilitation (i.e. Areas that are in poor condition)	Transformed Ecological Infrastructure (i.e. Areas where value has been lost, but there may be opportunities to reduce negative impacts)
Flood attenuation					
Rivers	Rivers	Riparian buffers (250m on larger rivers, 100m on smaller but perennial rivers)	1	1	1
Wetlands	Wetlands specifically important for flood attenuation	Channelled valley-bottom wetland with 50m buffer	1	1	1
		Floodplain wetland with 100m buffer	2	2	1
		Pans (Depression & flat) with 50m buffer	1	1	1
		Seep with 50m buffer	1	1	1
		Unchannelled valley-bottom wetland with 50m buffer	1	1	1
		Valleyhead seep with 50m buffer	1	1	1

Values:
2 = Key ecological infrastructure; 1 = Other Ecological Infrastructure

Table 5. Methods used to identify key areas of Ecological Infrastructure important for flood attenuation.

			Ecological Infrastructure: Intact areas for protection (i.e. Areas that are in good condition)	Potential Ecological Infrastructure: Areas for rehabilitation (i.e. Areas that are in poor condition)	Transformed Ecological Infrastructure (i.e. Areas where value has been lost, but there may be opportunities to reduce negative impacts)
Flood attenuation					
Rivers	Rivers	Riparian buffers (250m on larger rivers, 100m on smaller but perennial rivers)	1	1	1
Wetlands	Wetlands specifically important for flood attenuation	Channelled valley-bottom wetland with 50m buffer	1	1	1
		Floodplain wetland with 100m buffer	2	2	1
		Pans (Depression & flat) with 50m buffer	1	1	1
		Seep with 50m buffer	1	1	1
		Unchannelled valley-bottom wetland with 50m buffer	1	1	1
		Valleyhead seep with 50m buffer	1	1	1

Values:
2 = Key ecological infrastructure; 1 = Other Ecological Infrastructure

Annex 3: Biodiversity priorities

Methods and data sources

Independent of climate change, there are a range of key biodiversity assets and priority areas which underpin all ecosystem services across the district. As an intact and functional landscape is critical to supporting society as a whole, we have identified a set of overall spatial biodiversity priorities for inclusion into the integrated analysis. The analysis focused on the key question: Which areas are important for other biodiversity reasons?

Aquatic prioritisation

Excellent and up to date data produced by the National Biodiversity Assessment, National Estuary Biodiversity Plan and the National Freshwater Ecosystem Priority Areas project (NFEPA) exist on non-marine aquatic priority areas in South Africa[29]. The current assessment brings these analyses together into a single integrated layer of aquatic priorities.

Conceptually we have divided the aquatic features into three groups:

- *The aquatic feature* (actual river, wetland or estuary). The individual features from the underlying analyses were scored according to their priority level. Prioritized rivers had a range of scores according to their category (FEPA rivers = 10, Phase2FEPA=4, Fish Support Area and FishCorrid=3 and Upstream Management Areas=2); Wetland (priority FEPA wetlands = 10, Other wetlands =1); Estuaries were prioritized according to the desired protection level in the plan (Estuaries which had been selected for either full or partial protection were scored as 10, others were scored 1).
- *The immediate buffer* (river buffer, estuary buffer, or wetland buffer). Priority rivers, wetlands and estuaries were all buffered by 1km, with the buffer allocated a value of 5.
- *The catchment* (FEPA river catchment or wetland cluster). Priority catchments identified in the NFEPA project were scored using the values described in the aquatic feature section. Priority wetland clusters from NFEPA were given a score of 10.

A composite layer of all aquatic features was developed by identifying the maximum value from input layers. Cell statistics were used to identify maximum value from individual input layers. Transformed and degraded areas were removed to show the combined aquatic features value of remaining intact areas.

Critical Biodiversity Areas and equivalent priorities from the provincial conservation plan

The Namakwa District Biodiversity Sector Plan[30] (including the Critical Biodiversity Area Map) which is intended to help guide land-use planning, environmental assessments and authorisations; and, natural resource management in order to promote sustainable development remains a key input into spatial prioritization in the district. The layer was scored as follows:

- **Protected Areas**: An updated Protected Area layer was used. All areas were given a score of 10.
- **Critical Biodiversity Areas One**: All intact areas were given a score of 10.

[29] Nel, J.L., Driver, A. & Swartz, E.R. 2012. National Biodiversity Assessment 2011: Technical Report. Volume 2: Freshwater Component. CSIR Report Number CSIR/NRE/ECO/IR/2012/0022/A. Council for Scientific and Industrial Research, Stellenbosch.
Nel, J.L., Driver, A., Strydom, W.F., Maherry, A., Petersen, C., Hill, L., Roux, D.J., Nienaber, S., Van Deventer, H., Swartz, S. & Smith-Adao, L.B. 2011. Atlas of Freshwater Ecosystem Priority Areas in South Africa. WRC Report No. TT 500/11. Water Research Commission, Pretoria."
Turpie, J.K., Wilson, G. & Van Niekerk, L. 2012. National Biodiversity Assessment 2011: National Estuary Biodiversity Plan for South Africa. Anchor Environmental Consulting, Cape Town. Report produced for the Council for Scientific and Industrial Research and the South African National Biodiversity Institute.

[30] Available at http://bgis.sanbi.org/namakwa/project.asp

- **Critical Biodiversity Areas Two**: All intact areas were given a score of 5.
- **Ecological Support Areas**: All intact areas were given a score of 2.

A composite layer was developed by identifying the maximum value from input layers. Transformed and degraded areas were removed to show the value of remaining intact Critical Biodiversity.

Protected Area Expansion Priorities

National[31] protected area expansion priorities were used as no finer scale provincial protected area expansion areas have been identified yet. These areas were given a score of 10.

Overall integration

The individual input layers were integrated into a single layer with a range of 0-100 using an a weighted approach, with the CBA layer contributing 70%, the aquatic layer 20% and the protected area expansion priorities layer 10%.

[31] Holness, S., 2008. Focus areas identified in the National Protected Area Expansion Strategy conservation assessment.

Annex 4: Landscape Features Supporting Climate Change Resilience

Methods and Data Sources

Coastal Corridor: A coastal process and corridor layer was developed. It includes areas that comply with the legal definitions in the National Environmental Management: Integrated Coastal Management Act - a minimum of a 1km buffer inland of coastal features and landtypes associated with coastal geomorphological processes, especially sand dunes, and also coastal vegetation units as defined in the South African vegetation map.

Riparian corridors and buffers: Corridors provide critical ecological linkages between large core patches of intact habitat through hostile matrix areas of heavily modified habitat. Corridors are seen to be critical for the movement of a variety of animal species in the short term (pollinators, predators) from source to sink areas, to provide for genetic interchange between spatially separate populations of animals in the medium term, and in the long term are hoped to be important for the migration of plant and other species under conditions of global climate change. One of the most clearly defined corridors, especially in heavily modified arable agricultural landscapes, are those associated with rivers. Importantly, the river associated movement corridors also provide upland-lowland linkages on the landscape scale. A corridor layer was created based on the 2nd order and larger rivers and a cost surface derived from a transformation and fragmentation layer. A total corridor width of approximately 1km was aimed for in completely transformed landscapes, and 10km in completely natural areas, with the corridors varying in width in response to the level and pattern of transformation.

Areas with important temperature, rainfall and altitudinal gradients: Maintaining these areas is important in order to allow species and ecosystems to rapidly adapt to changing climate, as they represent the shortest routes for the species which make up ecosystems to move along upland-lowland and climatic gradients in order to remain within acceptable climate envelopes. These areas are particularly important for species which are not able to move rapidly in response to climate change. These areas also have high levels of climate and landscape heterogeneity, and hence are likely to contain a range of important micro-climates which may act as local refugia for those species that otherwise may not be able to adapt to rapid environmental change. A series of topographic and climatic indices were combined in the preparation of this layer.

- *Altitudinal heterogeneity*: A 90m resolution digital elevation model was examined at a 0.01 degree or just over 1 km squared resolution. Altitudinal differences were calculated based on the maximum and minimum altitudes found within a roving 7x7 grid (i.e. approximately 49km2 area). The output was divided into 8 quantiles with the top category considered to be the areas best representing high altitude gradient areas. This quantile corresponded to areas with greater than 340m of altitude variation within the 49km2 area.

- *Precipitation gradients*: Precipitation data from the Agricultural Research Council was examined at a 0.01 degree or just over 1 km squared resolution. Precipitation gradients were calculated based on the maximum and minimum values found within a roving 7x7 grid (i.e. approximately 49km2 area). The output was divided into 8 quantiles with the top category considered to be the areas best representing high precipitation gradient areas. This quantile corresponded to areas with greater than 235mm of precipitation variation within the 49km2 area.
- *Temperature gradients*: Temperature data from Agricultural Research Council was examined at a 0.01 degree or just over 1 km squared resolution. Temperature gradients were calculated based on the maximum and minimum values found within a roving 7x7 grid (i.e. approximately 49km2 area). Areas with over 4°C difference in average temperature within a 49km2 area, were classified as areas with high temperature gradients.

These three layers were combined to provide a summary map of all areas with high climate and landscape heterogeneity and gradients.

Areas with high biotic diversity: These are areas where relatively high numbers of biomes, vegetation groups or vegetation types occur in close proximity . They contain an extremely diverse set of habitats, landscapes and microclimates, and represent areas that are likely to be very important for supporting biodiversity adaptation capacity. These areas have high levels of floristic diversity and are likely to represent areas of high levels of speciation. Areas with high levels of biodiversity heterogeneity were identified using the South African Vegetation Map at three scales: biome, vegetation group and vegetation type. The number of biomes, groups or types was calculated for each 49km2 area. Areas were considered to have high habitat heterogeneity if they contained three or more biomes, three or more vegetation groups, or four or more vegetation types.

- *Biome heterogeneity*: The South African Vegetation Map was converted to a 0.01 degree or just over 1 km2 resolution raster layer in Idrisi. The number of biomes found within a roving 7x7 grid (i.e. approximately 49km2 area) was calculated. Various other methods (such as other relative richness indices, and varying in pixel size and search radius) were also explored, but this simple method gave a robust clearly understandable answer. Areas were considered to have high diversity at the biome level if 3 or more biomes were found within the 49km2 area.
- *Vegetation group heterogeneity*: Similar to the biome heterogeneity calculation, the vegetation map was converted to a 0.01 degree raster layer, and the number of vegetation groups found within a roving 7x7 grid (i.e. approximately 49km2 area) was calculated. Areas were considered to have high diversity at the bioregion level if 3 or more bioregions were found within the 49km2 area. Note that this will inevitably include the areas identified in the biome heterogeneity assessment, in addition to extra areas.

- *Vegetation type heterogeneity*: As for the above calculations, the vegetation map was converted to a raster, and the number of vegetation types found within a roving 7x7 grid (i.e. approximately 49km2 area) was calculated. Areas were considered to have high diversity at the bioregion level if 4 or more vegetation types were found within the 49km2 area.

These three layers were combined to provide a summary map of all areas with high habitat heterogeneity.

Centres of floral endemism: Southern Africa has extremely high levels of floristic diversity and endemism, with more than 10% of vascular plant species (over 30 000 species) found in 2.5% of the world's surface area. 60% of these species are endemic to the region. Most of these endemic species are concentrated in a few relatively small and clearly defined centres of endemism. At a national scale these centres represent i.) an area of concentrated unique biodiversity pattern (i.e. there are concentrations of endemic plant species here which are not found elsewhere), ii.) areas with a particular combination of ecological processes that have resulted in high levels of biodiversity and endemism developing, and iii.) the characteristics which allow these high levels of diversity to persist, as these are areas where species have survived previous eras of climate change, and hence are likely to be very important for supporting biodiversity adaptation capacity. The floristic centres of endemism summarised in Regions of Floristic Endemism in Southern Africa were clipped to remaining extent of natural habitat (transformed, degraded and fragmented areas were excluded from the dataset).

Local refugia- south-facing slopes and kloofs: Refuge sites include south-facing slopes and kloofs. These sites tend to be wetter and cooler that the surrounding landscape, and represent key shorter term refugia which allow species to persist in landscapes.

- *South facing slopes*: A 90m digital elevation model was used as the basis for identifying south facing slopes. Standard Idrisi modules were used to identify all areas with a southerly aspect, which was defined as having an aspect of between 135° and 235°. Slope angles were then calculated to identify all steeper slopes (i.e. those area where aspect is likely to play an important role in solar inputs), which were defined as all slopes steeper than 10°. These layers were combined to get a subset of steep south facing slopes; this layer was converted to a vector layer and all areas under 25ha were removed; and the layer was reconverted to a raster layer.
- *Kloofs*: The identification of kloofs/gorges at a landscape scale requires some assumptions to be made about what a kloof is. For the purposes of this analysis, kloofs are seen as areas with steep slopes in close proximity to rivers. The 90m digital elevation model used in previous analyses was again used as the basis for identifying steep slopes, which for this analysis were defined as being steeper than 15° (this value is deliberately higher than that used for the south facing slope calculation), using standard modules of Idrisi. River lines were converted to a raster layer with the same resolution as the 90m DEM, on the basis that any

pixel that overlapped with a river line was classified as river and given a numerical value. A maximum filter was then run in Idrisi using a 7x7 roving window to identify all pixels which were within a maximum of 7 pixels (x or y distance) away from a river pixel. These areas were defined as being river proximity pixels, and were intersected with the steep slopes raster layer to give the subset of areas with steep slopes in close proximity to rivers. This was converted to a vector layer and all areas under 25ha were removed; and the layer was reconverted to a raster layer.

The local refugia mapwas derived by spatially combining the south-facing slopes and kloofs layers.

Priority large unfragmented landscapes: These include existing protected areas as well as large areas identified in the National Protected Area Expansion Strategy as priorities for protected area expansion to meet biodiversity targets for terrestrial and freshwater ecosystems. The ecological processes which support climate change adaptation are more likely to remain functional in unfragmented landscapes than in fragmented ones.

- *Protected areas*: Formal protected areas, which include National Parks, provincial Nature Reserves, proclaimed Mountain Catchment Areas and local authority Nature Reserves, were included. Representation of species, ecosystems and ecological processes in an ecologically robust protected area network is widely recognized as one of the most effective adaptation strategies for responding to climate change. Intact natural habitats found in protected areas are likely to play an important role in supporting landscape scale resilience to climate change through acting as refuge areas for ecosystems and species which are likely to be under more pressure in production landscapes, in supporting the ecological processes required for long term adaptation to climate change, and in the provision of key ecosystem services. Although not all protected areas will have the same importance, even small reserves will be important for supporting local scale adaptation. In addition, the layer of priority large unfragmented landscapes (see below) is incomplete if considered without the existing protected areas.
- *Priority large unfragmented landscapes*: The spatial assessment of the National Protected Area Expansion Strategy used a systematic conservation planning process to identify focus areas for land-based protected area expansion which are large, intact and unfragmented areas of high importance for biodiversity representation and ecological persistence, suitable for the creation or expansion of large protected areas. They present the best opportunities for meeting the ecosystem-specific protected area targets set in the NPAES, and were designed with strong emphasis on climate change resilience, supporting ecological processes and the requirements for freshwater ecosystems. Although these areas were identified from a large formal protected areas expansion perspective, and therefore do not

sufficiently address all conservation priorities (e.g. threatened species and habitats in highly fragmented landscapes such as the Chrissiesmeer area are poorly incorporated), they nevertheless represent the best examples of intact landscapes with functioning ecological processes which are likely to play a significant role in long term climate change adaptation.

The priority unfragmented areas map was derived by spatially combining the existing protected areas with the priority large unfragmented landscapes layer.

Areas supporting resilience: Coastal Corridor, Riparian corridors and buffers and areas with important temperature, rainfall and altitudinal gradients and biotic diversity play a big role in supporting resilience. Maintaining these areas is important in order to allow species and ecosystems to rapidly adapt to changing climate, as they represent the shortest routes for the species which make up ecosystems to move along upland-lowland and climatic gradients in order to remain within acceptable climate envelopes.

These areas are particularly important for species which are not able to move rapidly in response to climate change. These areas also have high levels of climate and landscape heterogeneity, and hence are likely to contain a range of important micro-climates which may act as local refugia for those species that otherwise may not be able to adapt to rapid environmental change.

All of the above separate natural features contributing to climate change resilience were combined into a single composite map.

Combination and refinement process:

A base raster file was constructed with a resolution of 0.00083333333DD (i.e. 3 arc seconds or 90m). Where necessary (and this was avoided for many layers by utilizing an identical base raster layer in the underlying analyses) input layers were reclassified and resampled to the extent of the base layer, so that the extent and resolution of all input layers were identical. A cumulative total area approach was used to summarize each resilience theme (e.g. areas with important temperature, rainfall and altitudinal gradients were summarized by combining all the areas identified as important in the underlying analyses, and all areas identified would have the same value whether they include only a steep temperature gradient or whether they had steep gradients for more than one variable).

Areas important for each resilience theme were then given an equal numerical value. An unmodified value representing the value of a particular area for supporting climate change resilience was then calculated by adding the individual resilience theme scores. Crucially, these areas can support resilience to climate change only if they remain in a natural or near-natural state. For this reason areas where natural habitat has already been irreversibly lost were removed from the analysis, and degraded and fragmented areas were reduced in value by half. The result was the final Areas important for supporting climate change resilience map.

Annex 5: Socio-economic Vulnerability Index

Methods and data sources

Overall prioritization method

The social demand analysis developed three key initial summary indices:

- Population densities and location – this examined where households are located within the district.
- General Poverty Index – based on proportions of households which meet specific poverty criteria. The General Poverty Index was made up of four components, namely an index based on the proportions of low income households, a dependency ratio, an access to services measure of poverty, and a consumption measure of poverty.
- Specific environmental dependency index – this focussed on groundwater dependency and communal grazing.

These three initial summary indices were combined to produce a single social demand index. Finally, the areas of high demand were combined with the landcover maps to identify the natural and semi-natural areas in these high demand areas. These are the areas which need to be most carefully managed to ensure the ongoing supply of good quality environmental goods and services.

Population densities and location

In an area as sparsely populated as Namakwa District (with approximately 105 000 people in an area the size of Limpopo which has a population of 5.6 million people), one of the primary determinants of social demand is the location and density of the population. Unfortunately available census data are only useful for the towns as, very large rural areas are lumped together as single units. Therefore, an indicator of population density was developed using the following method:

- The Eskom database on buildings was used at the starting point. This indicated that Namakwa District contained 41 092 buildings.
- The analysis assumed that the population of 105 721 people was evenly distributed across the buildings (i.e. 2.572 people per building).
- The number of buildings (and hence people) were summarized within a 5km by 5km grid.
- The population of a grid was then allocated to the centre point of the grid.
- An inverse distance weighted approach was then used to identify regions of higher population density. Values for a site were based on the values for the 50 closest points with points close to a site carrying a heavier weight that distant points.
- The resulting raster layer was then reclassified into 10 quantiles, from areas of lowest density to areas of highest density.
- These values were then given a scoring from 1 (lowest density) to 10 (highest density).

A final map of relative population density was created

General Poverty Index

A General Poverty Index was developed for Namakwa District. It is made up of four components:

***The proportion of low income households*.**

Household income was derived from the Census 2011 data for the Namakwa District. We attempted use the Census data to identify households which were living on the equivalent of one government grant or less per year. Unfortunately, as the Census divides incomes into specific categories which do not coincide with values such as a nationally defined poverty line or a government grant, we had to use the nearest category division to identify the lowest income households. Households were considered to be low income if they had a combined income of under R9600/year or had with no income at all. The data were further processed using the following approach:

- The base value was converted to an index in order to provide identify areas of relative high and low proportions of low income households. The index approach was used to identify areas of relative high and low values, allow the different measures to be combined, and to deal with some statistical issues such as the skewed sample data (i.e. where there are a few very high values in the dataset).

- We used the following formula to calculate values: $10*(n/n_{90})$, where n is the individual value for a unit, and n_{90} is the value for the 90th percentile of that value for communities in Namakwa District[32]. Any resultant values over 10 were reclassified as 10.

- This approach gives an index from 0 (lowest proportion of low income households) to 10 (highest proportion of low income households).

A map of the proportion of low income households was created.

[32] For the proportion of low income households calculations n_{90} was 35.25 for communities of Namakwa District.

A dependency ratio

This examined the ratio of people who are employed to those who are not. For each sub-place, the total shows the ratio of people who are employed to people who are unemployed, discouraged work-seekers, not economically active or under 15. It attempts to identify areas where there are very high dependency levels. The data are displayed as a ratio of employed people per hundred. This data was further processed using the following approach:

- (100 – (Ratio employed/100))/10. The formula gives a value between 0 (areas with lowest dependency levels) and 10 (areas with highest dependency levels).

- The standard formula and method described for proportion of low income households was used to develop the index[33].

- This approach gives an index from 0 (lowest dependency ratio) to 10 (highest dependency ratio).

A map of the dependency ratio index was created.

Access to services

Specifically this looked at proportions of households without sufficient access to electricity, decent sanitation, water supplies and refuse collection. Level of access to services provides an additional measure of poverty. We defined reasonable access to services as the following:

- For access to electricity, we examined whether households were using electricity for lighting. In many cases, even though electricity is theoretically available for cooking and heating it may be too

[33] For the dependency ratio calculations n90 was 86.63% for communities of Namakwa District.

expensive to be used on these energy intensive tasks. However, use of electricity for lighting is far more widespread and provides a good indication of whether electricity access is available.

- We defined decent access to sanitation as having a flushing toilet (either linked to a sewage system or a septic tank), a chemical toilet or a ventilated pit toilet. Insufficient access was defined as a standard pit toilet (i.e. not ventilated), a bucket system or no toilet at all.
- We defined decent access to water as having access to piped water either in one's house, in the yard or within 200m. Anything further than that, or where there is no access to piped water, was defined at insufficient access to water.
- We defined reasonable access to refuse collection as having refuse removed by a local authority or private company (at any frequency). Any other arrangement was seen as being insufficient.

A ratio of sufficient access to each individual service was calculated (ranging from 1 = full access to 0 = no access). Poverty of access to a specific service was then calculated by subtracting the value from 1. Finally, poverty of access to the four components were summarised adding the individual scores. This gave a score between 0 and 4, with the highest scores being in areas with no access to services. This value was then processed as follows:

- The standard formula and method described for proportion of low income households was used to calculate values in order to benchmark the levels of access to services (measured as a proportion with decent access) by a particular community against the levels found across Namakwa District[34].
- This approach gives an index from 0 (highest levels of access to services) to 10 (lowest levels of access to services).

A map of the lack of access to services index was created.

Consumption

This involved examining levels of ownership of various goods as a proxy for poverty. As reported household income often gives a poor reflection of actual household income, we developed an additional indicator of poverty based on the ownership of goods as reflected in the Census 2011 data for the Namakwa District. The index of poverty as measured by the lack of ownership of all goods (i.e. car, cell phone, computer, DVD player, refrigerator, radio, satellite television, electric/gas stove, television, vacuum cleaner and washing machine) was derived as follows:

- The ownership of all types of goods recorded in the census was summarized for our planning units.
- We then added up everything owned by a household and divided this by the maximum possible levels of goods ownership (i.e. the sum of items owned and items not owned). This gave an ownership ratio, which we then subtracted from 1 to give a lack of ownership ratio.
- The standard formula and method described for proportion of low income households was used to calculate values in order to

[34] For the lack of access to services calculations n90 was 1.760 for communities of Namakwa District.

benchmark the levels of ownership of goods by a particular community against the levels found in the district[35].

- This approach gives an index from 0 (highest levels of consumption) to 10 (lowest levels of consumption). Note that as level of consumption is being used as a proxy for poverty, the highest value of the index identify communities with the least goods.

A map of the consumption index was created.

***General Poverty Index*.**

Finally, a General Poverty Index was calculated using an equal weighted average of the four indices discussed above. This gives an overall picture of which areas have the highest dependency ratio which examined the ratio of people who are employed to those who are not, the highest proportion of low income households, the highest levels of the consumption based measure of poverty (examining levels of ownership of various goods as a proxy for poverty), and the highest level of poverty of access to services (specifically looking at access to electricity, decent sanitation, water supplies and refuse collection).

A General Poverty Index map was created.

Specific environmental dependency index

In addition to the General Poverty Index, we examined specific areas where households are directly dependent on the environment. For Namakwa District, this focussed on the core issues groundwater dependency and communal grazing.

[35] For the consumption index calculations n90 was 0.678 for communities of Namakwa District.

***Groundwater Dependency*.**

As before, we made use of collected in Census 2011data collated by StatsSA at a “small-place” level as the basis for the analysis. We examined the portions of people who were dependent on groundwater (including springs) for their water supply. Although the Census 2011 data does indicate where specific households are dependent on springs or boreholes, all houses receiving water from a regional scheme are considered to be a single category whether or not that water originates from a dam, river or municipal borehole. Therefore, an area of towns supplied by Orange River water was designated (Amanda Bourne, pers. comm.). Outside of the towns receiving river water, all households that were identified as water scheme supplied in the census data, were designated as ground water scheme supplied. We then calculated the proportions of households that were groundwater dependent. However, an issue remained where large sparse rural areas (where households are very likely to be groundwater dependent), were in a single unit with an overall low level of groundwater dependence. Therefore a manual mapping process was undertaken based on the assumption that (where the actual source was not known) that households near rivers and water supplied towns were the ones most likely to be supplied by river water (whether it is directly via a scheme or via a tanker). This manual mapping process was done to define three categories:

- Highly groundwater dependent areas. These areas were all areas south of the river water supplied towns, as well as rural areas away from perennial rivers where there was no other possible water source apart from groundwater. These areas were given a score of 10.

- Partially groundwater dependent areas. These areas were the scheme supplied areas of Port Nolloth and Komaggas which have both groundwater and river water schemes. These areas were given as core of 5.

- Non-groundwater dependent areas. The Orange River supplies water to all the towns along the Orange River itself (which have their own pump stations), some of the little rural Richtersveld towns, (Kuboes, Lekkersing) which also draw water on their own small pipelines, and the Nama Khoi towns on the bulk water supply system - Springbok and surrounds, Bulletrap and Steinkopf and Kleinsee. These areas were given a score of 0.

A map of groundwater dependency was created.

***Communal Grazing*.**

Communal grazing areas represent a primary resource for poor Namakwa communities. These grazing resources are central to community economic livelihoods of the region and the way of life of people in these areas. Further, this resource is at great risk under great risk of climate change related impacts. Hence these areas are also a focus for implementation activities by CSA. We scored commonage areas as 10 and other areas as 0.

A communal grazing areas map was created.

Finally, a Specific environmental dependency index was calculated through an equal weighted summary of the values from the values for Groundwater Dependency and Communal Grazing. A map of this was not created as the two individual components are more informative shown on their own.

Overall integration method

As explained in the previous sections, the social demand analysis developed three key initial summary indices:

- Population densities and location examines where households are located within the district.

- General Poverty Index is based on proportions of households which meet specific poverty criteria. The General Poverty Index was made up of four components, namely an index based on the proportions of low income households, a dependency ratio, an access to services measure of poverty, and a consumption measure of poverty.

- Specific environmental dependency index which focussed on groundwater dependency and communal grazing.

These three initial summary indices were combined to produce a single social demand index.

A map of the social demand index was created.

Annex 6: Maps

Temperature and rainfall maps

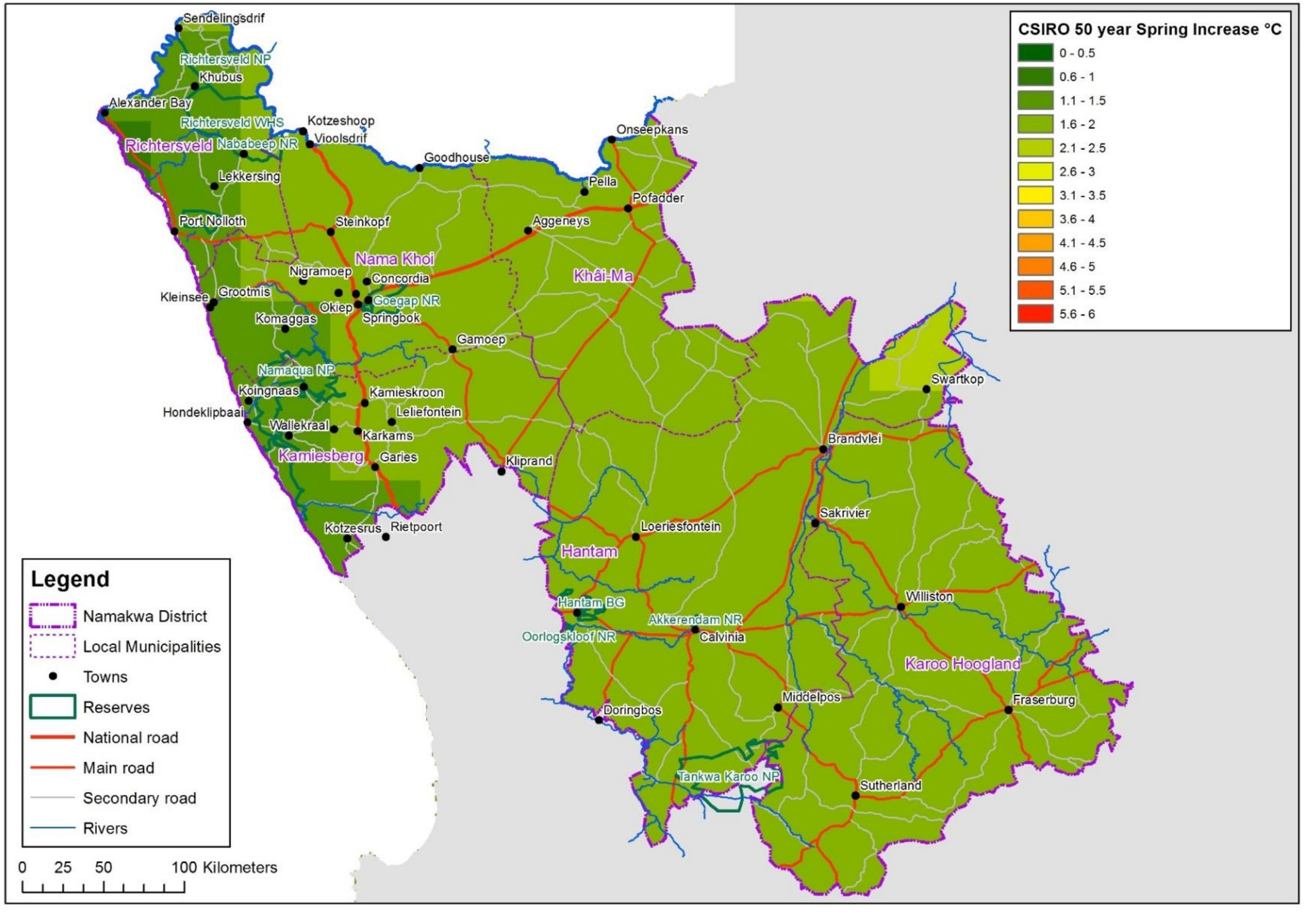

FIGURE 34: SPRING TEMPERATURE INCREASES FOR NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

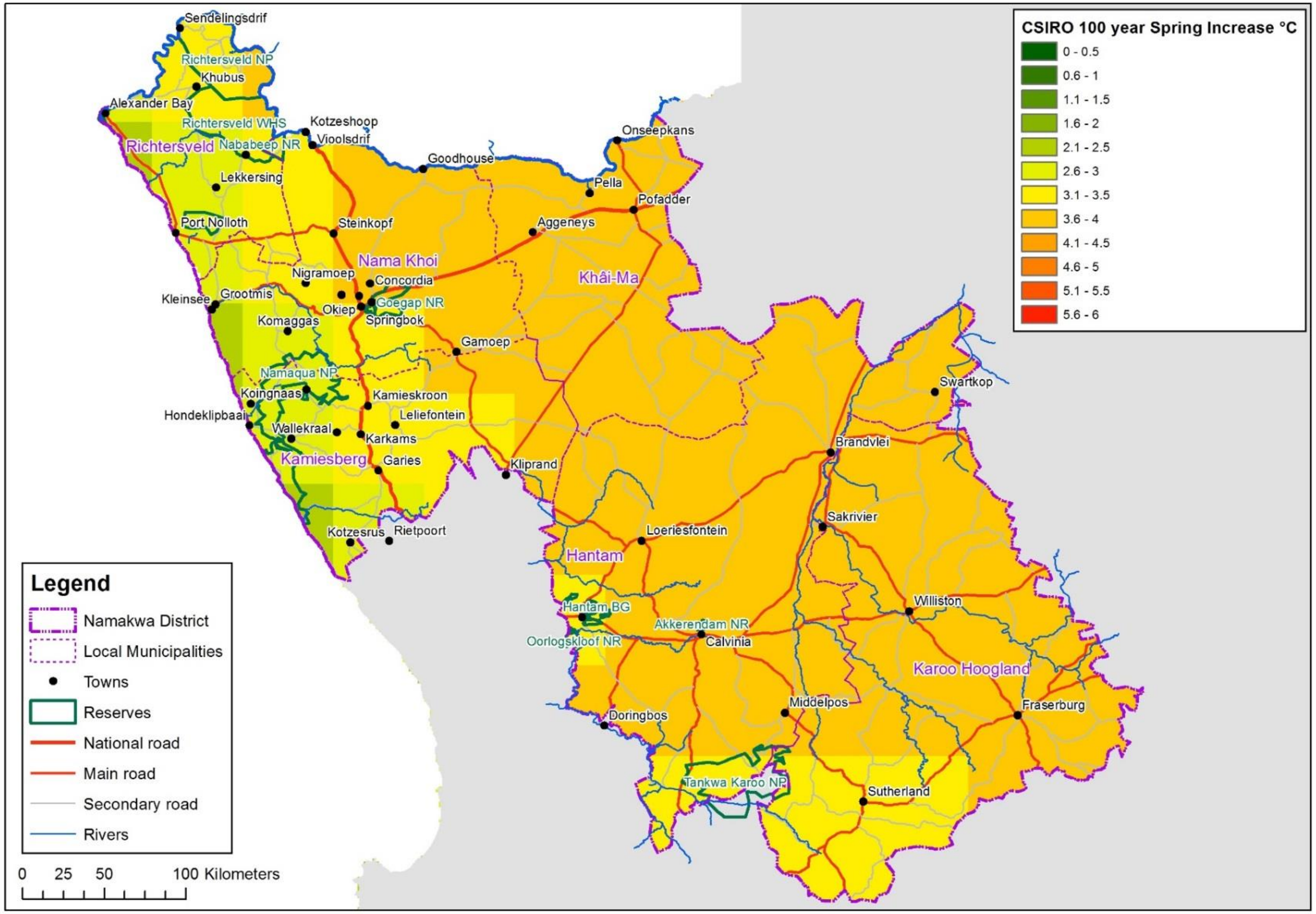

FIGURE 35: SPRING TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

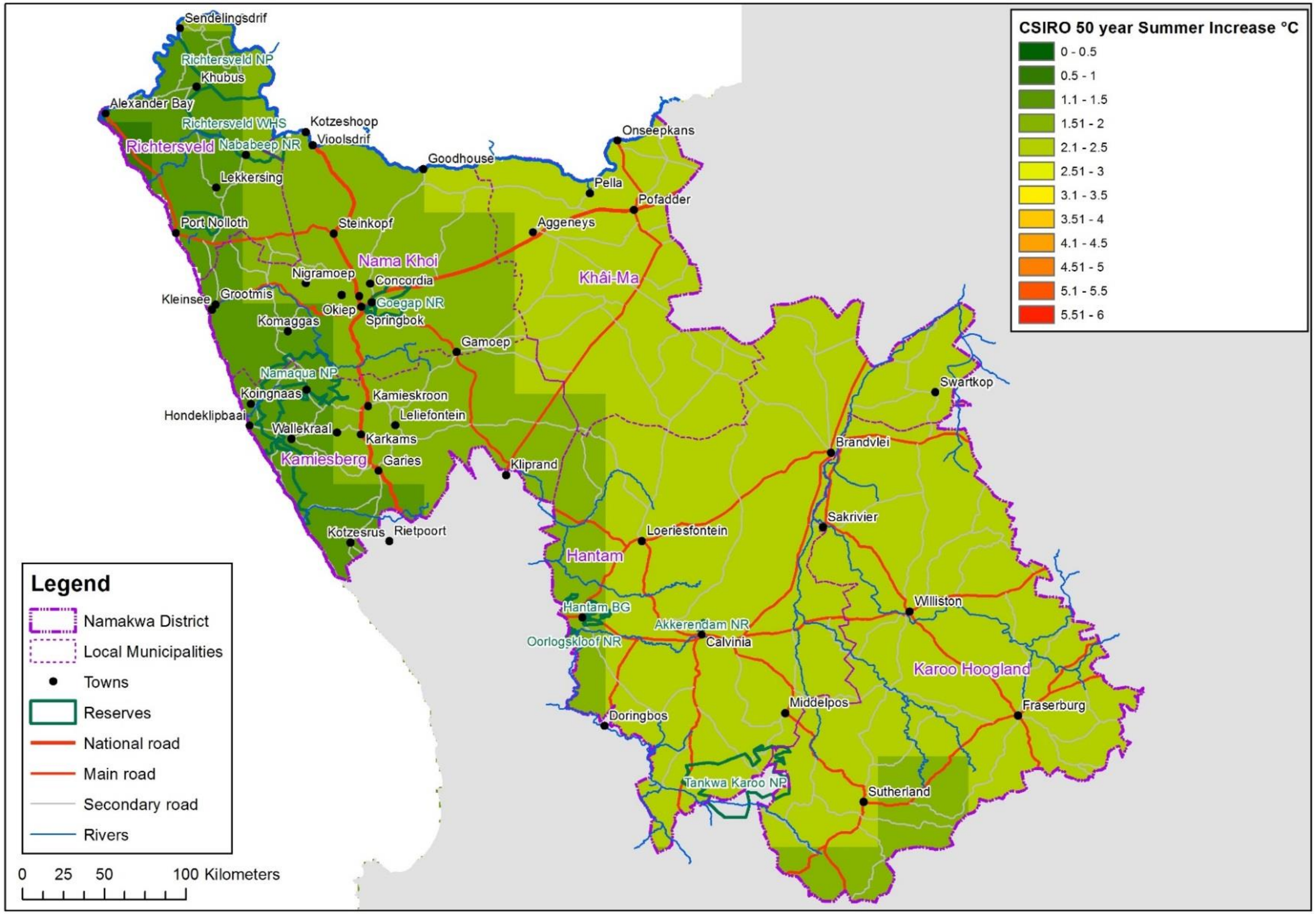

FIGURE 36: SUMMER TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

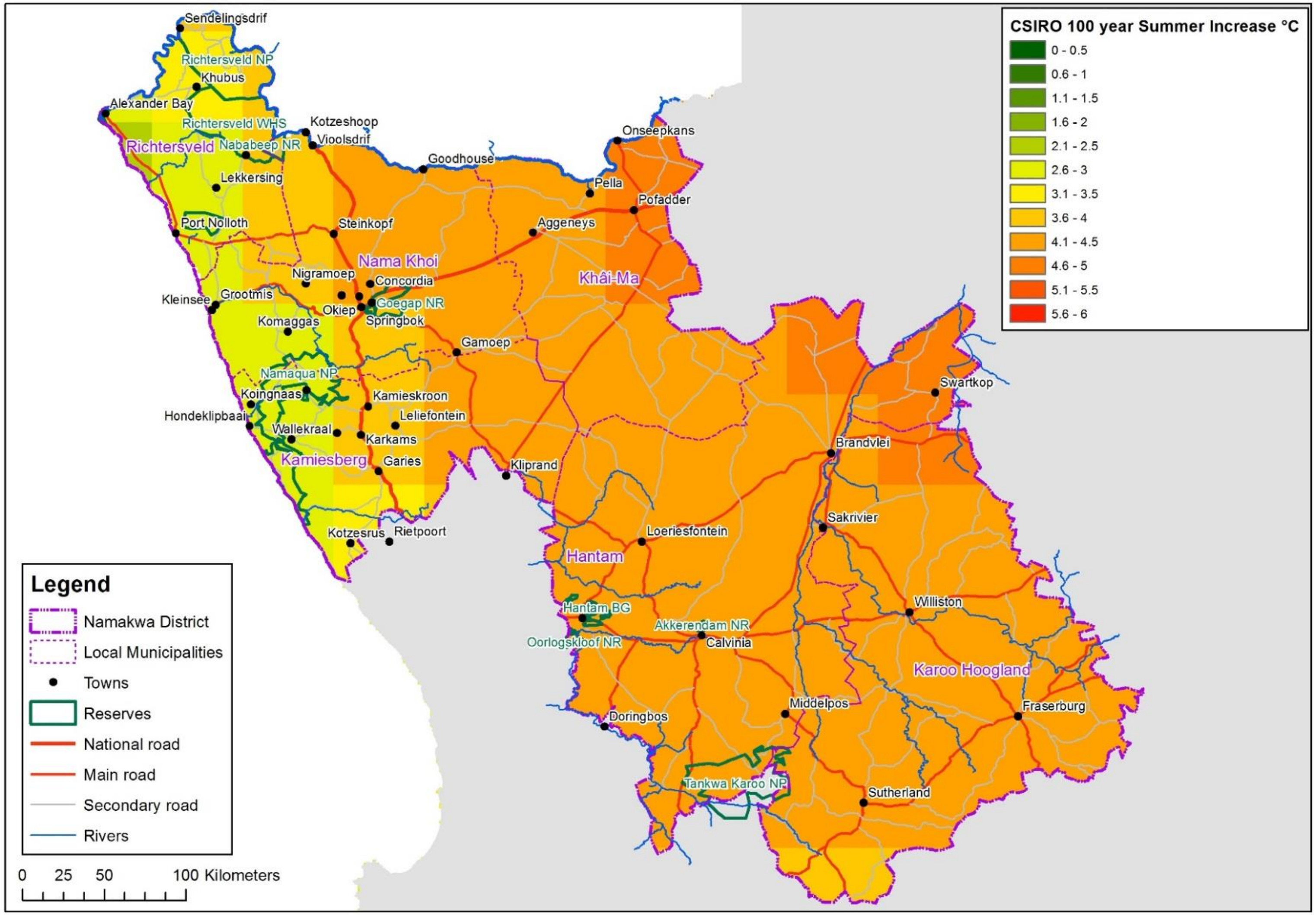

FIGURE 37: SUMMER TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

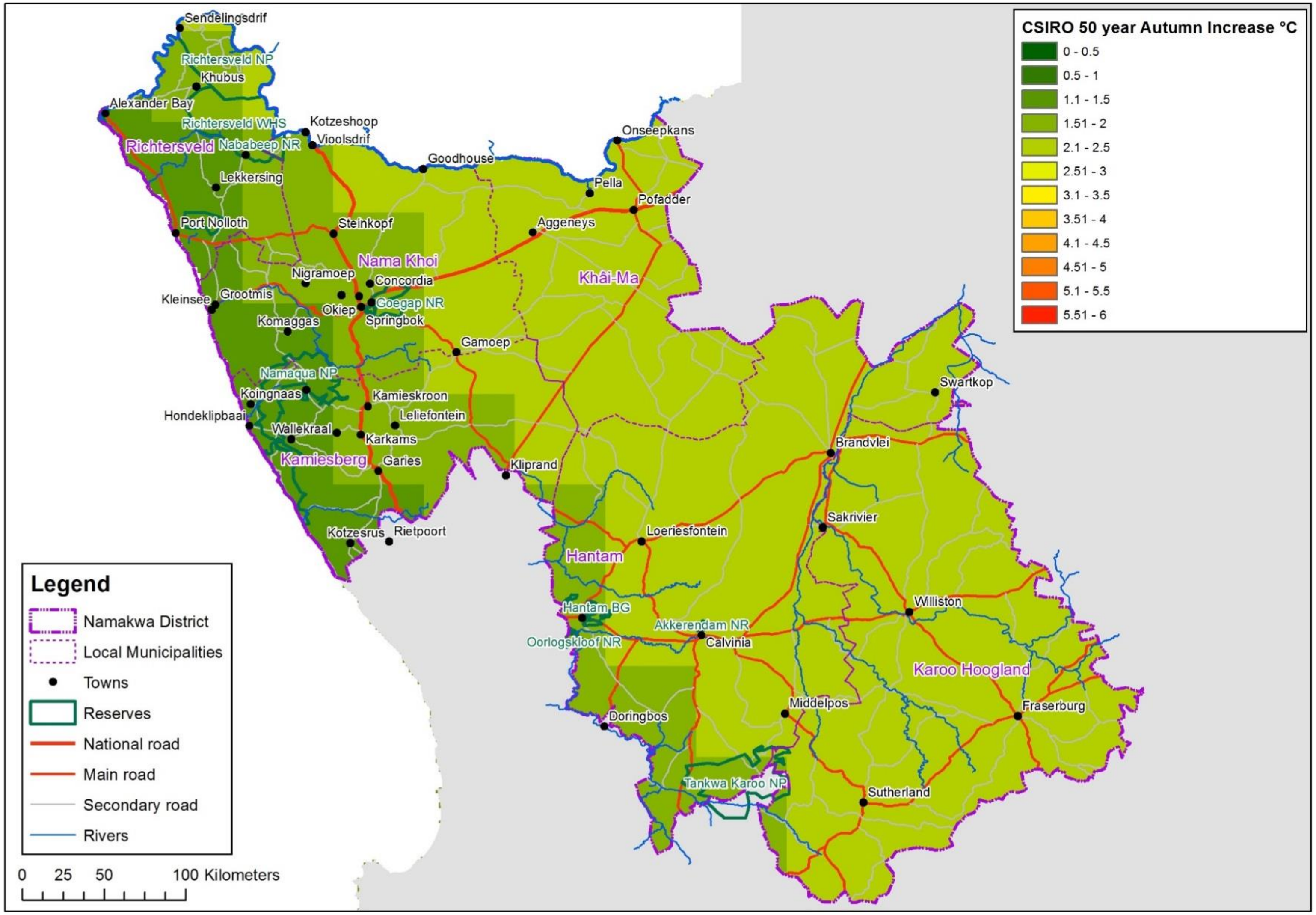

FIGURE 38: AUTUMN TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

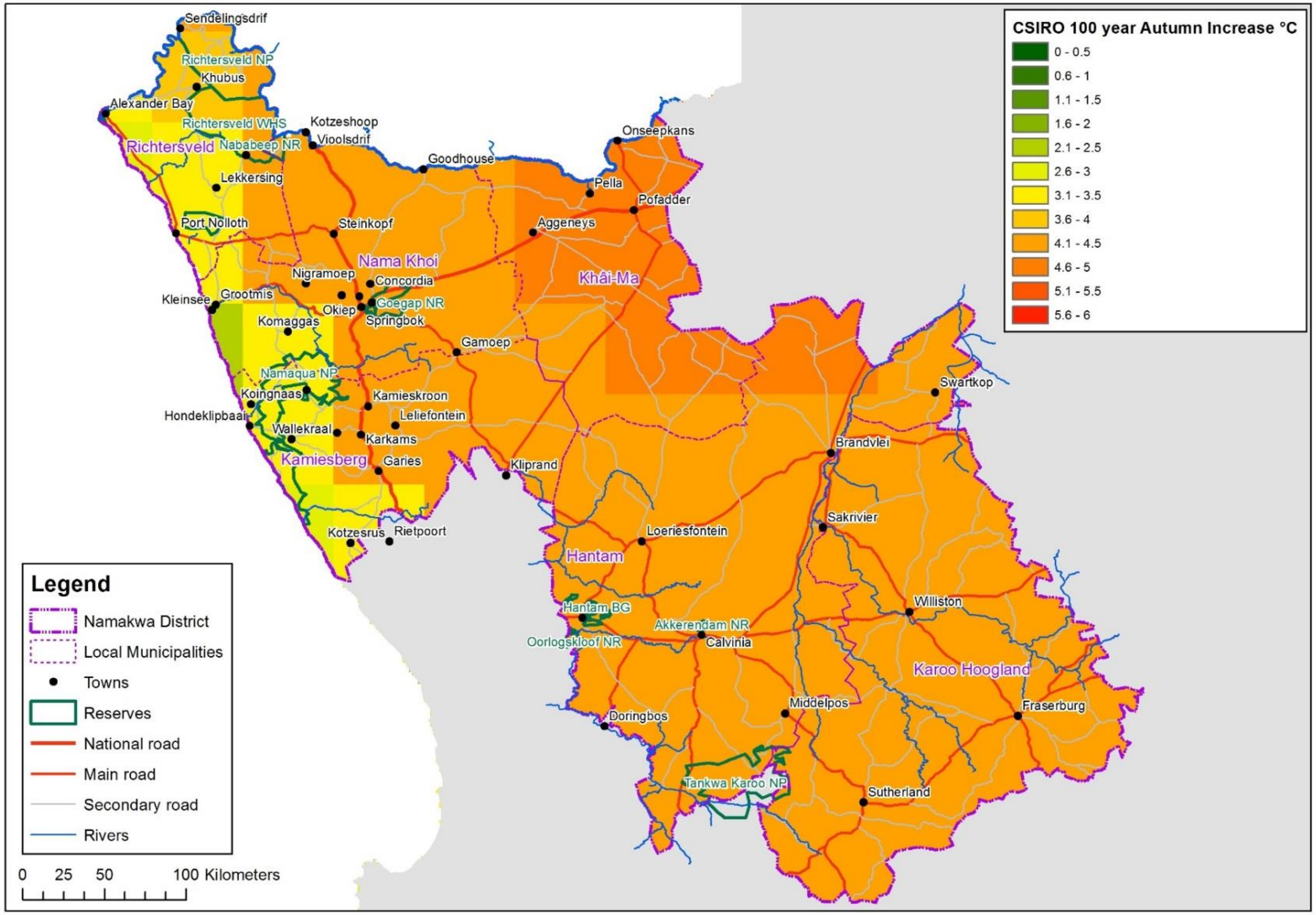

FIGURE 39: AUTUMN TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

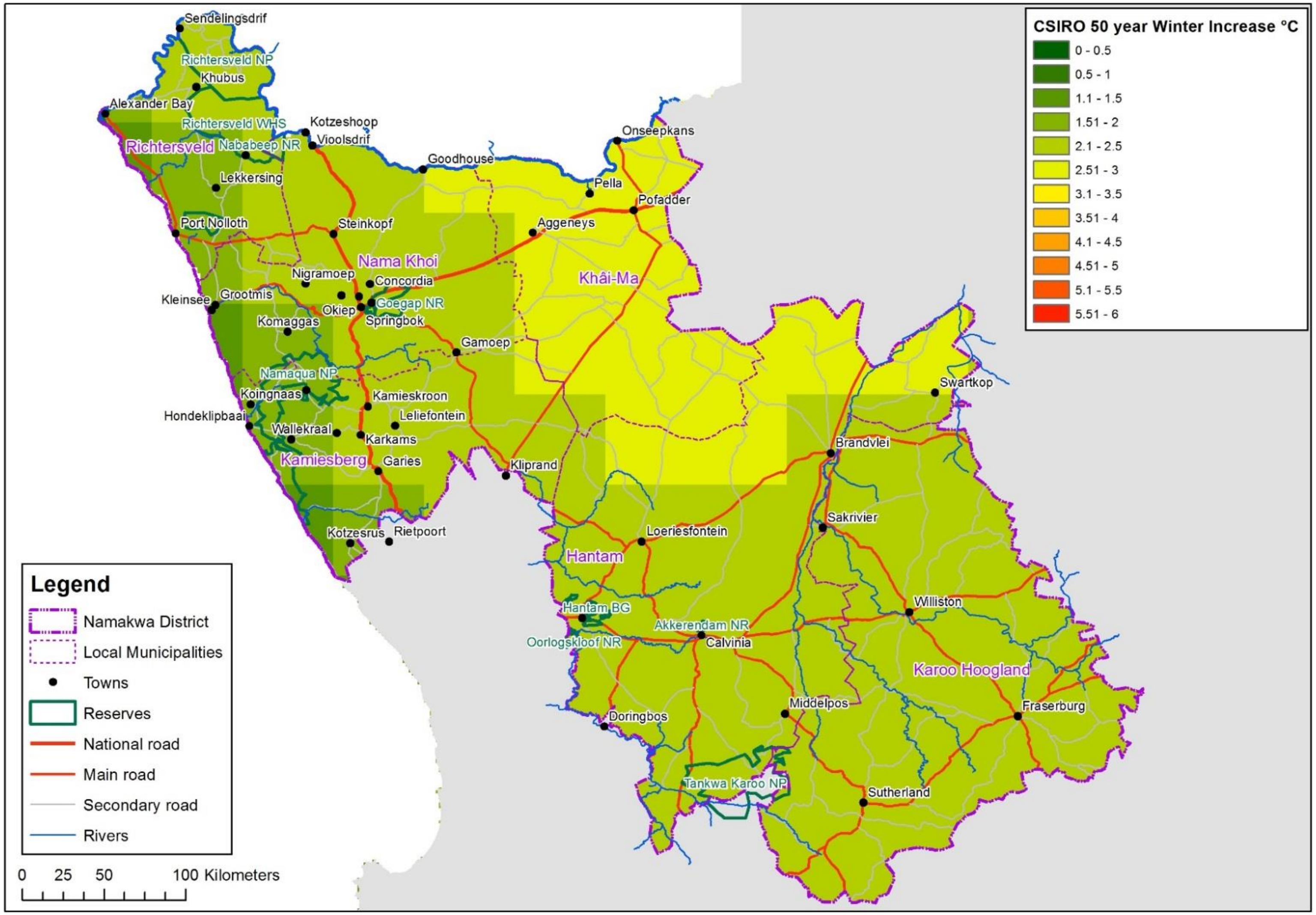

FIGURE 40: WINTER TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

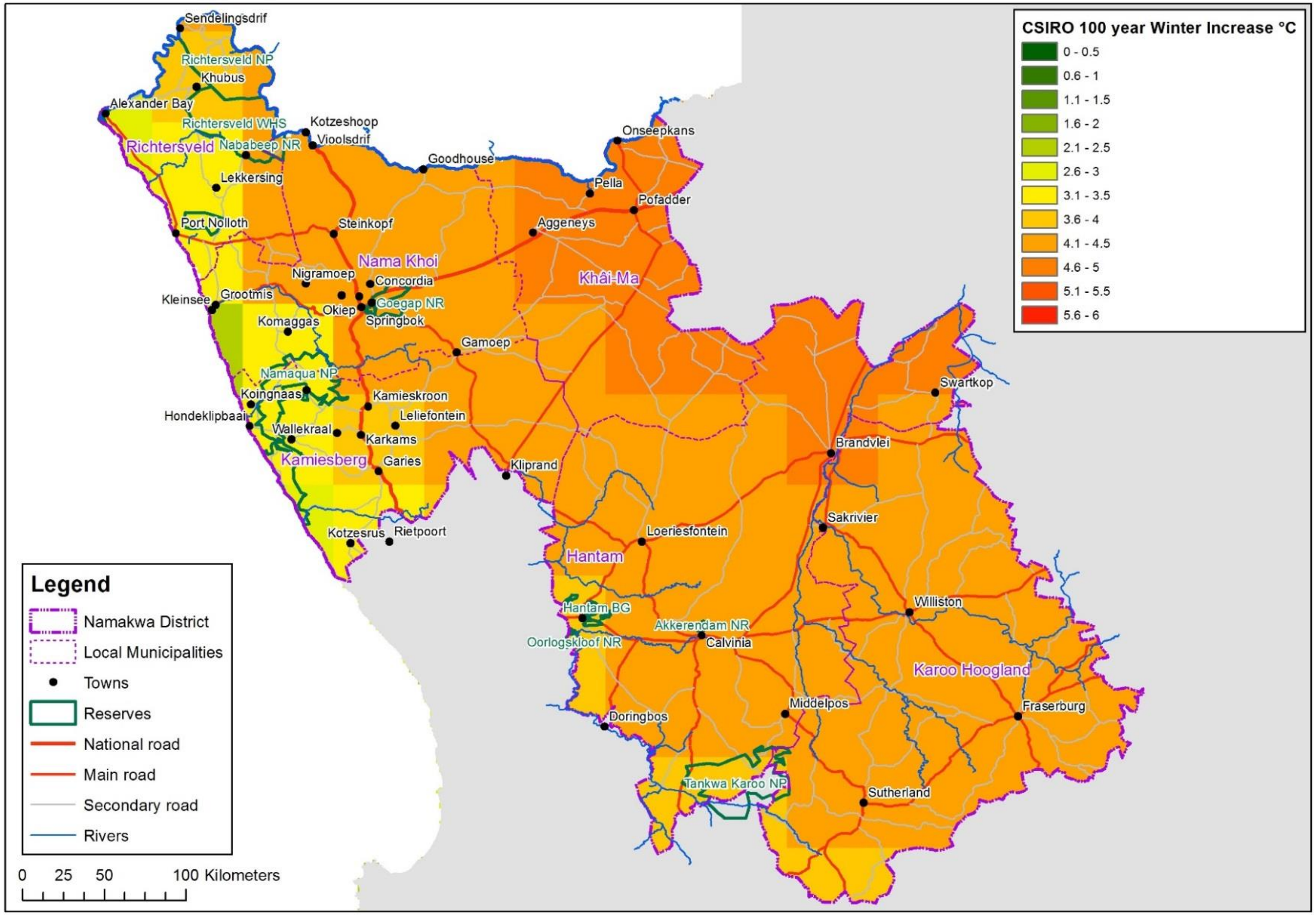

FIGURE 41: WINTER TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

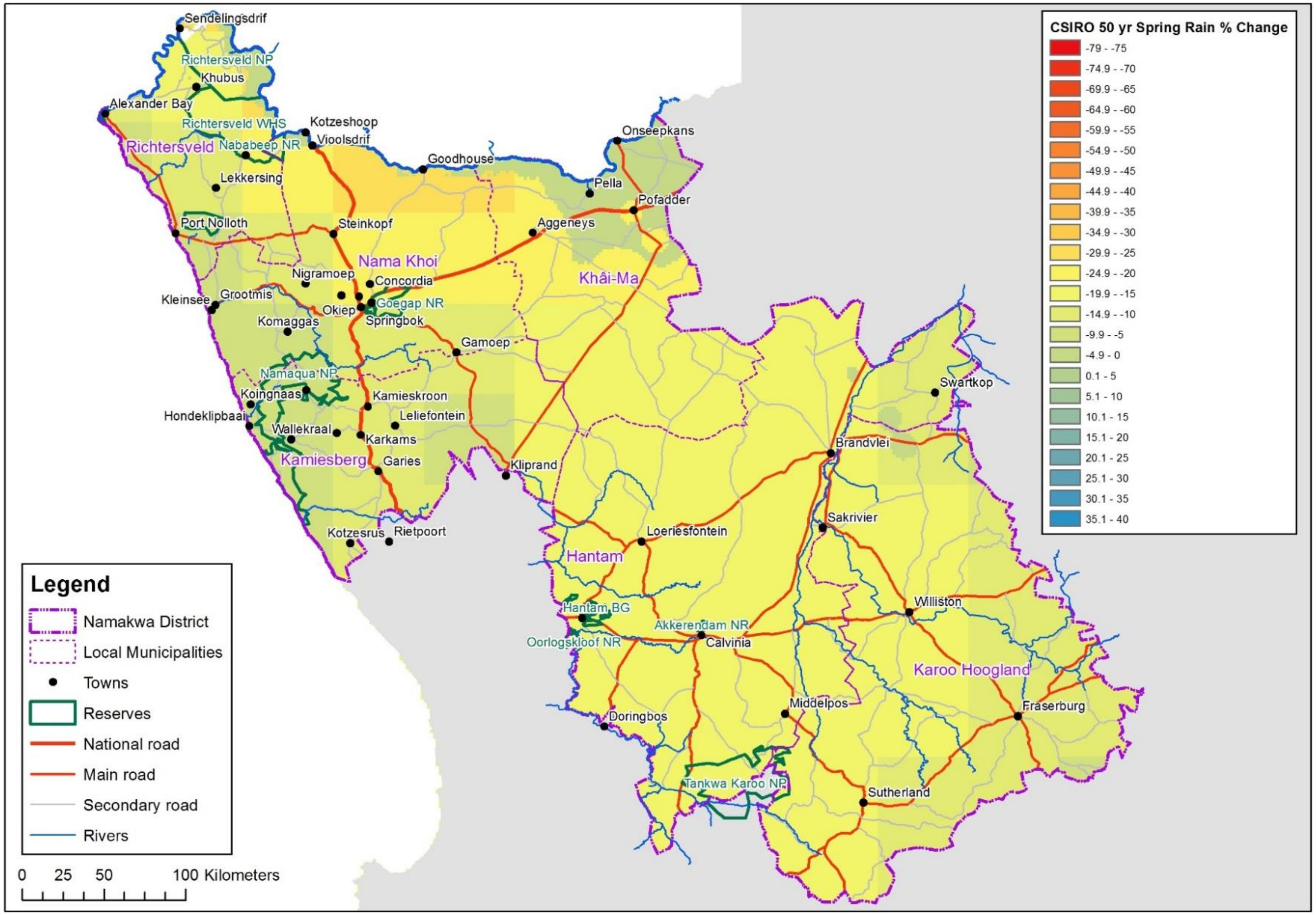

FIGURE 42: SPRING RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

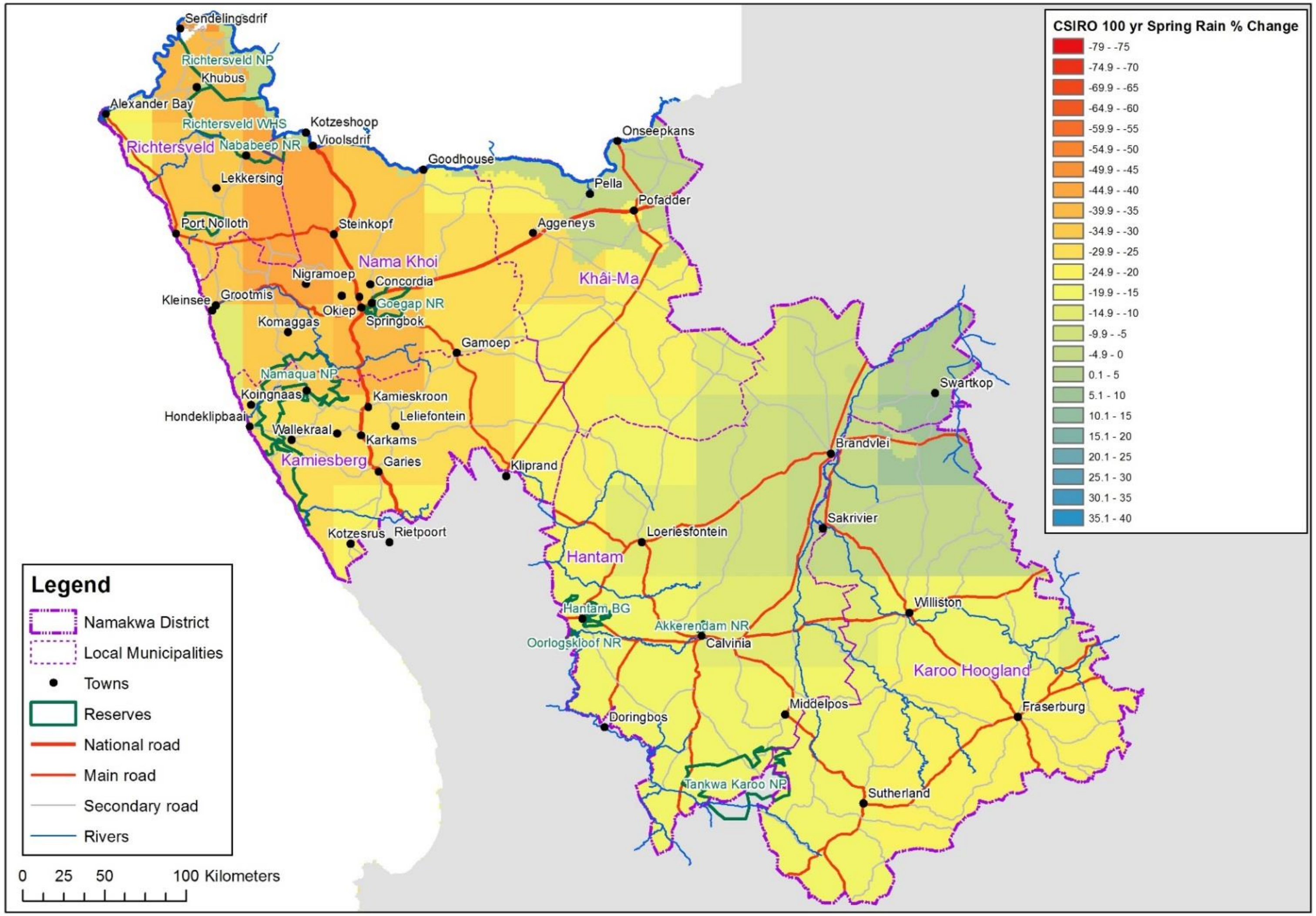

FIGURE 43: SPRING RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

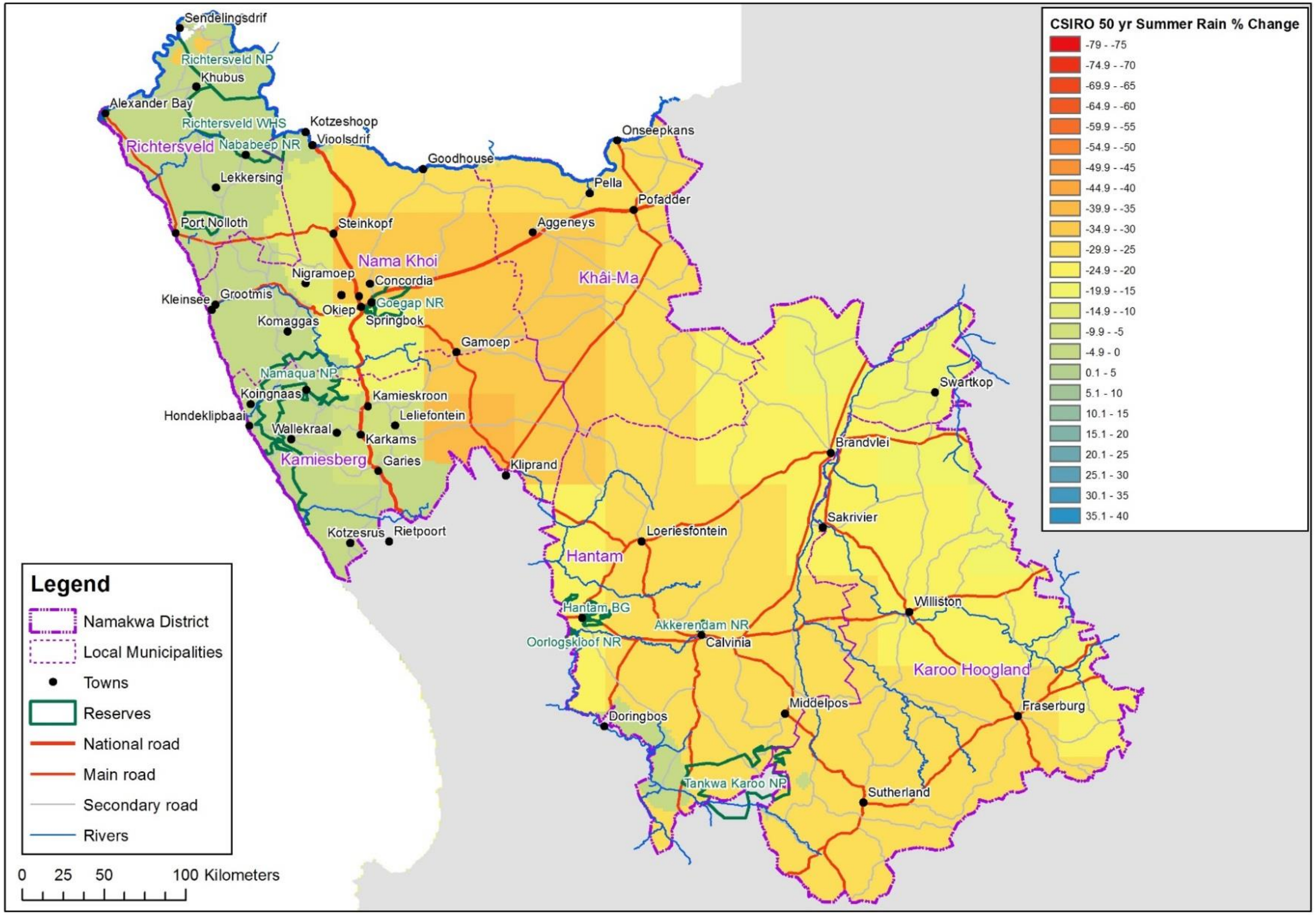

FIGURE 44: SUMMER RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

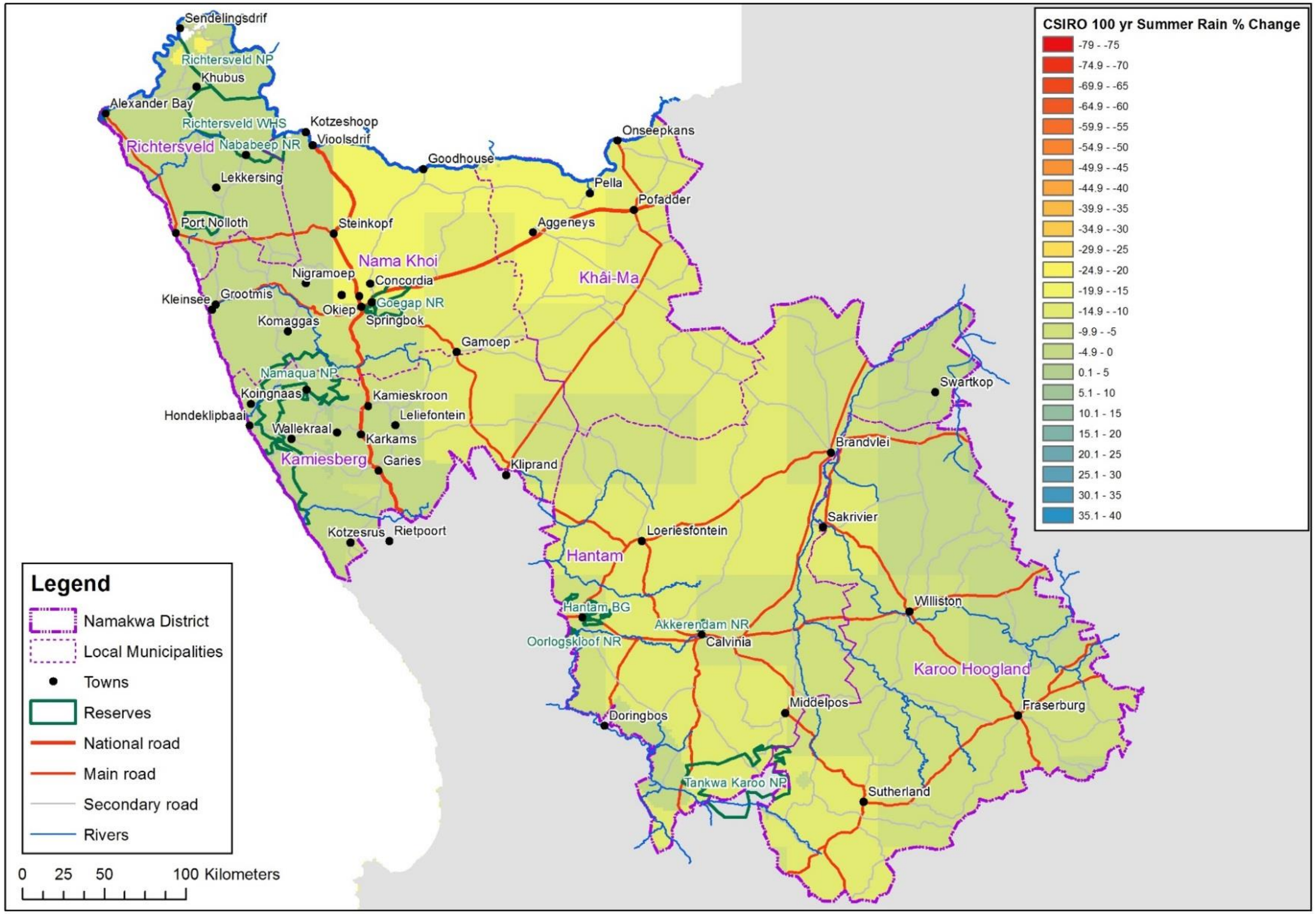

FIGURE 45: SUMMER RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

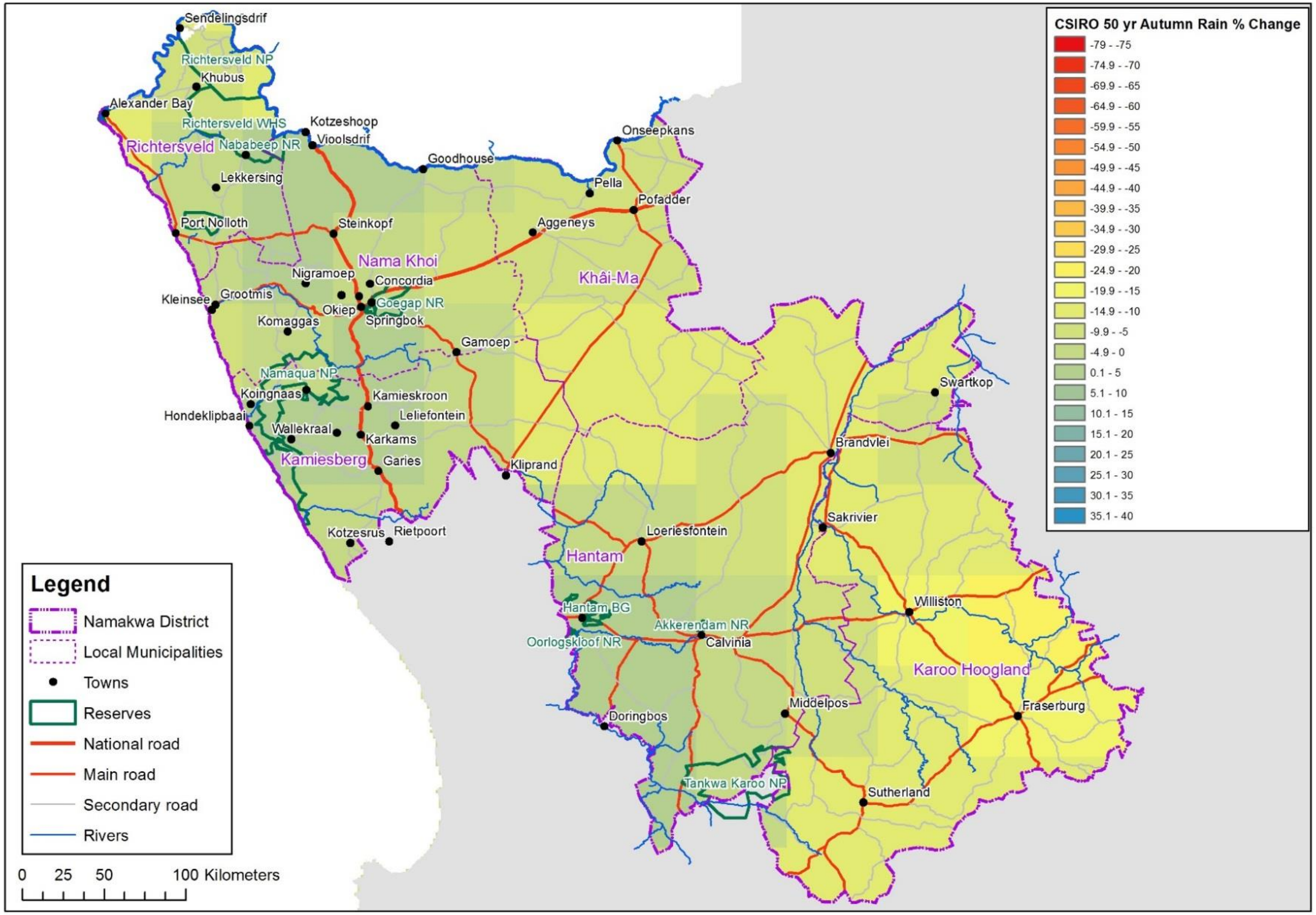

FIGURE 46: AUTUMN RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

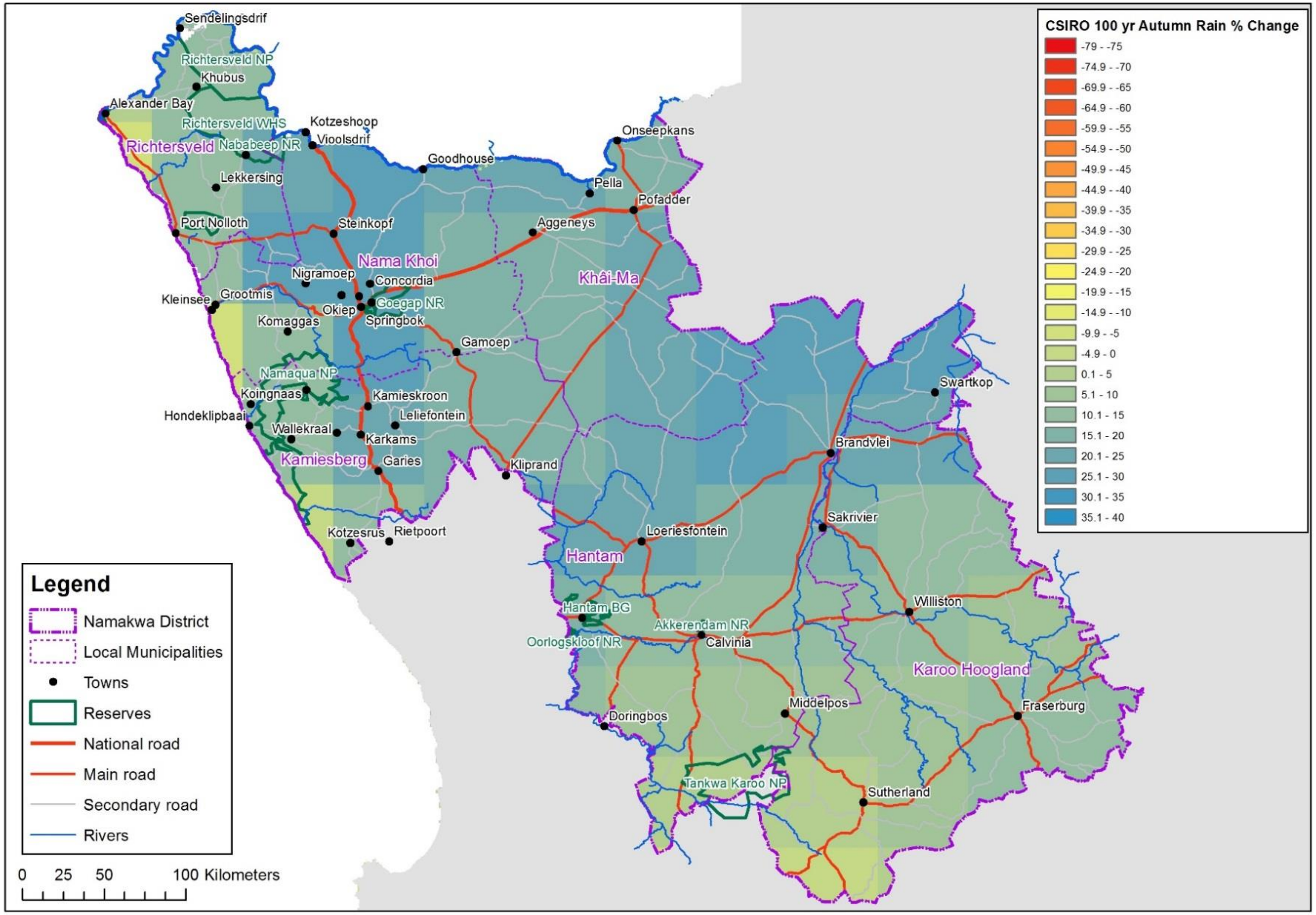

FIGURE 47: AUTUMN RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

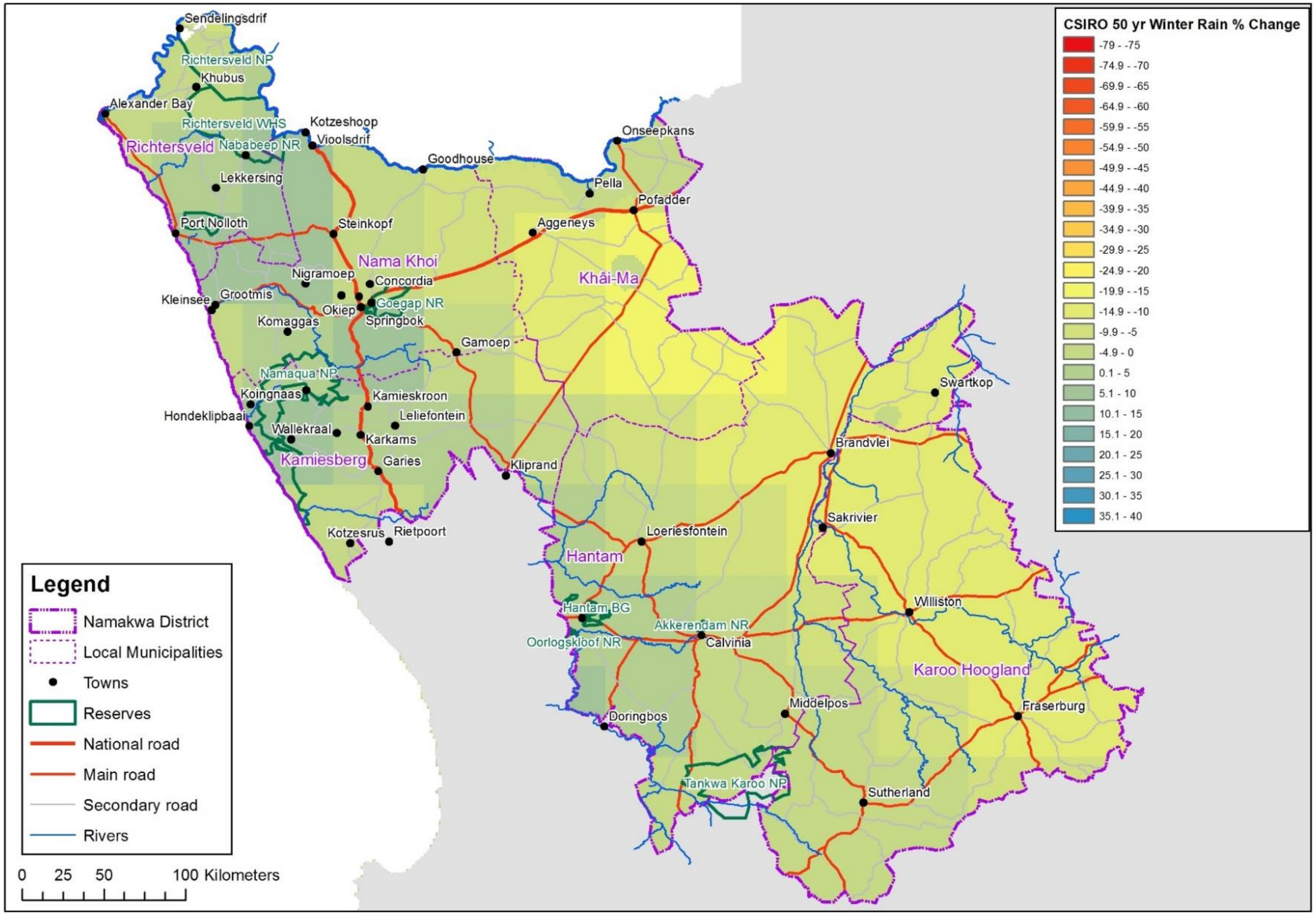

FIGURE 48: WINTER RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

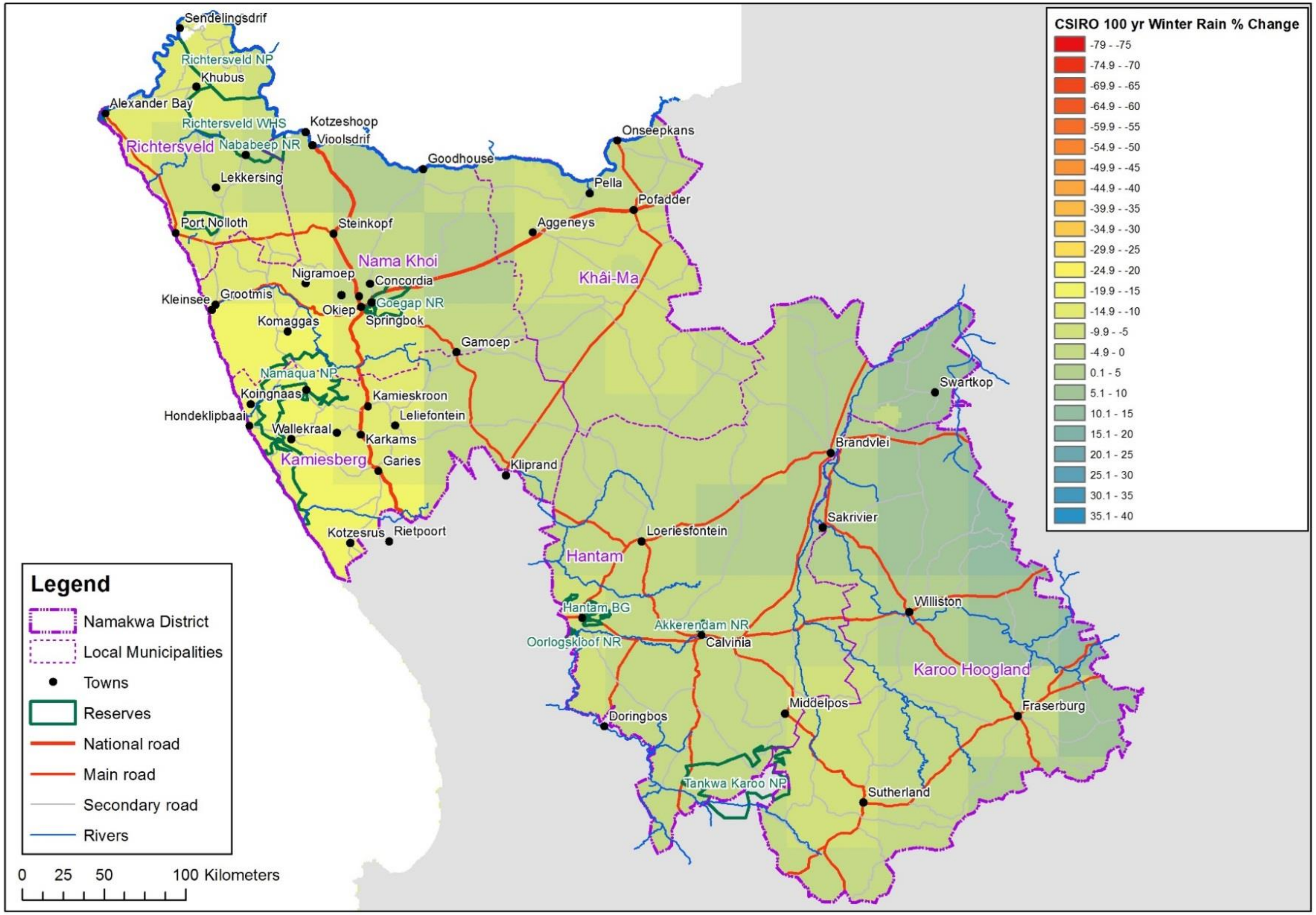

FIGURE 49: WINTER RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE CSIRO MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

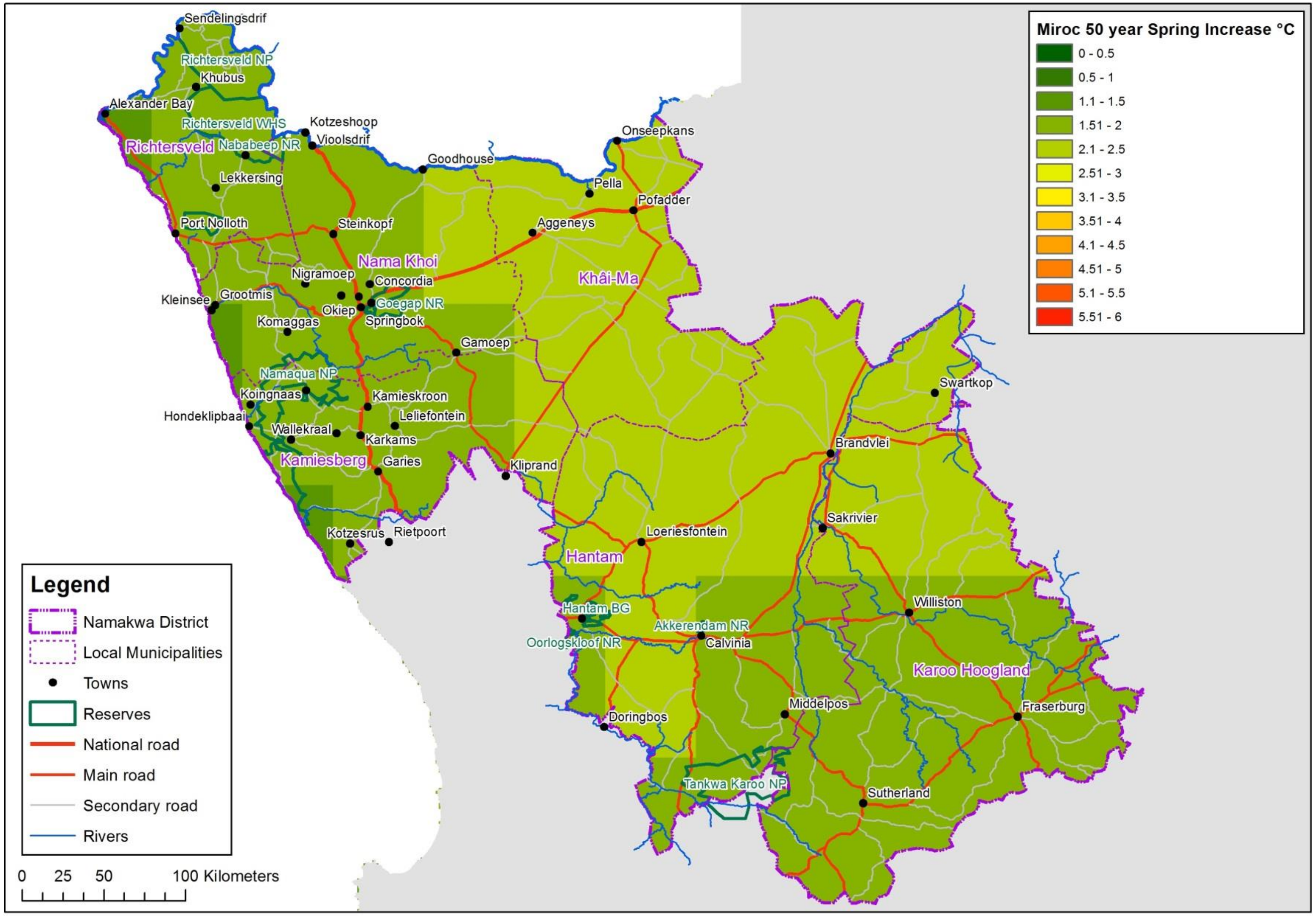

FIGURE 50: SPRING TEMPERATURE INCREASES FOR NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

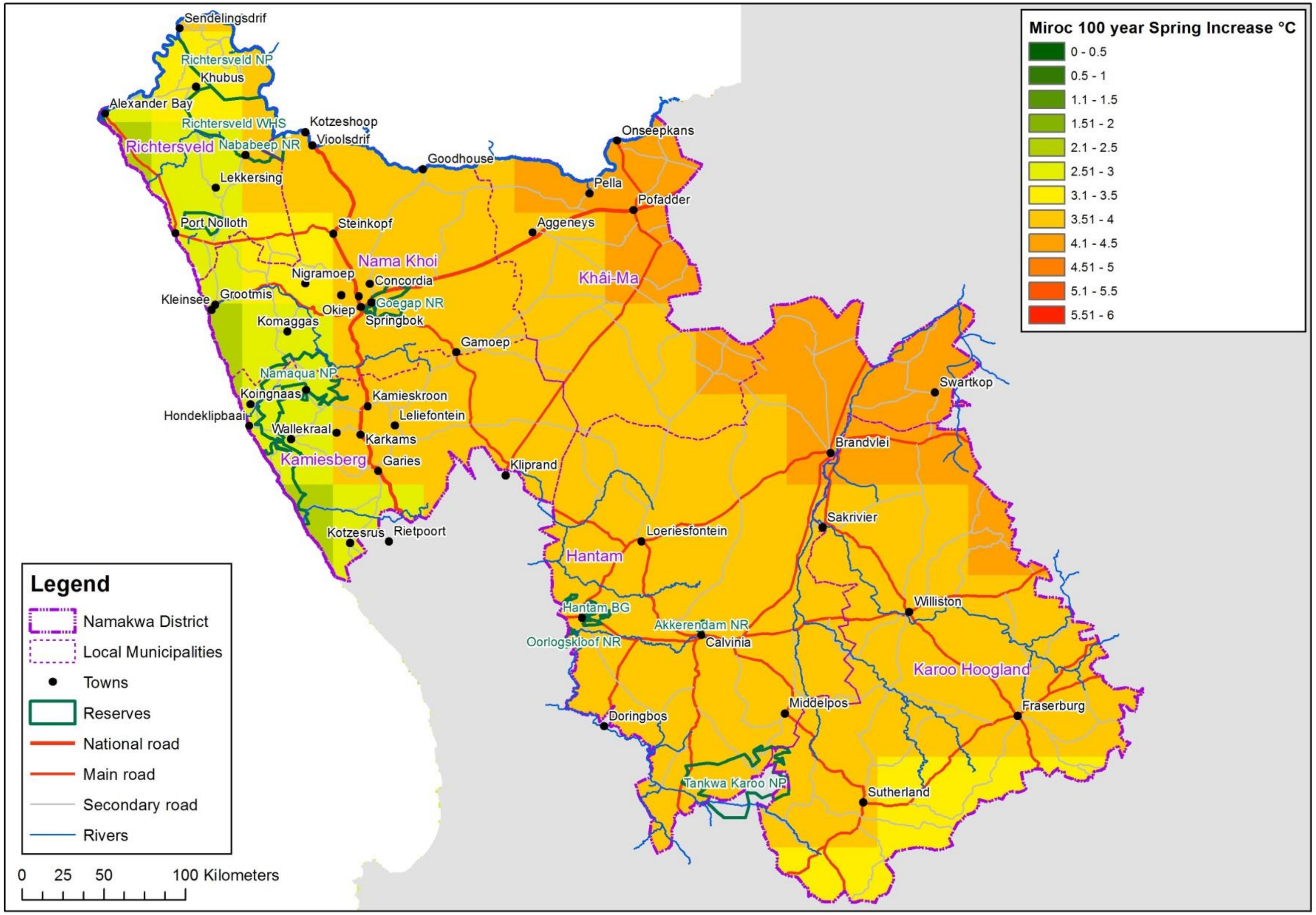

FIGURE 51: SPRING TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

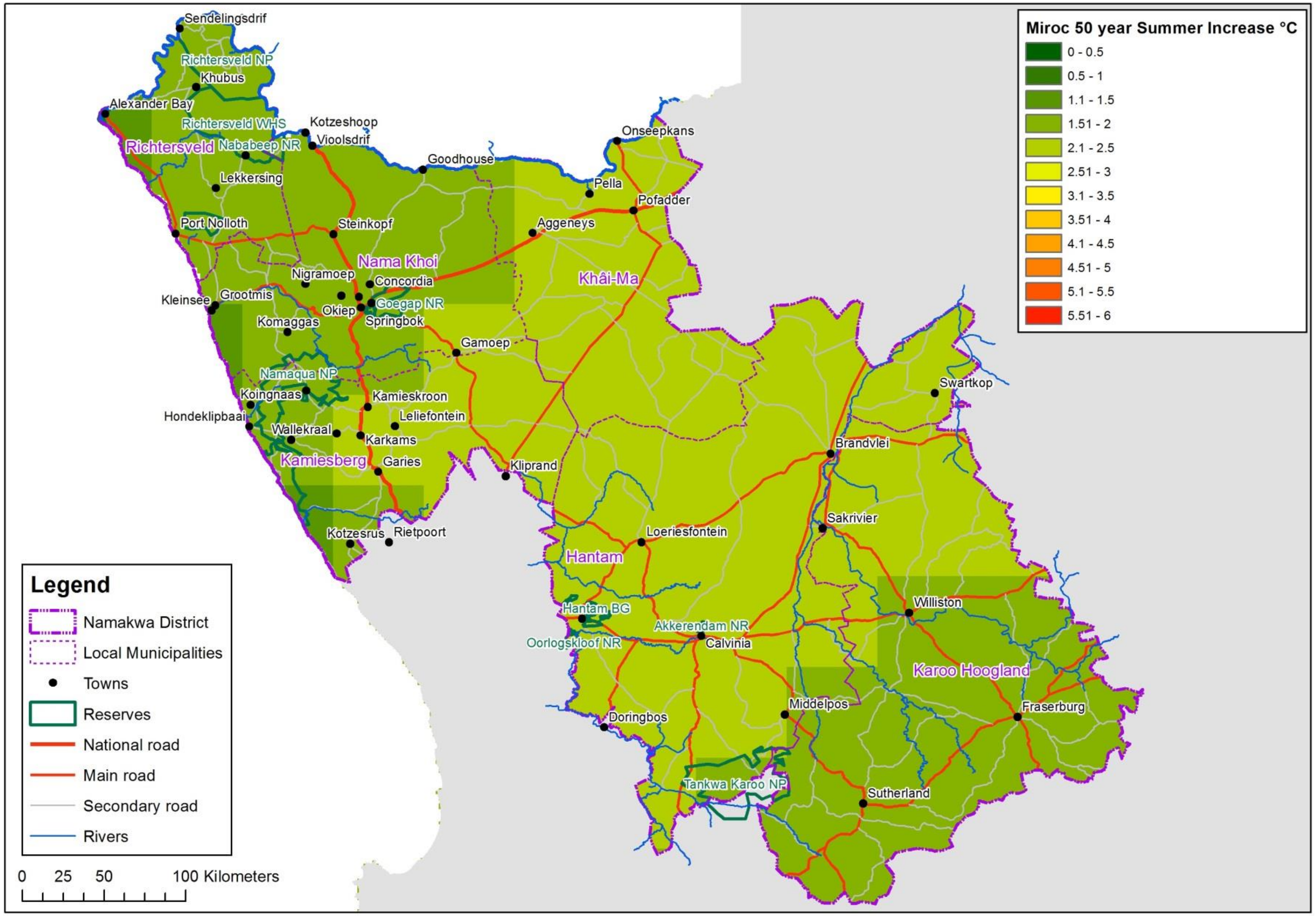

FIGURE 52: SUMMER TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

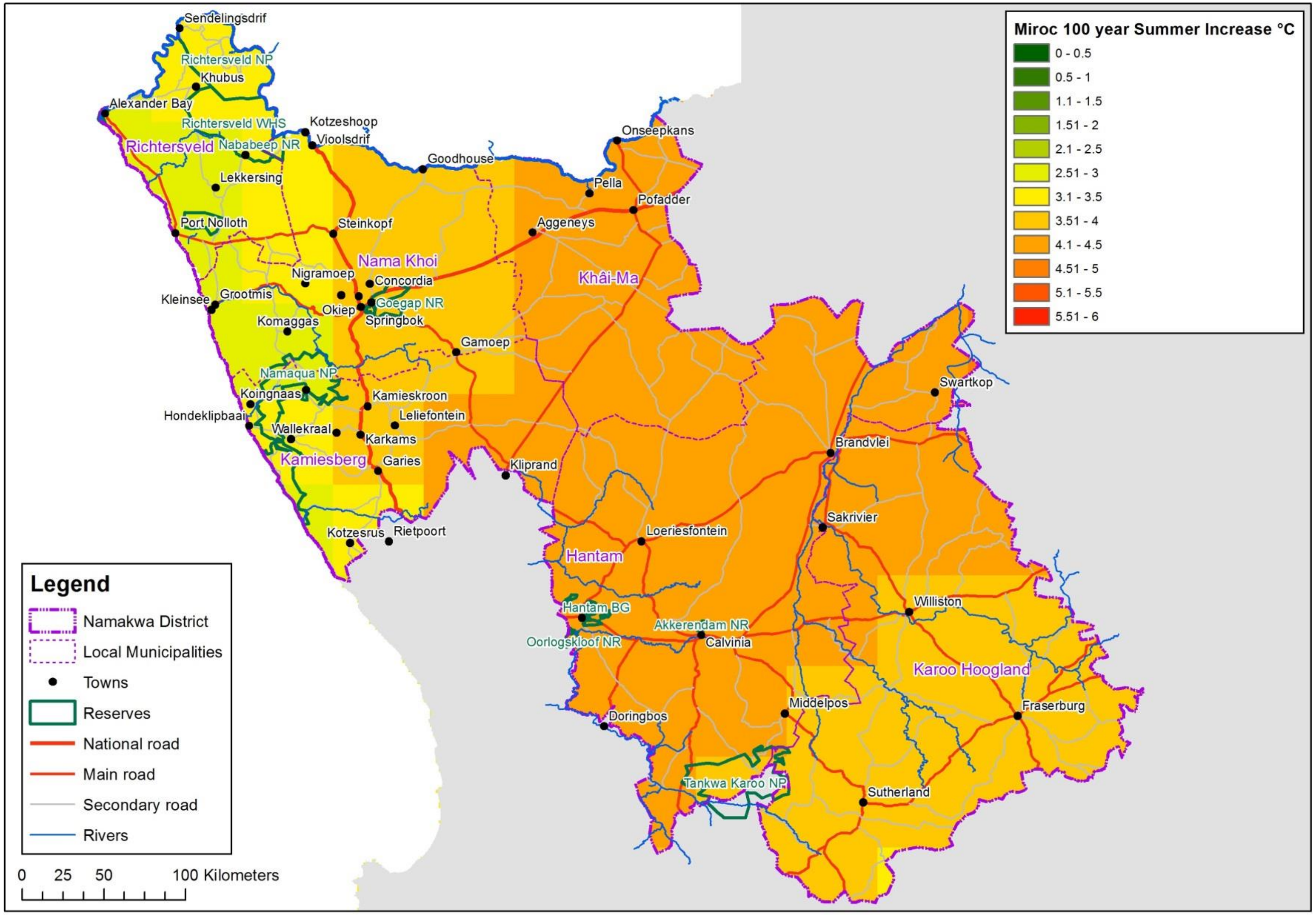

FIGURE 53: SUMMER TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

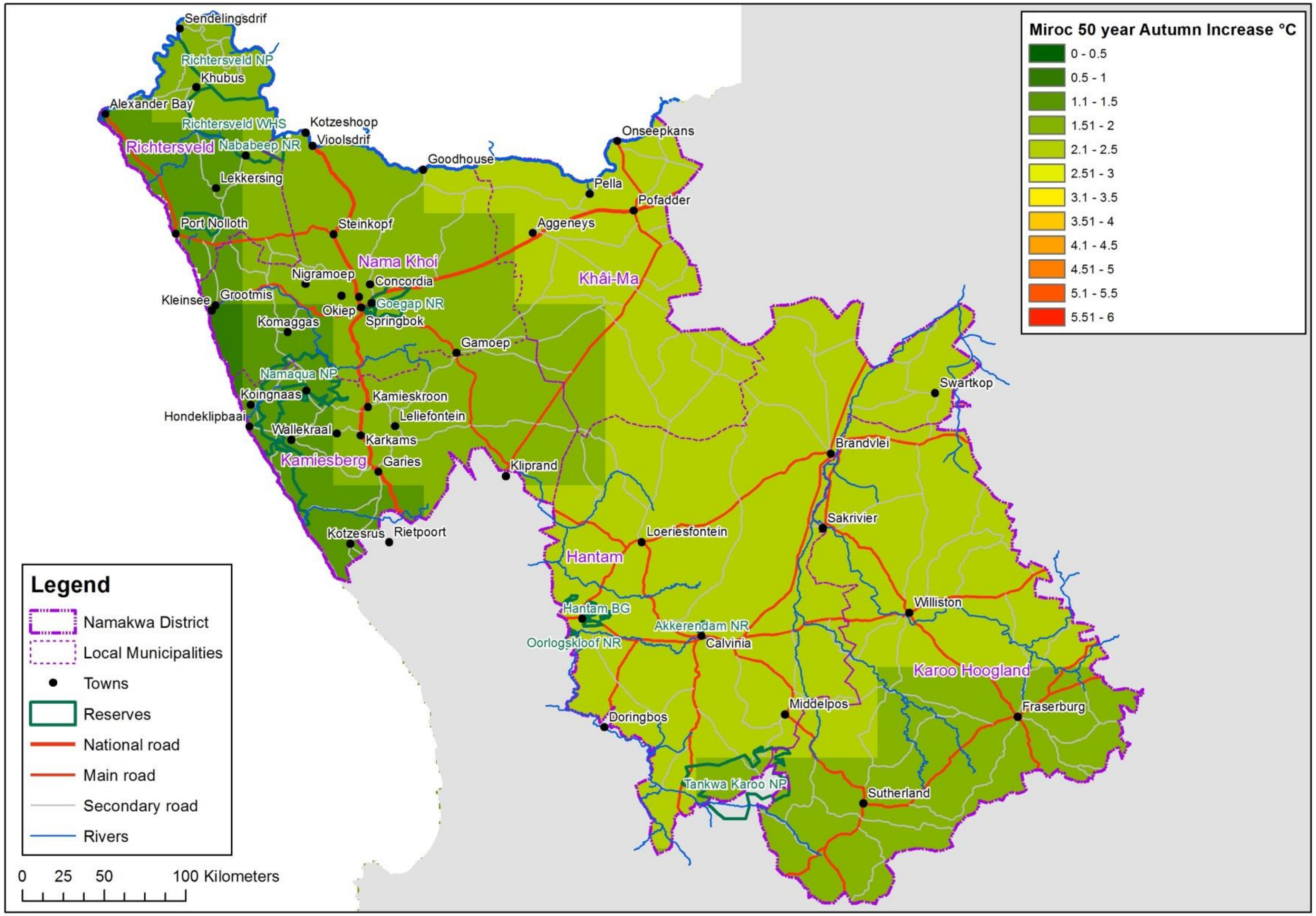

FIGURE 54: AUTUMN TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

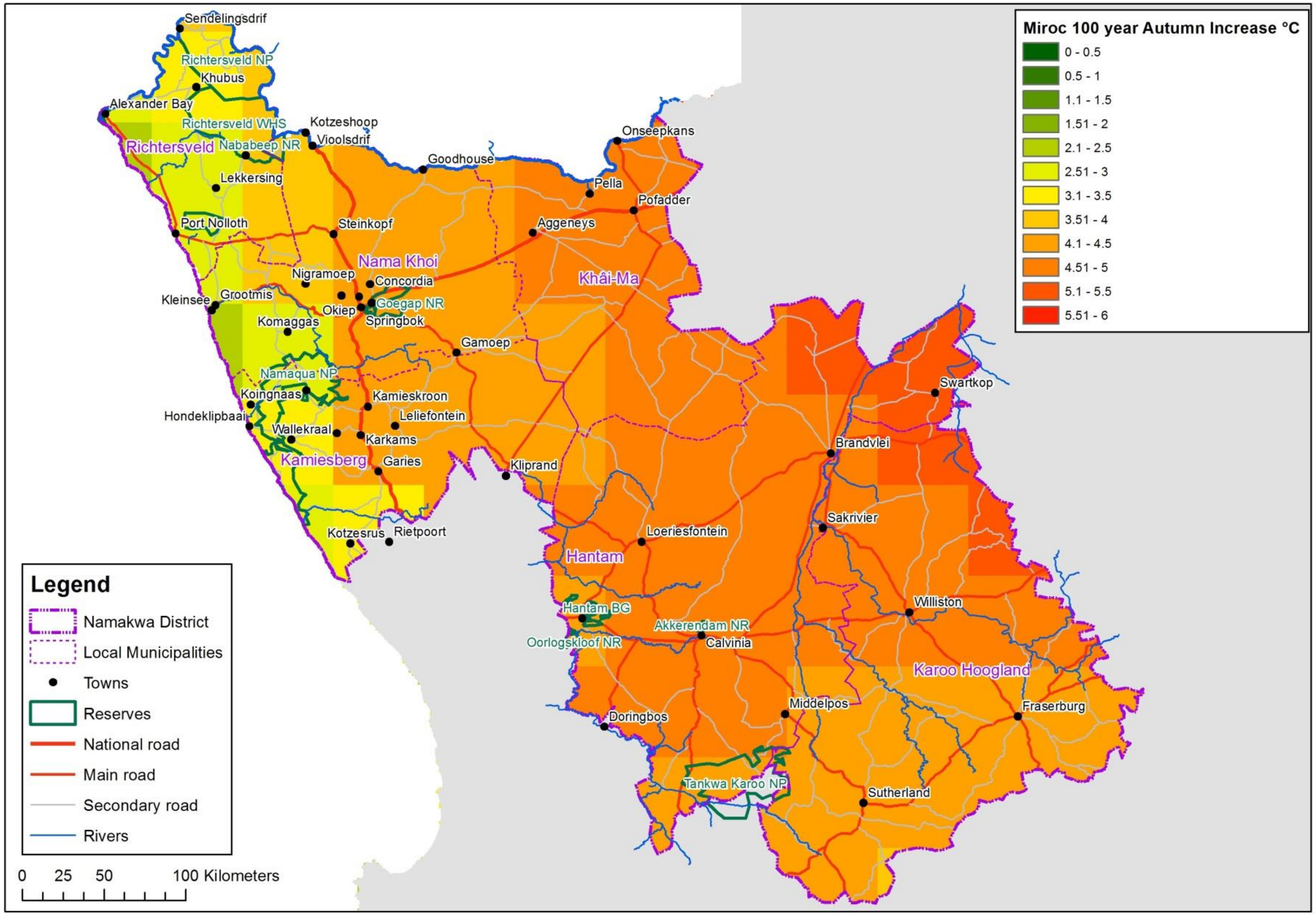

FIGURE 55: AUTUMN TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

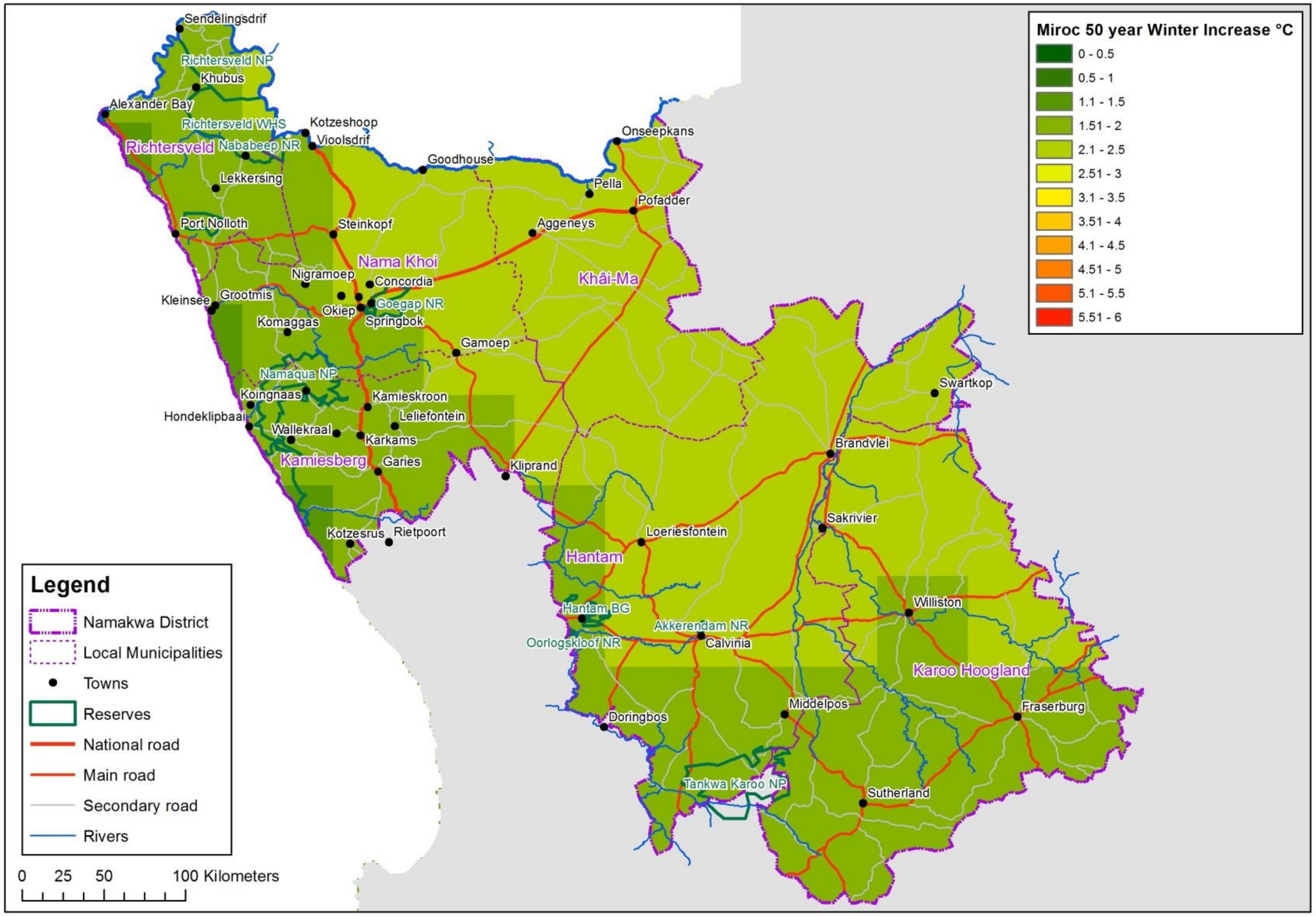

FIGURE 56: WINTER TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

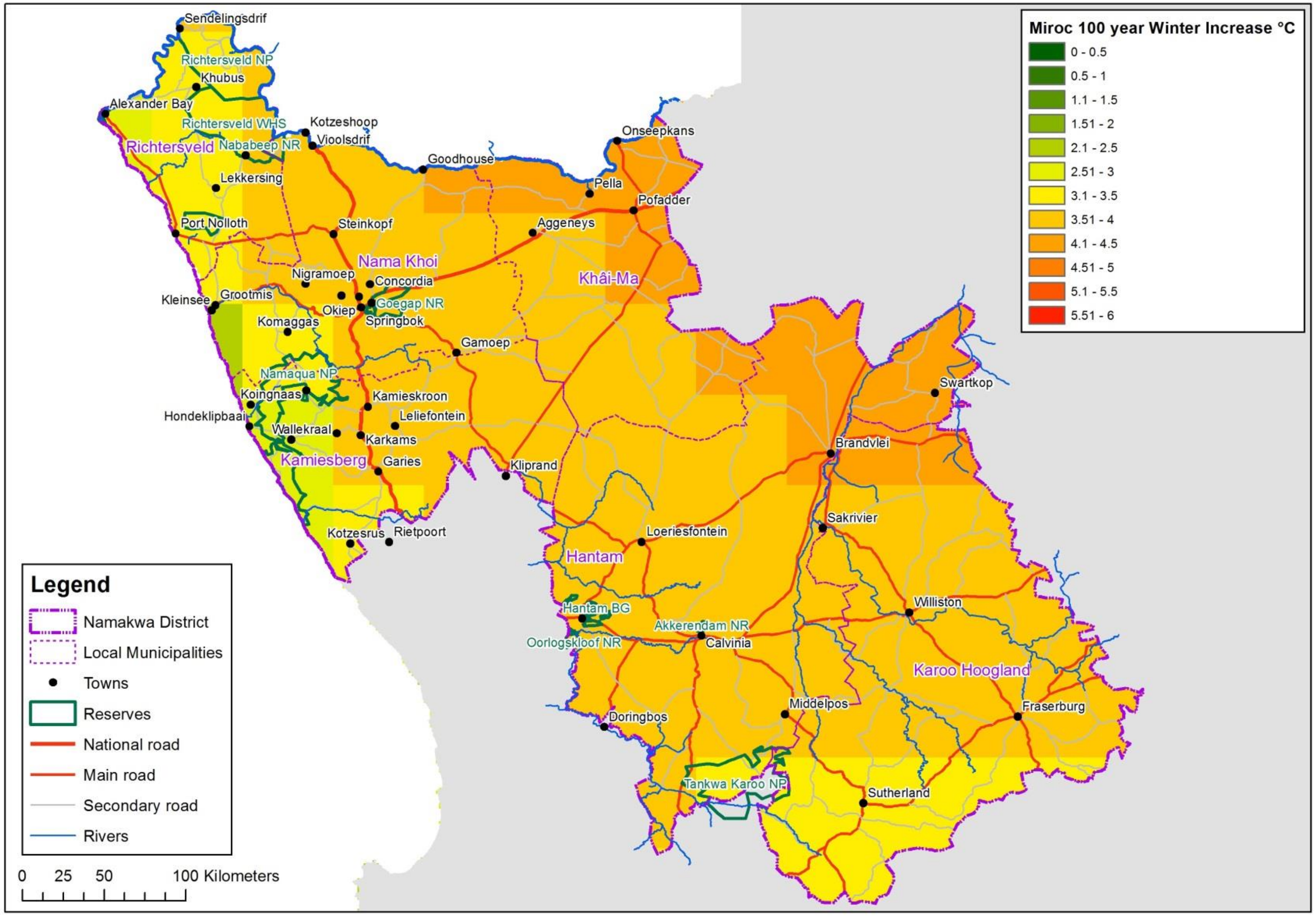

FIGURE 57: WINTER TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

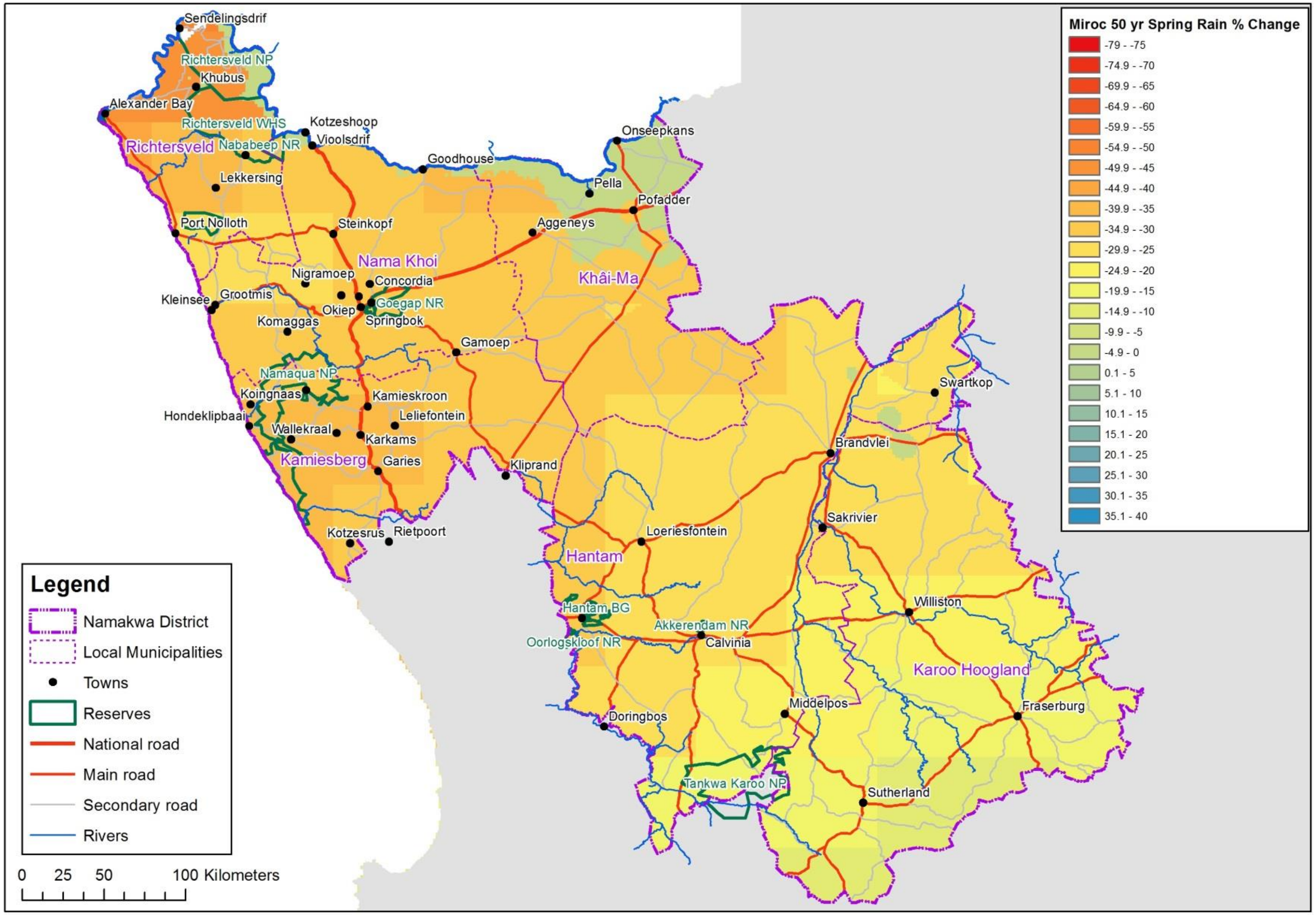

FIGURE 58: SPRING RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

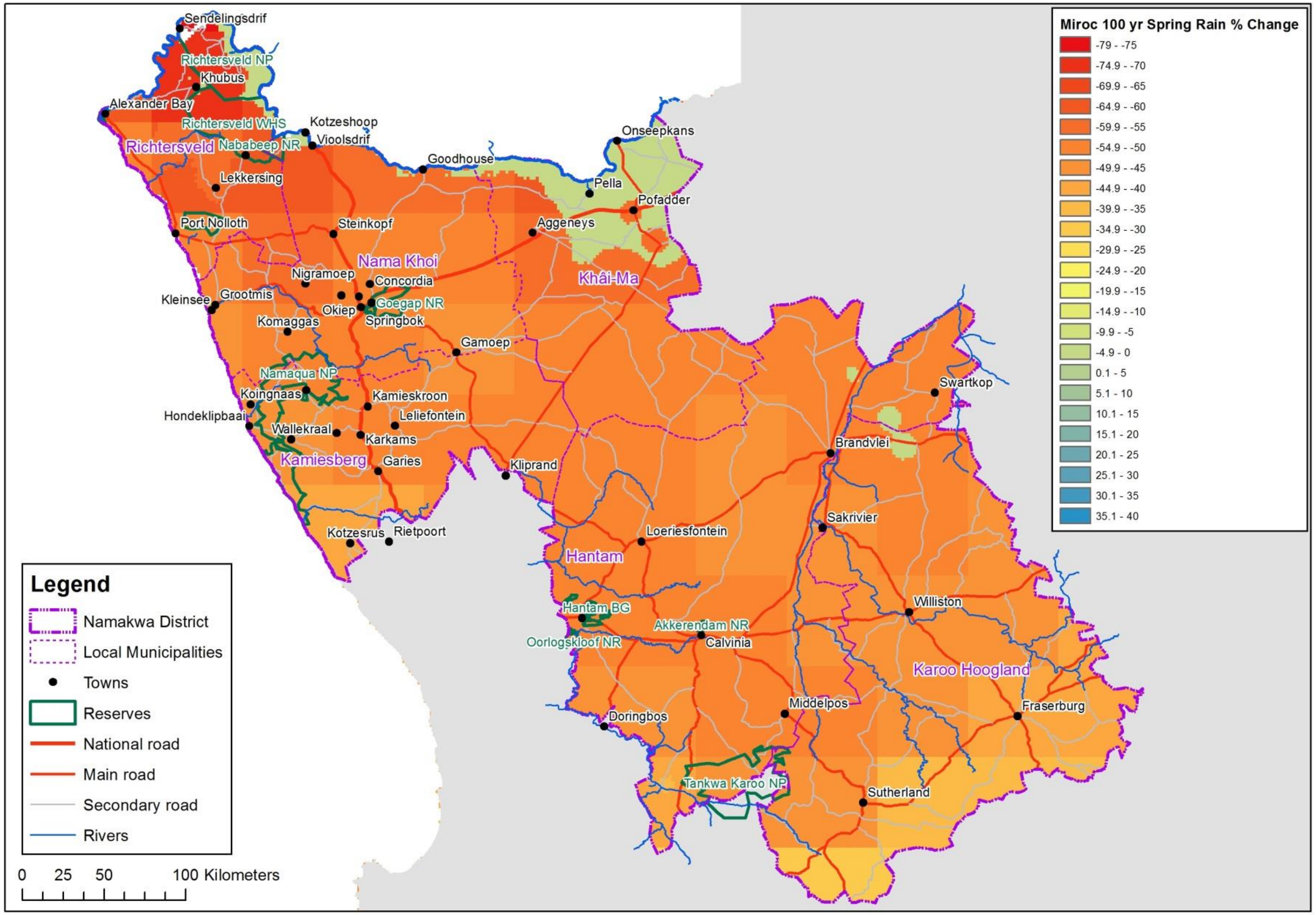

FIGURE 59: SPRING RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

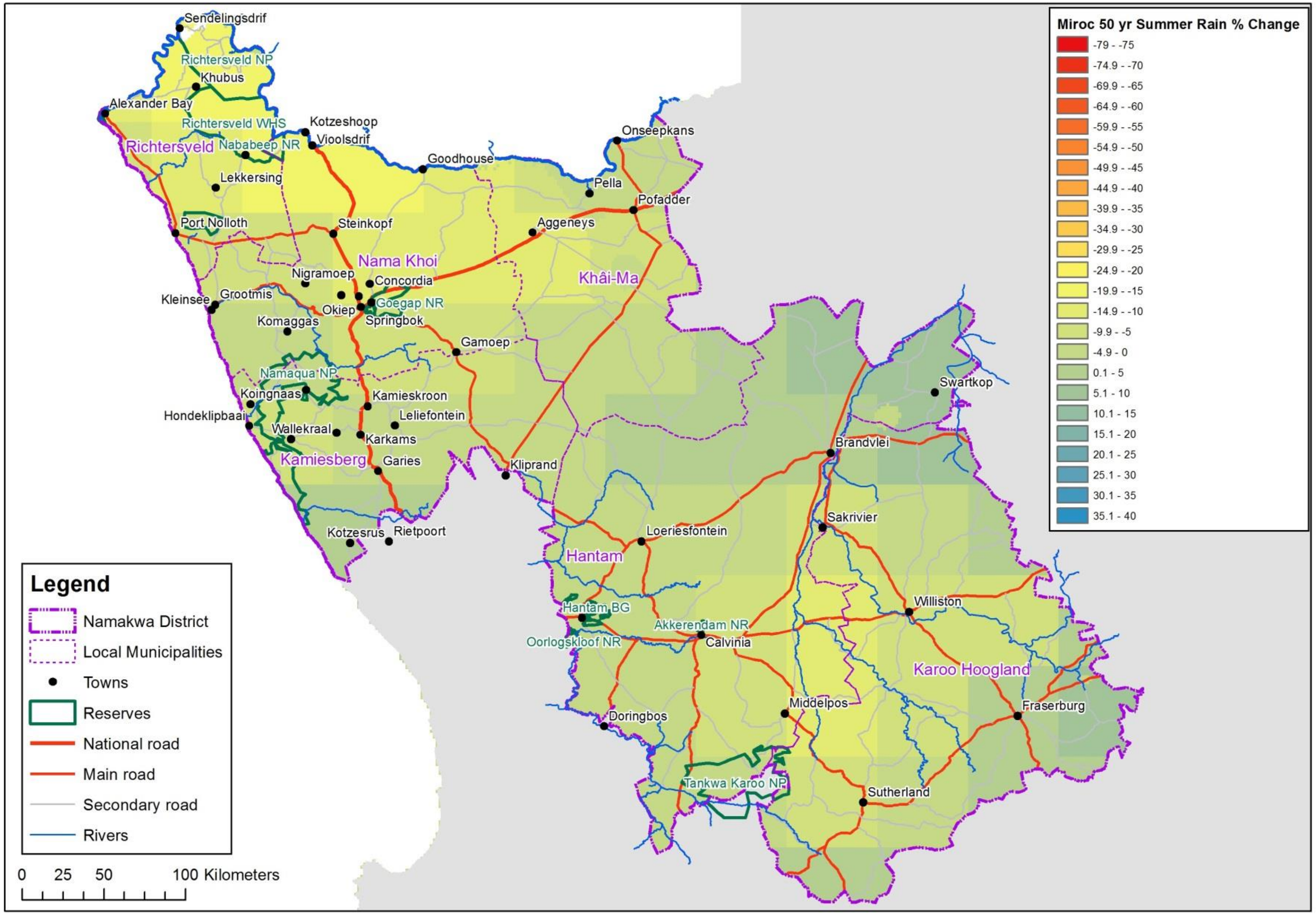

FIGURE 60: SUMMER RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

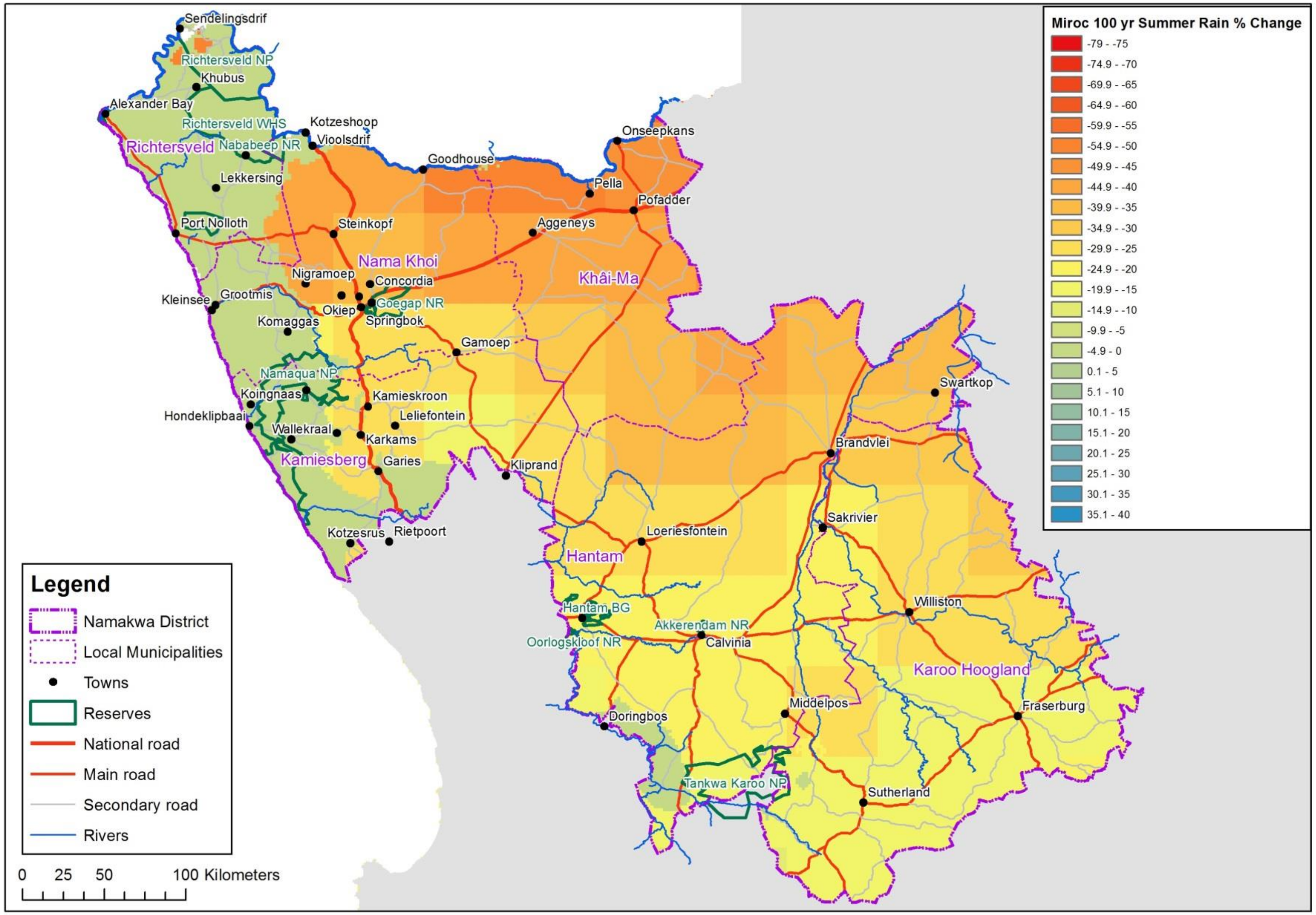

FIGURE 61: SUMMER RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

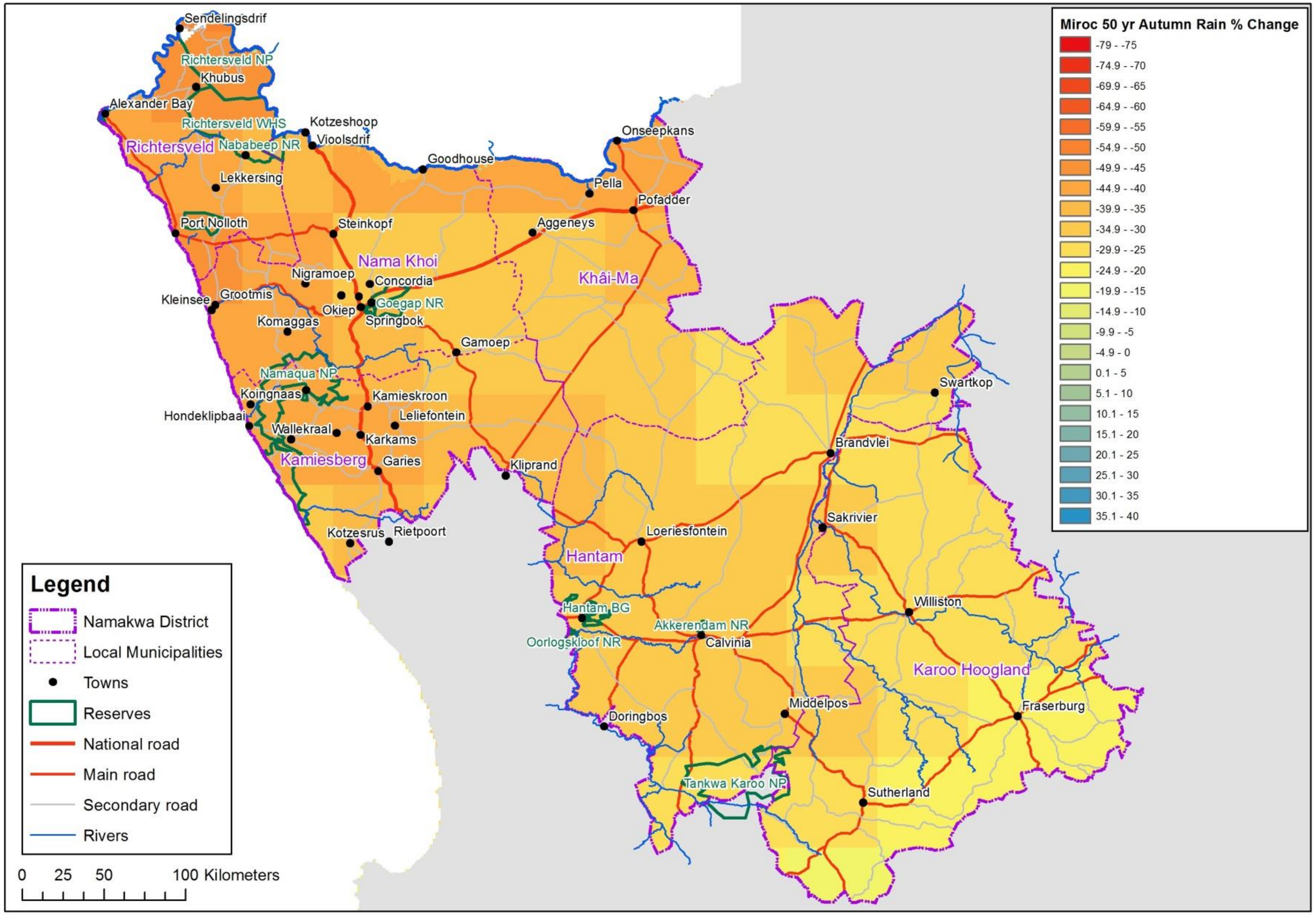

FIGURE 62: AUTUMN RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

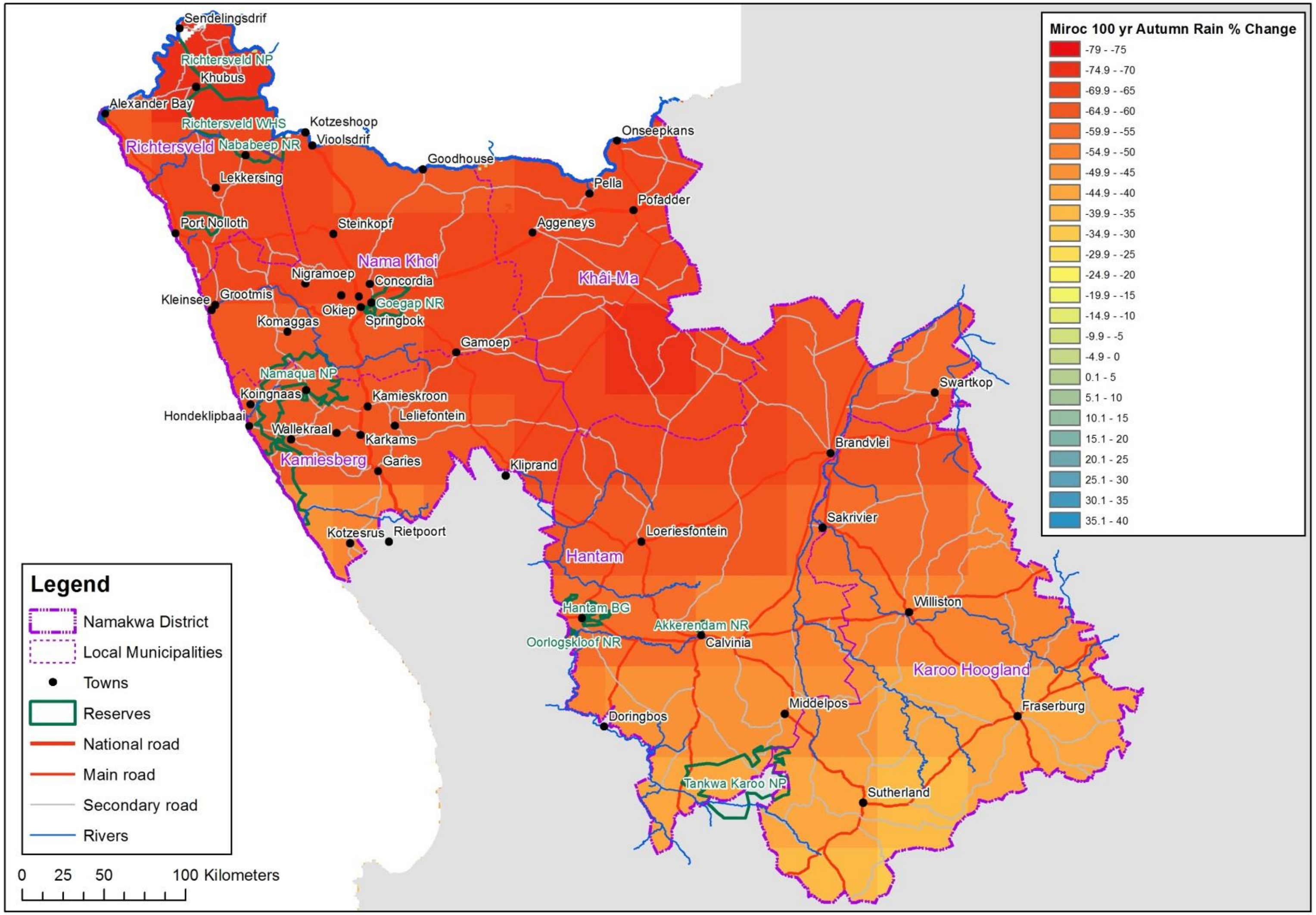

FIGURE 63: AUTUMN RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

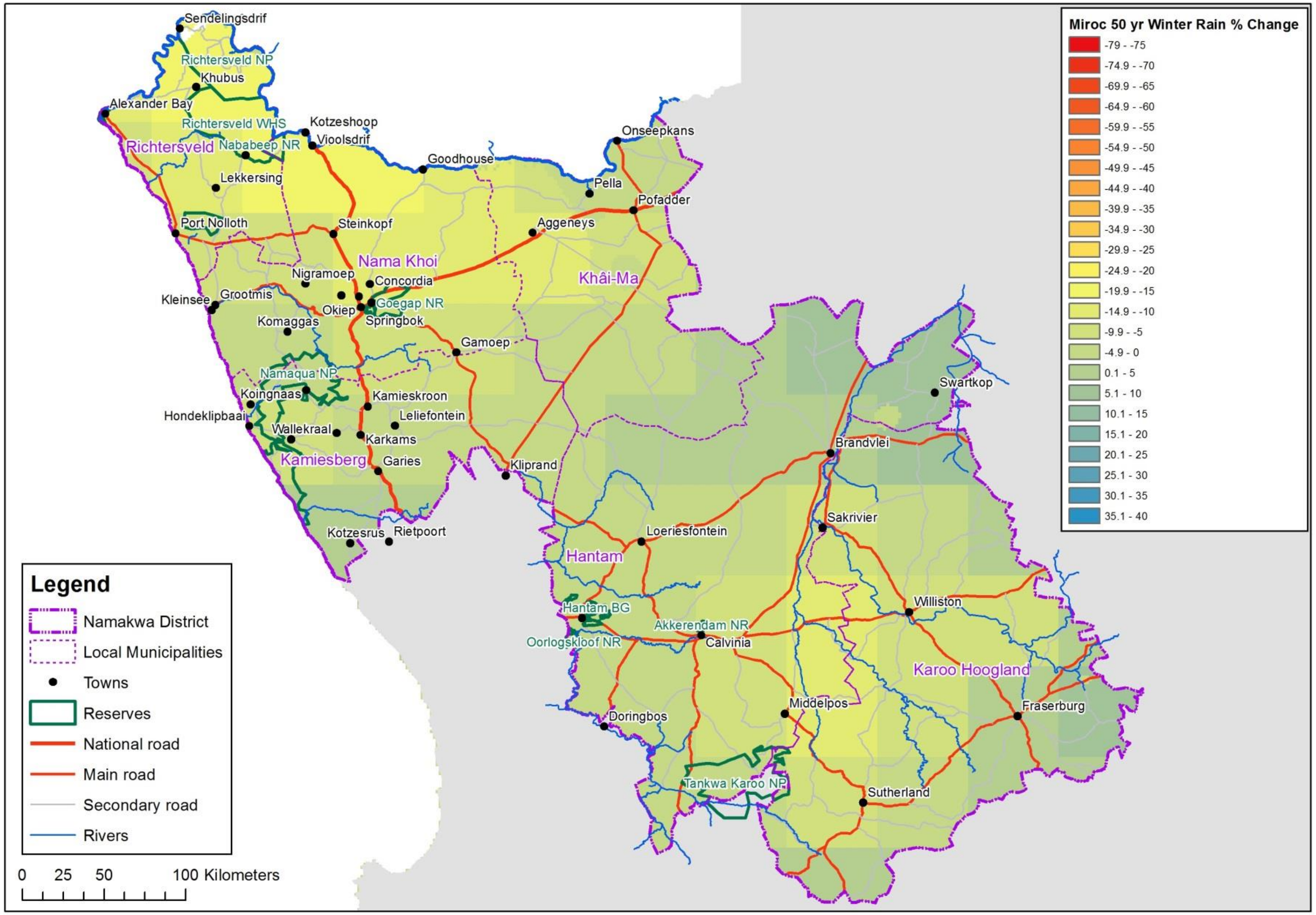

FIGURE 64: WINTER RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

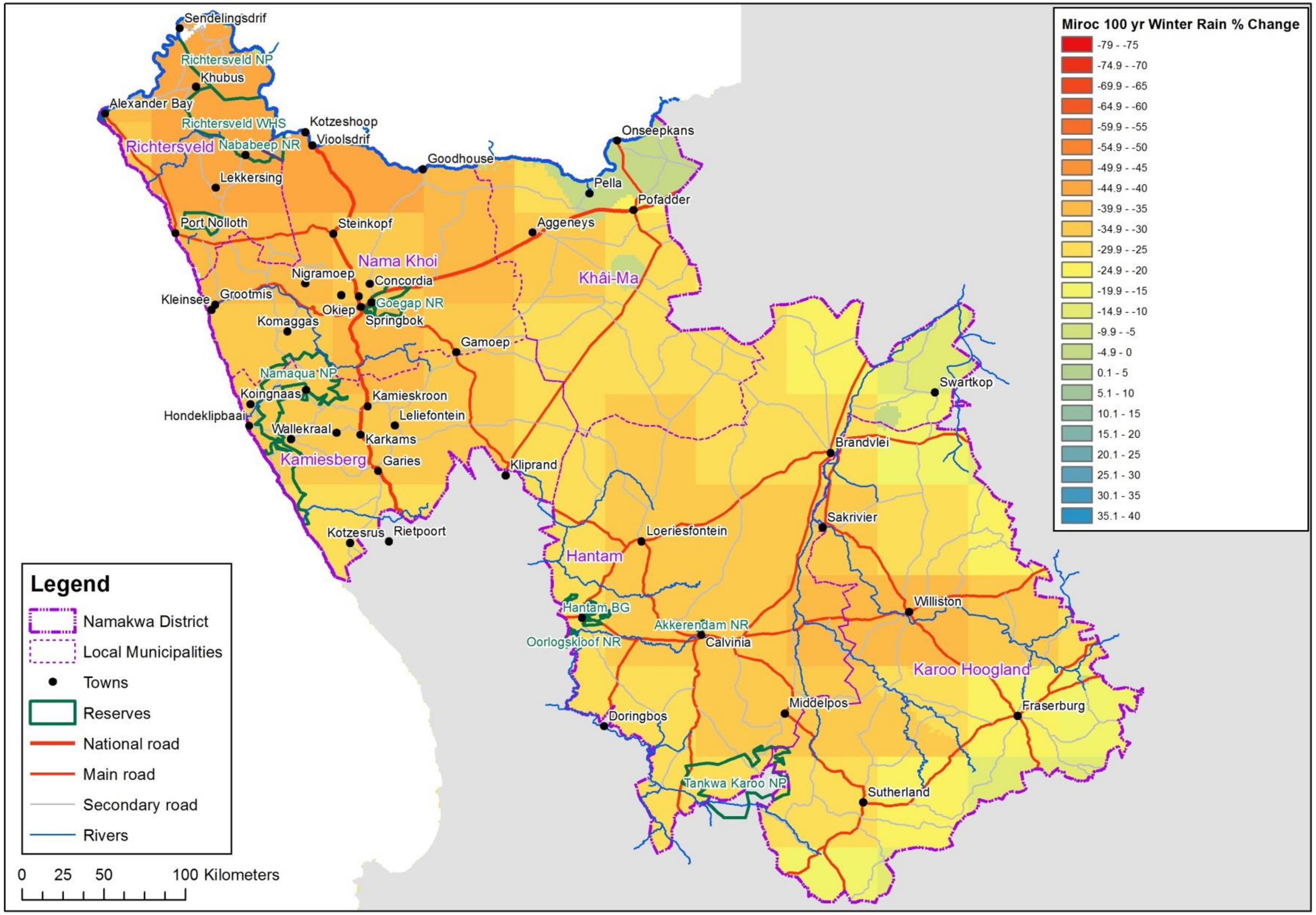

FIGURE 65: WINTER RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

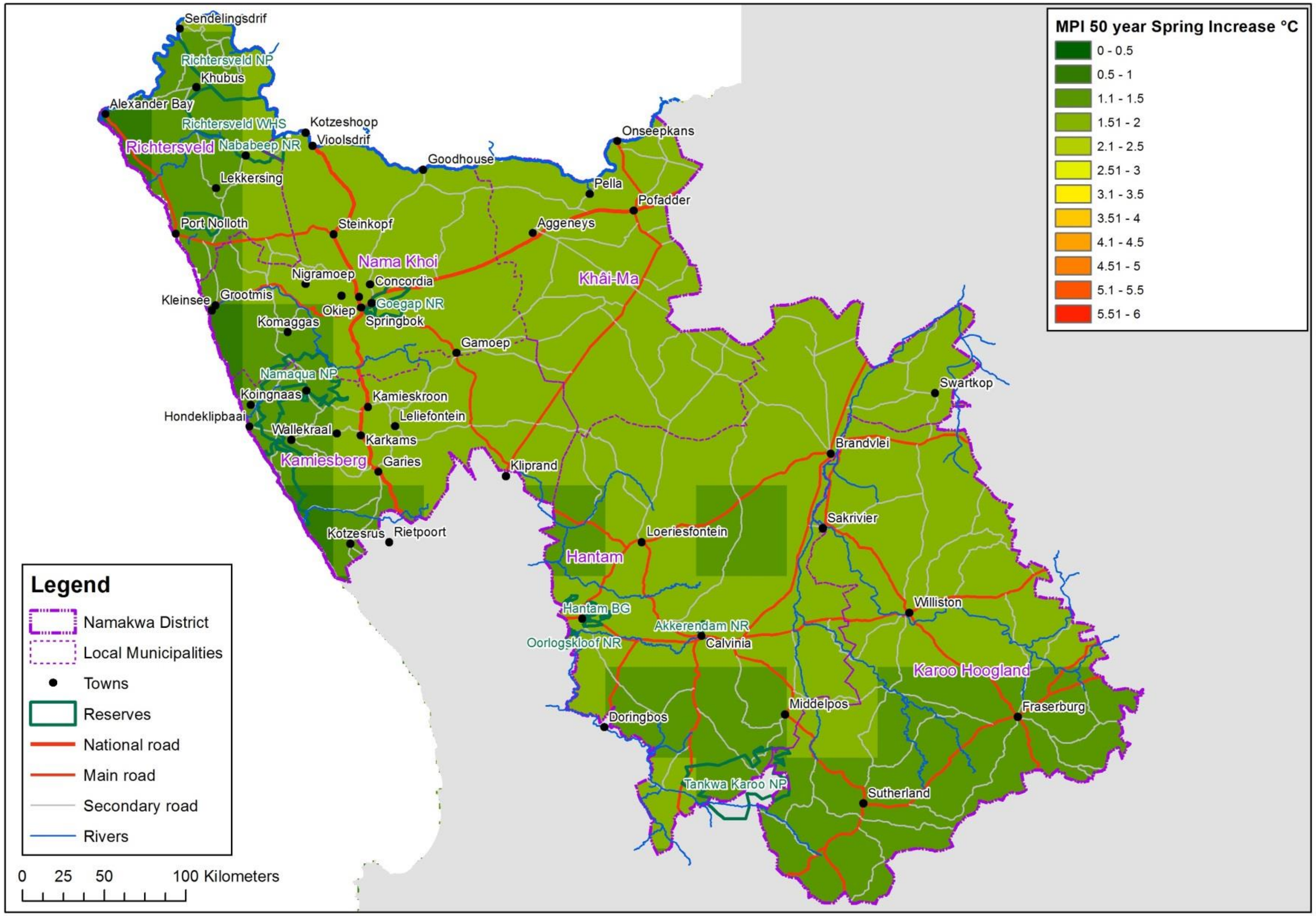

FIGURE 66: SPRING TEMPERATURE INCREASES FOR NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

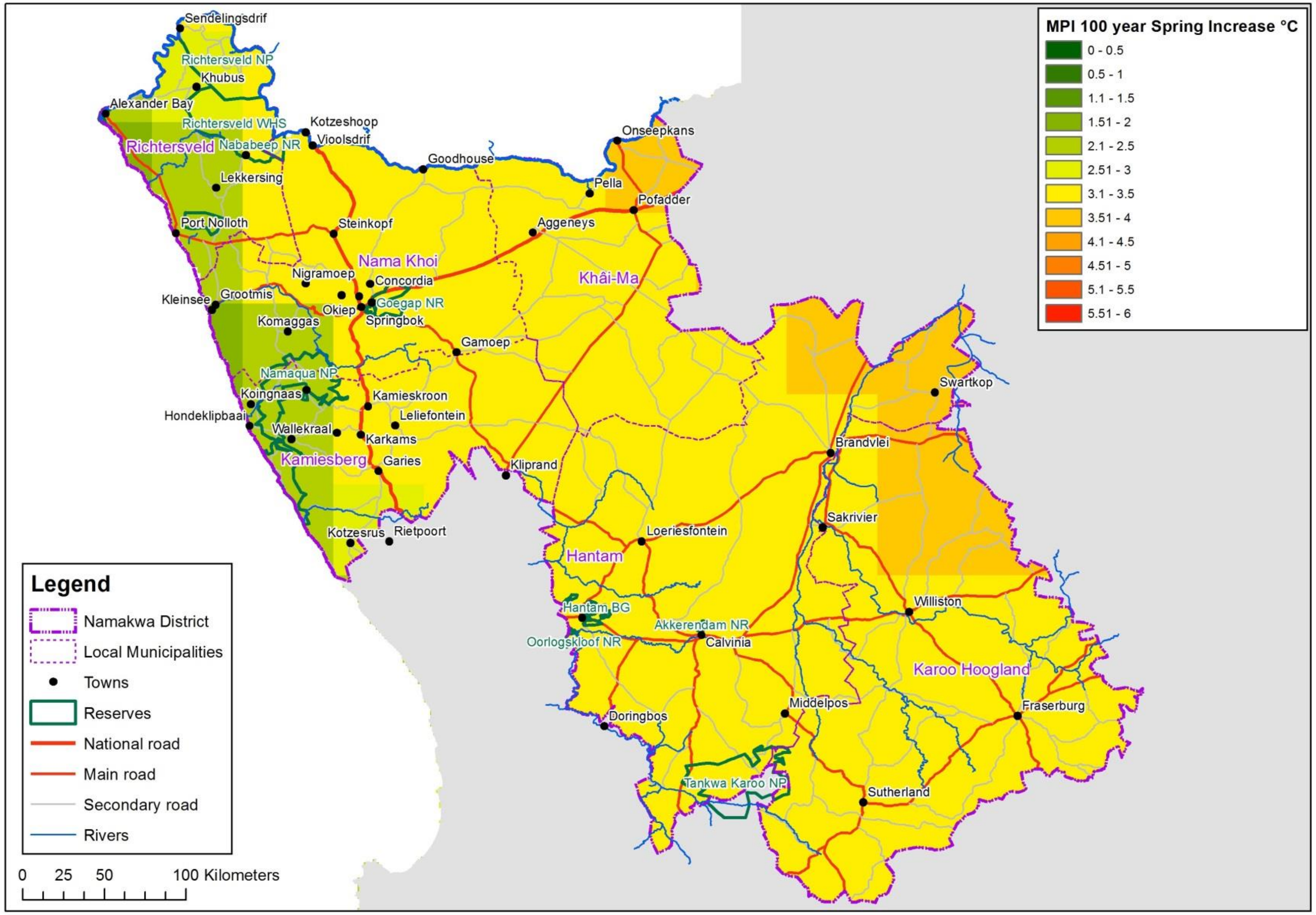

FIGURE 67: SPRING TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

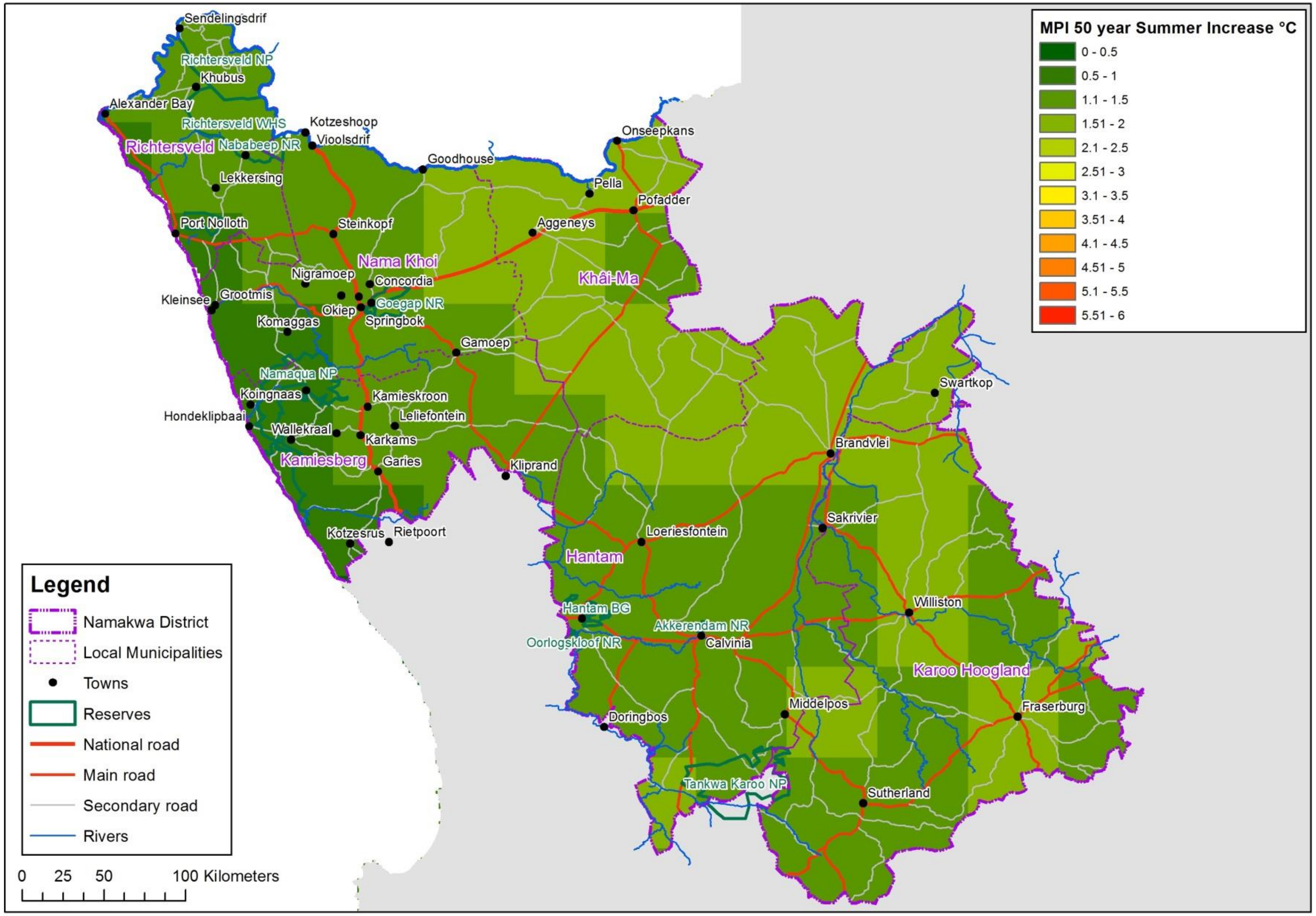

FIGURE 68: SUMMER TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

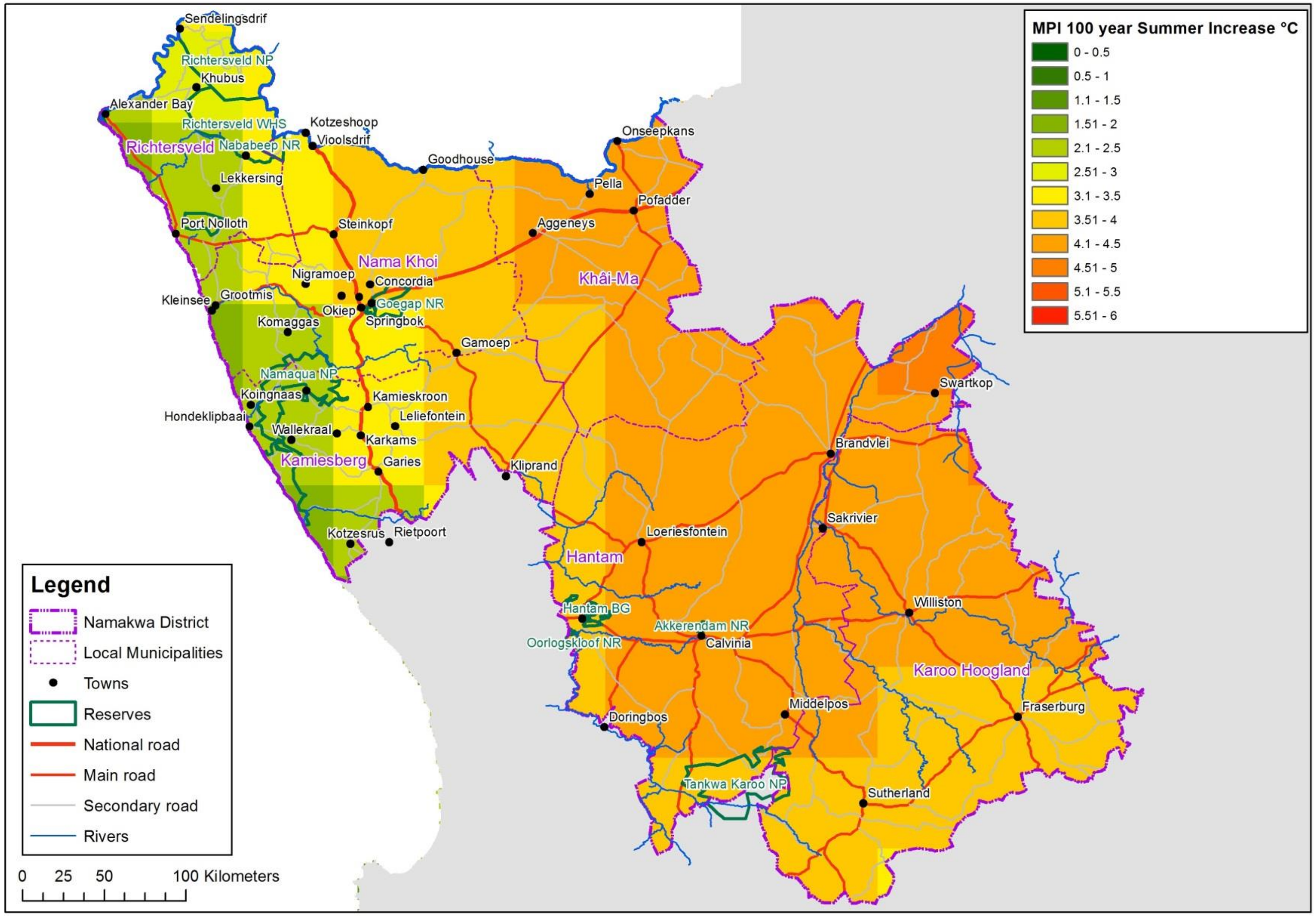

FIGURE 69: SUMMER TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

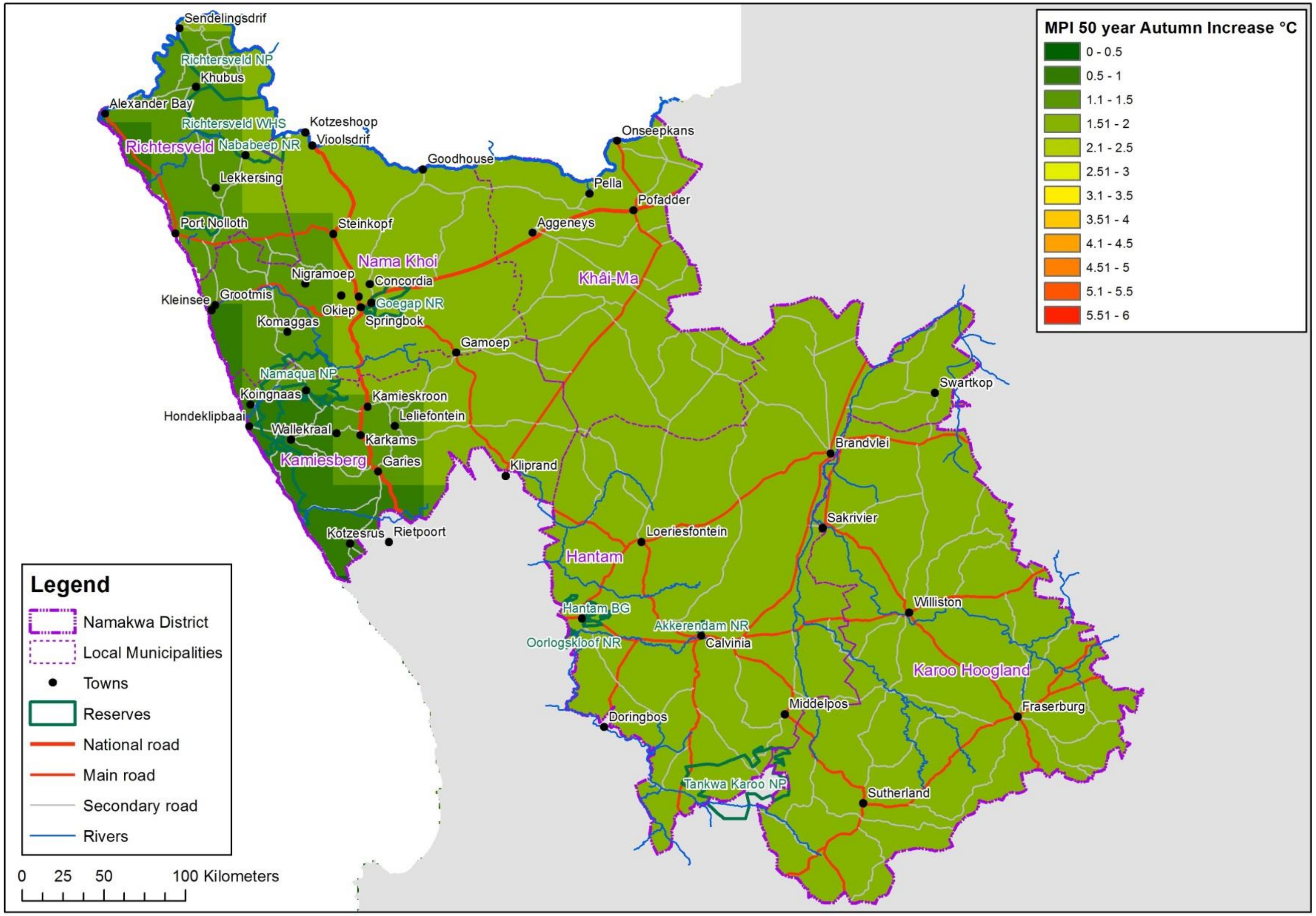

FIGURE 70: AUTUMN TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MIROC MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

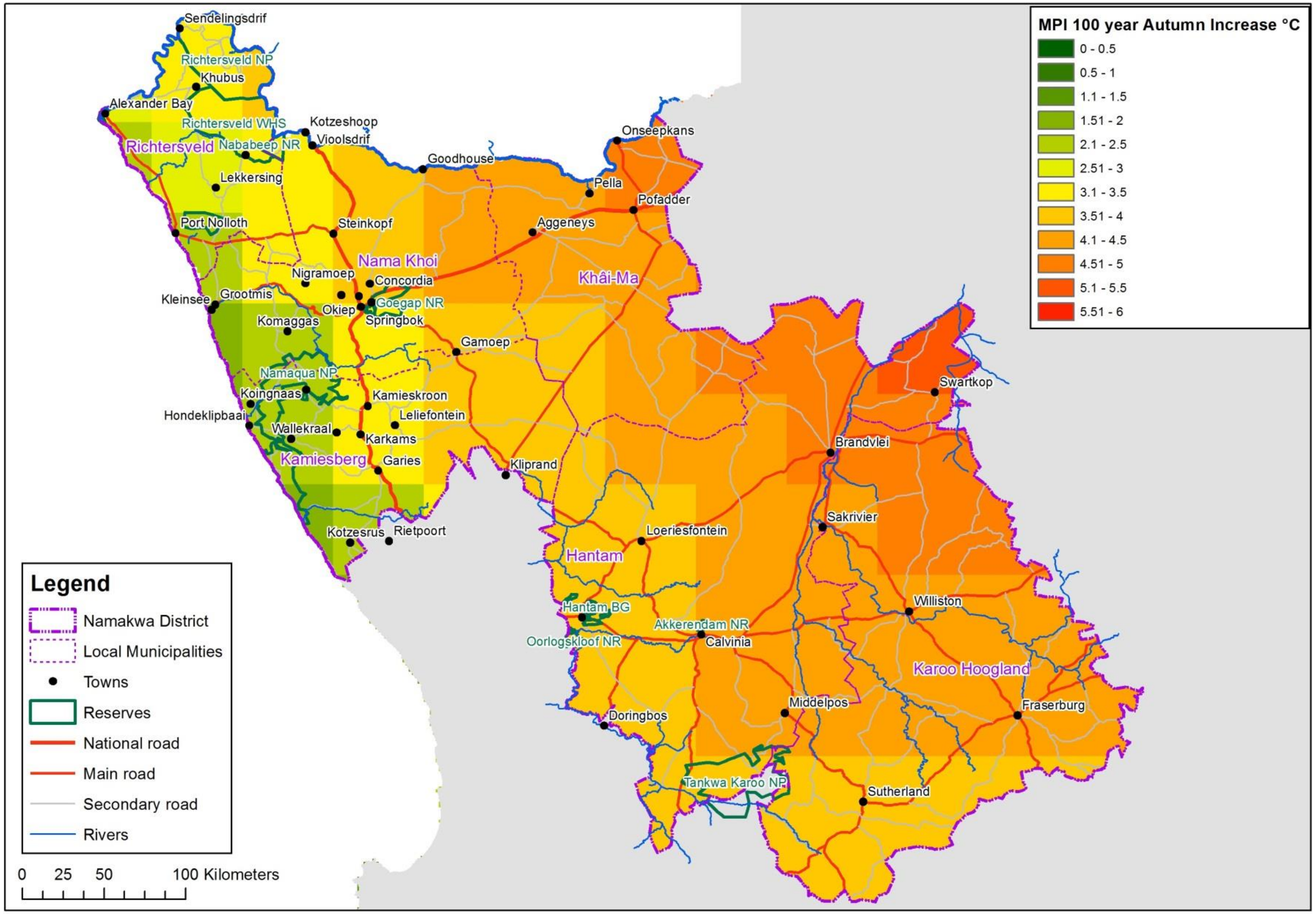

FIGURE 71: AUTUMN TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

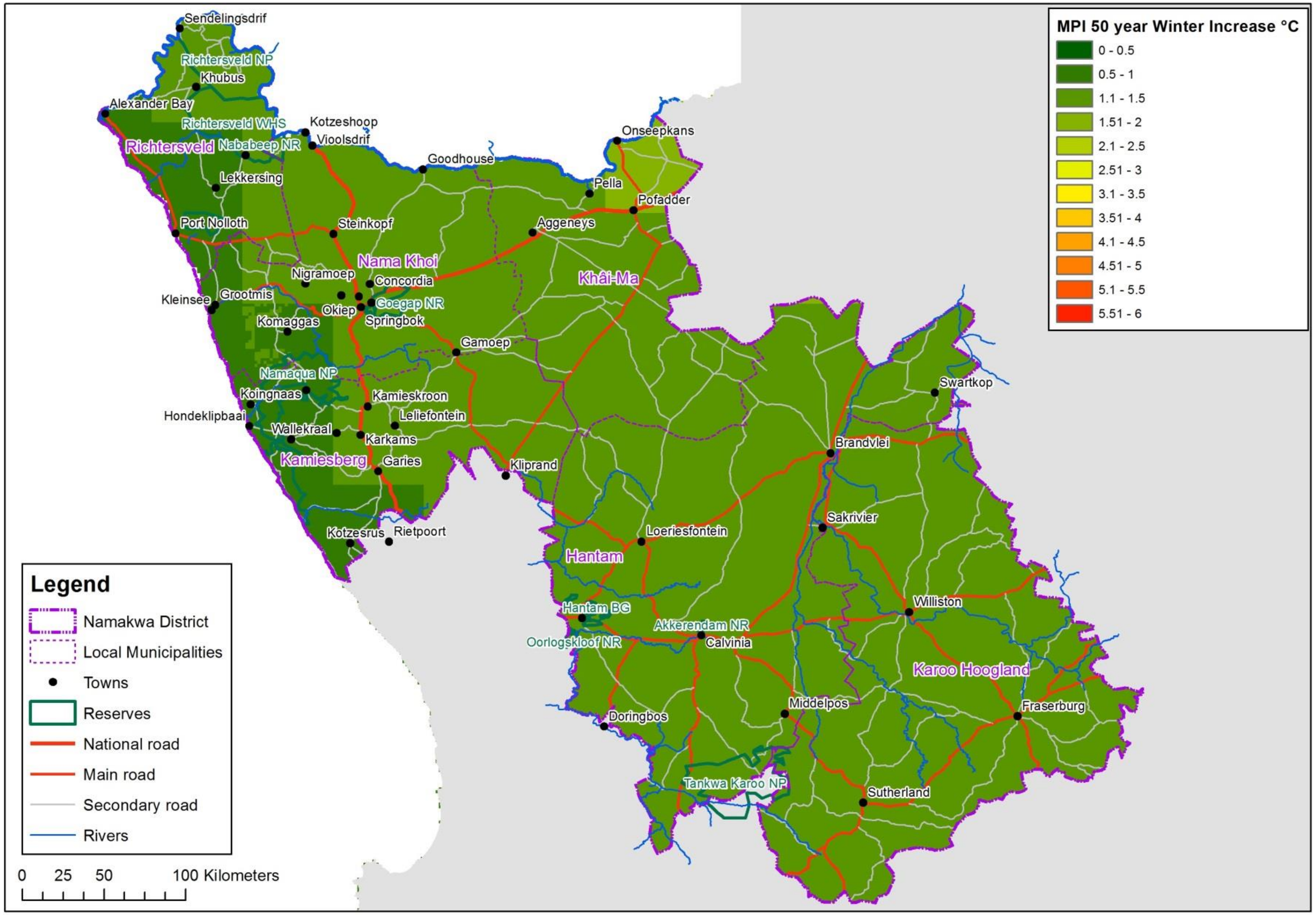

FIGURE 72: WINTER TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

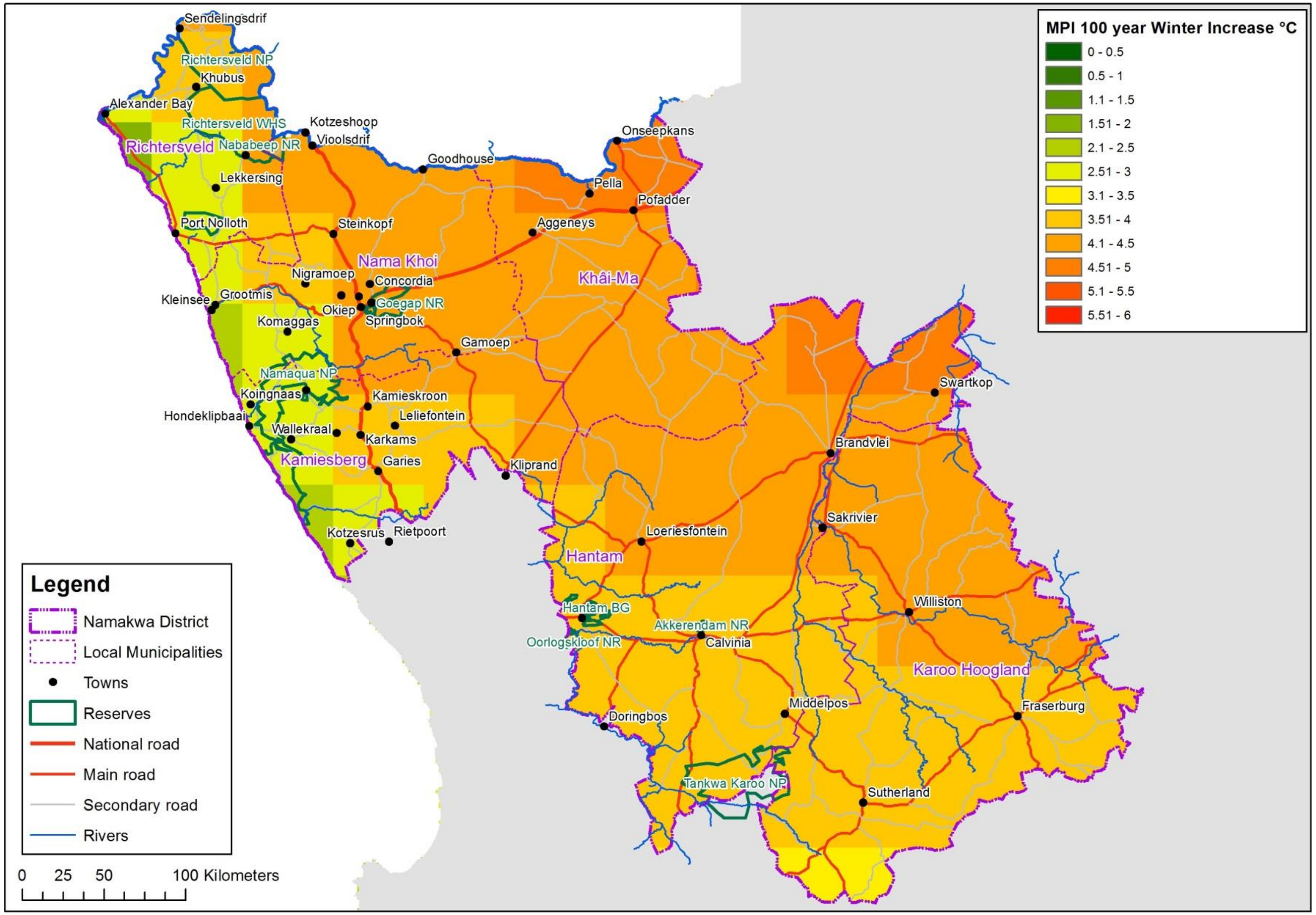

FIGURE 73: WINTER TEMPERATURE INCREASES FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

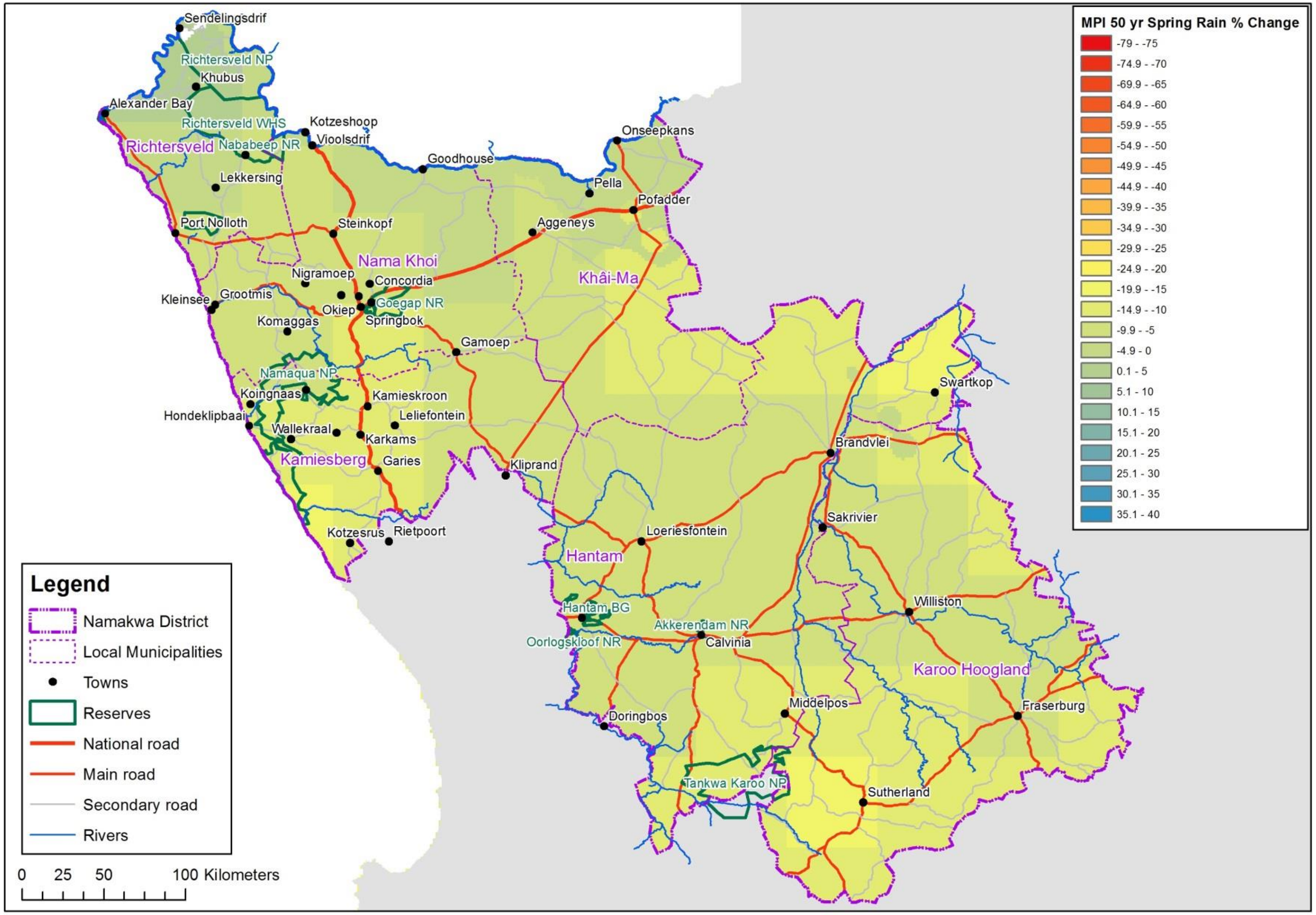

FIGURE 74: SPRING RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

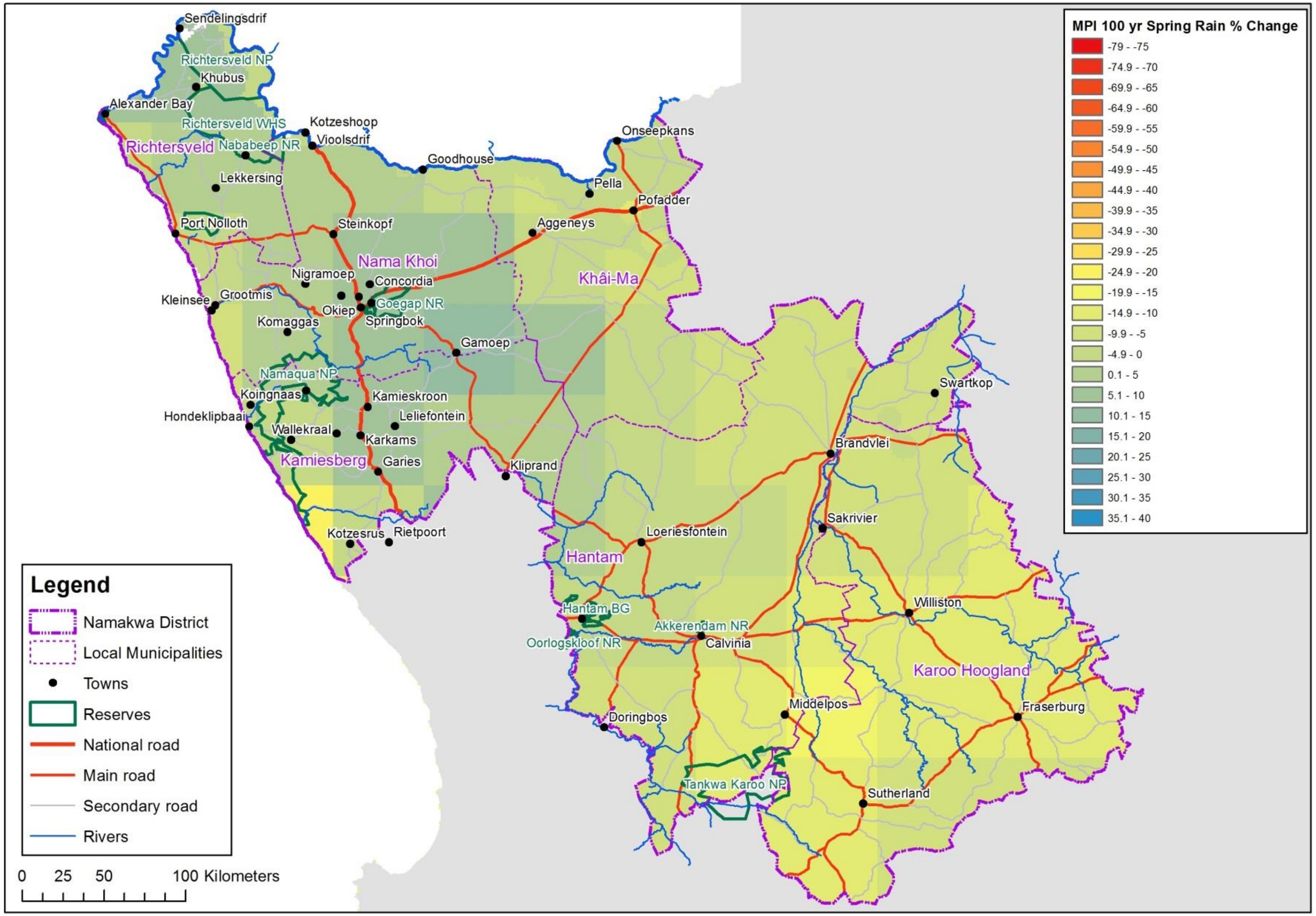

FIGURE 75: SPRING RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

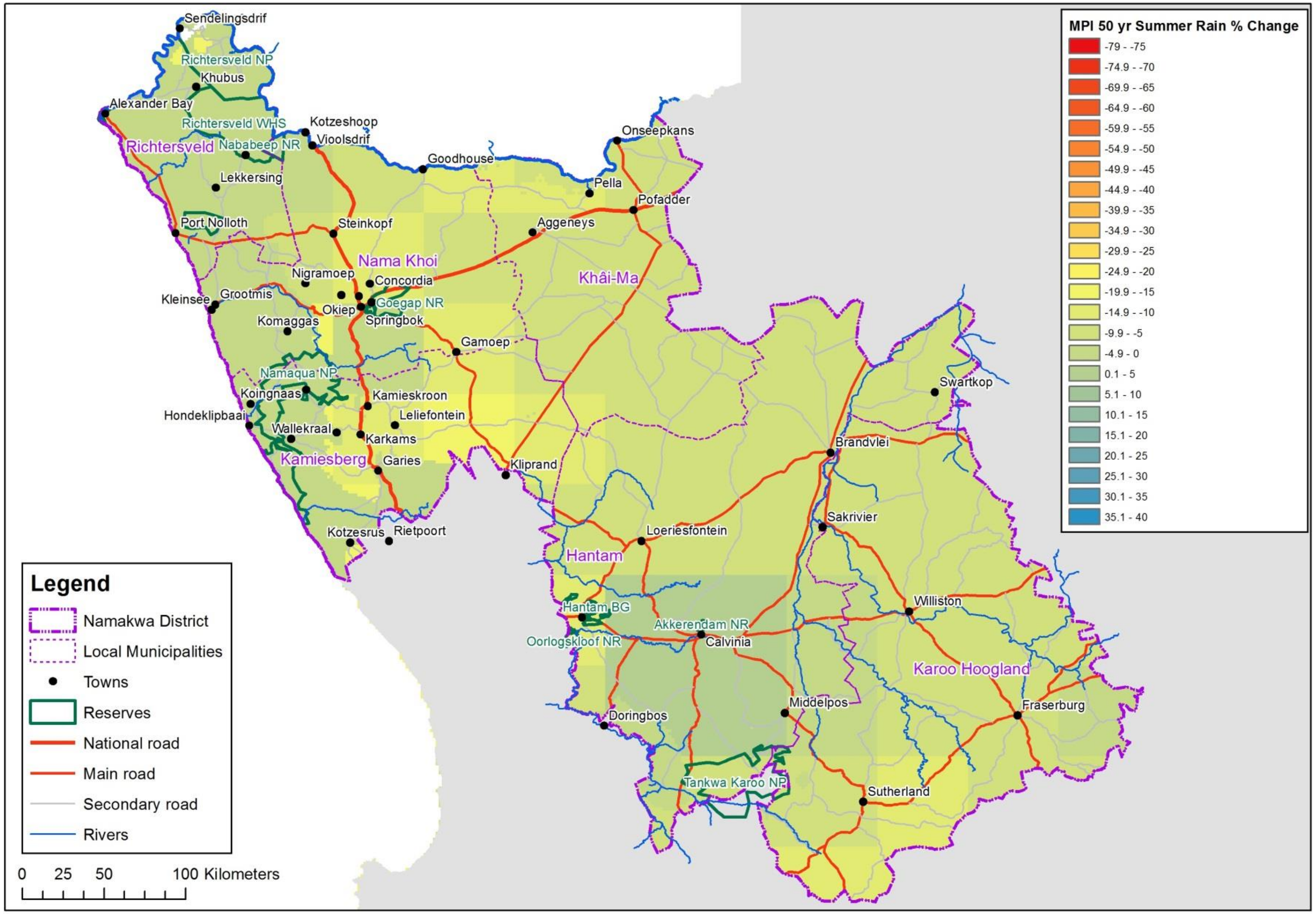

FIGURE 76: SUMMER RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

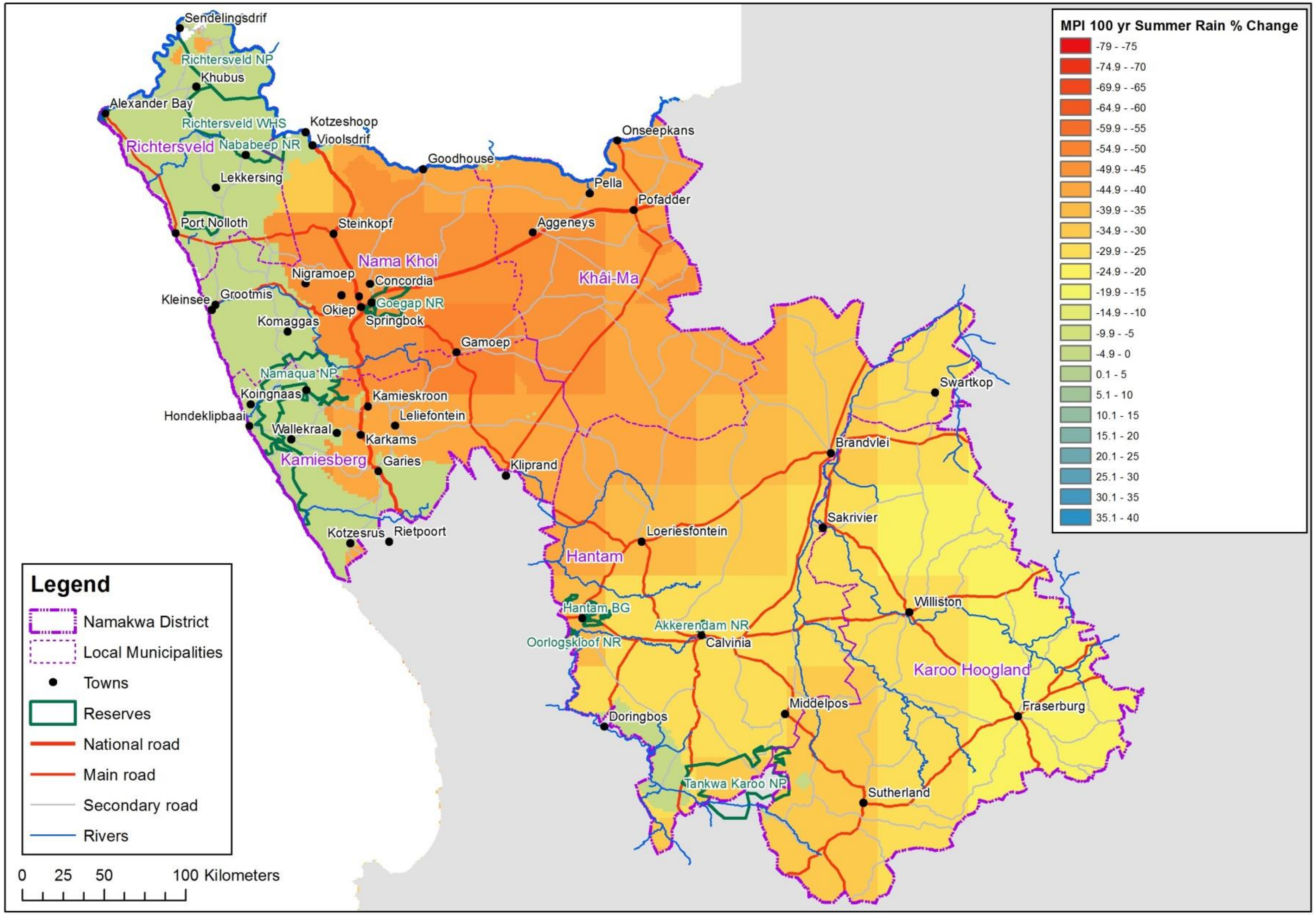

FIGURE 77: SUMMER RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

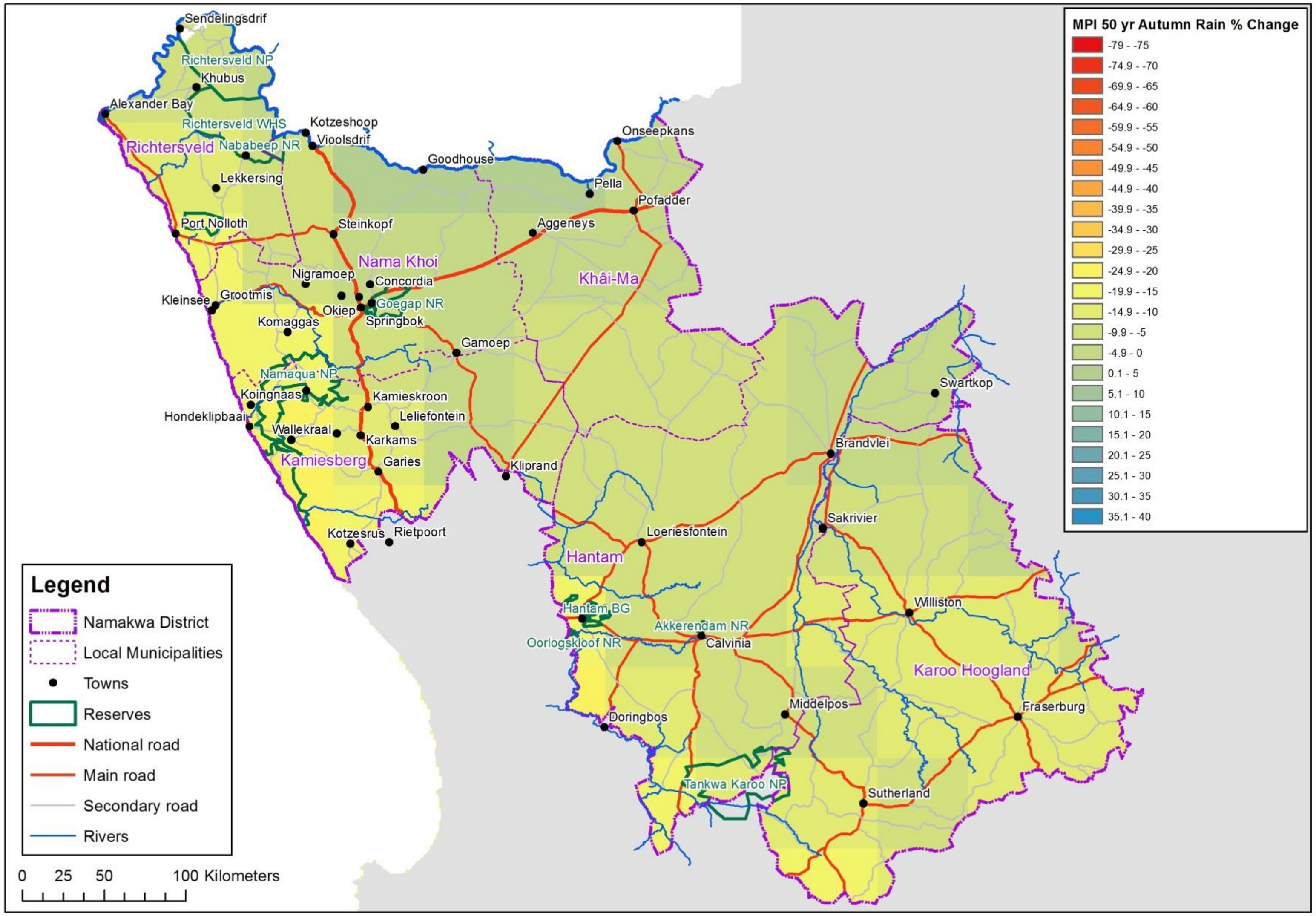

FIGURE 78: AUTUMN RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

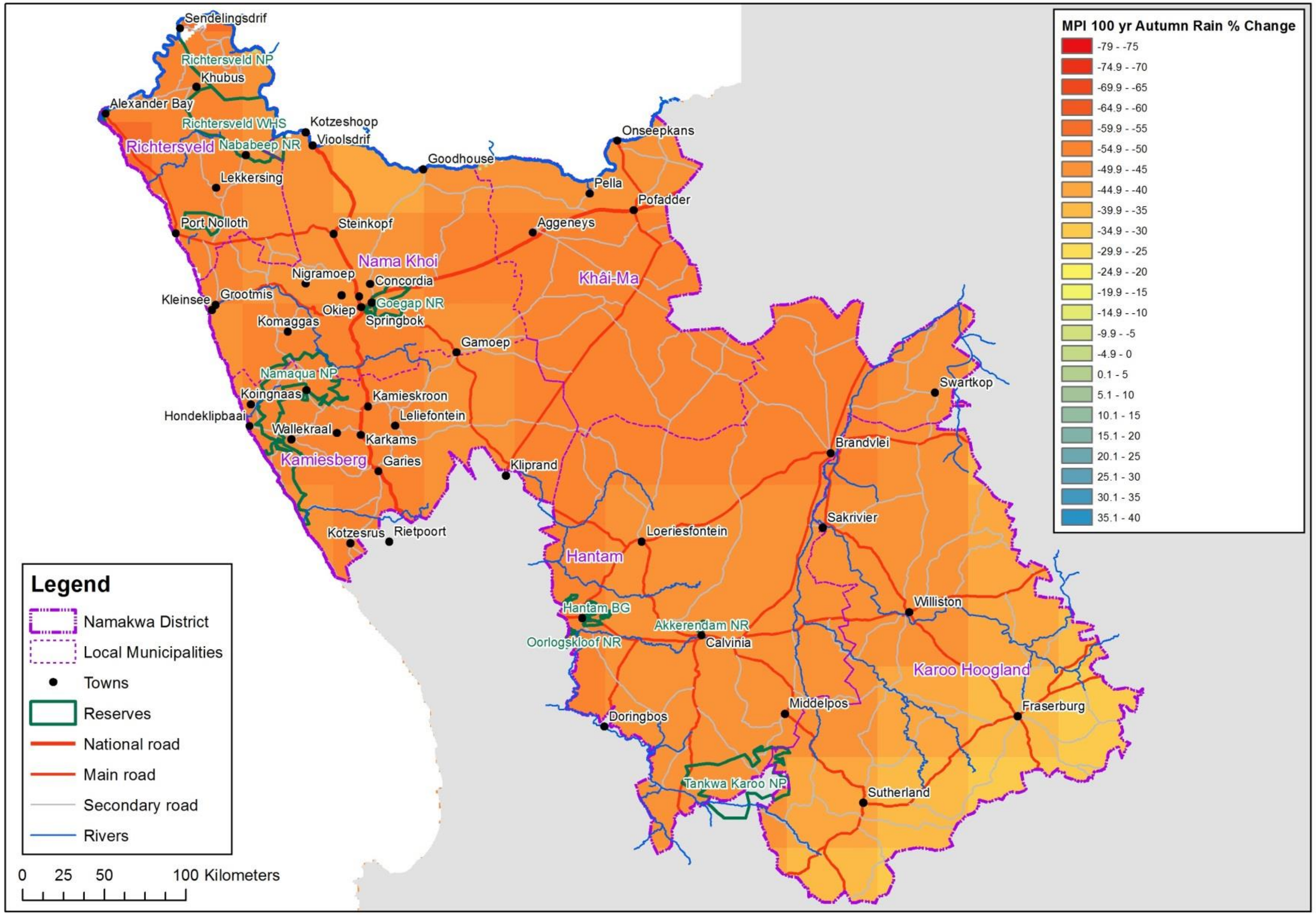

FIGURE 79: AUTUMN RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

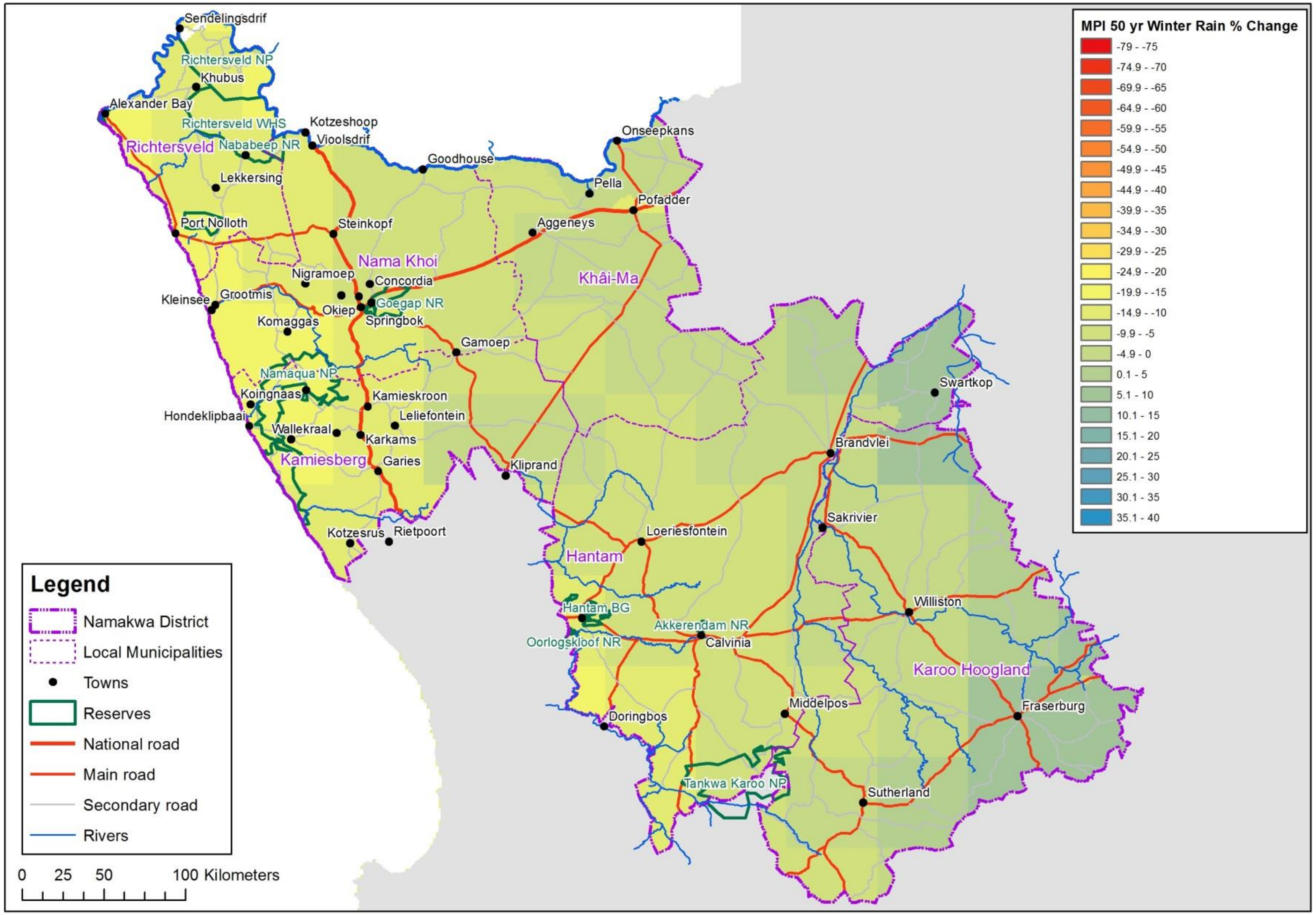

FIGURE 80: WINTER RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES MEDIUM TERM PREDICTED CHANGE (50 YEAR).

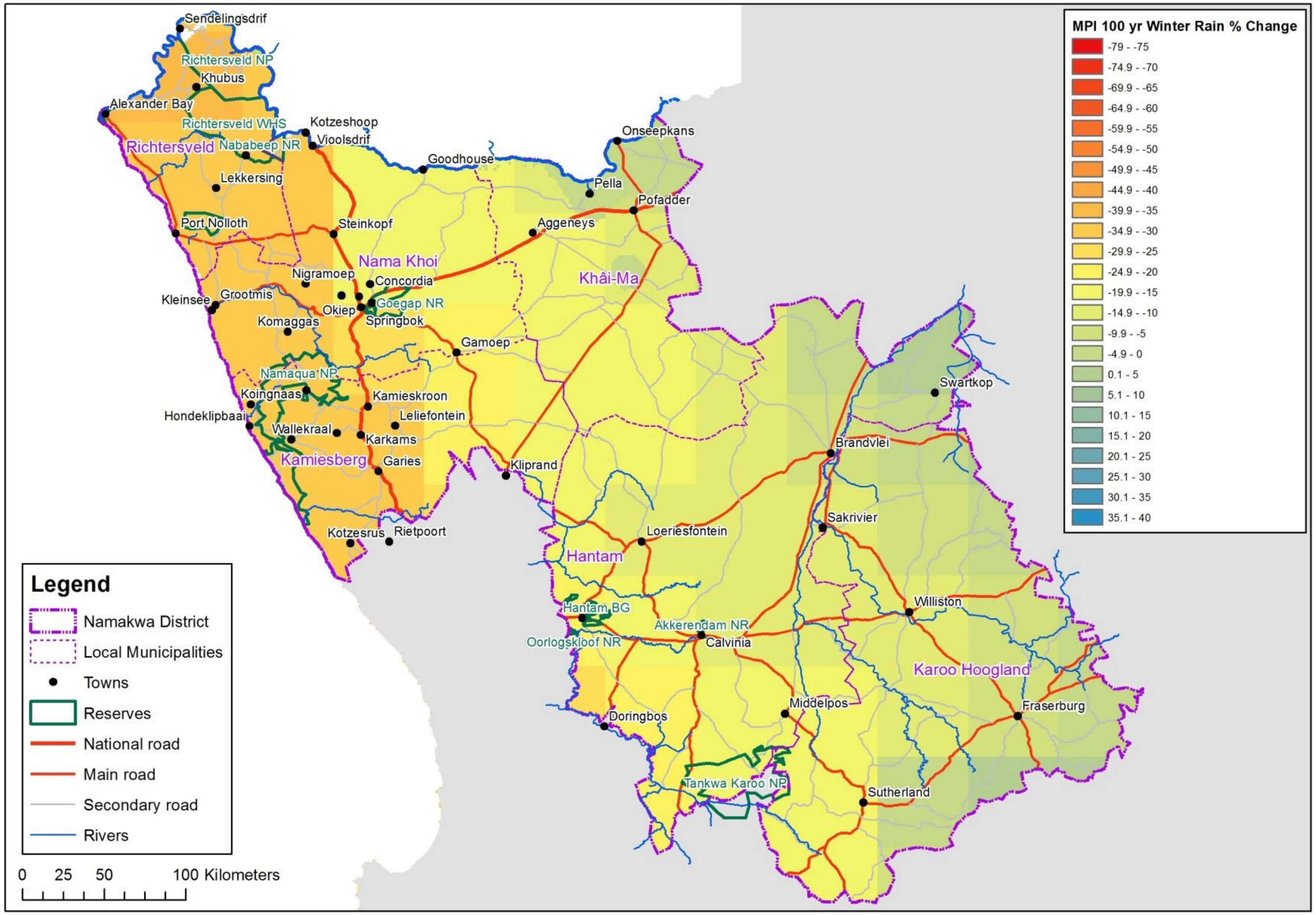

FIGURE 81: WINTER RAINFALL CHANGE FOR THE NAMAKWA DISTRICT FROM THE MPI MODEL. MAP INDICATES LONG TERM PREDICTED CHANGE (100 YEAR).

Biome stability maps

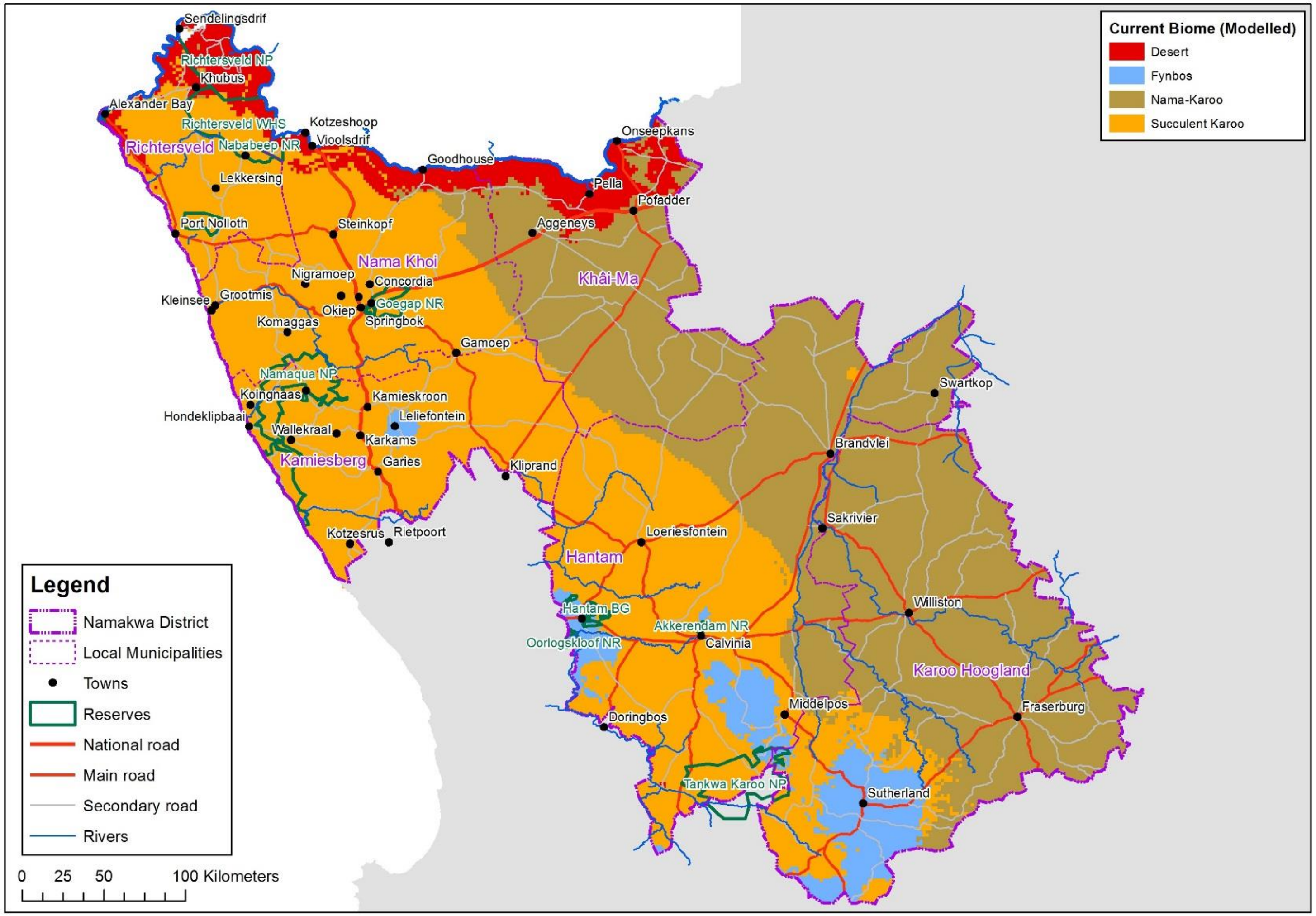

FIGURE 82: CURRENT MODELLED DISTRIBUTION OF BIOMES IN THE NAMAKWA DISTRICT.

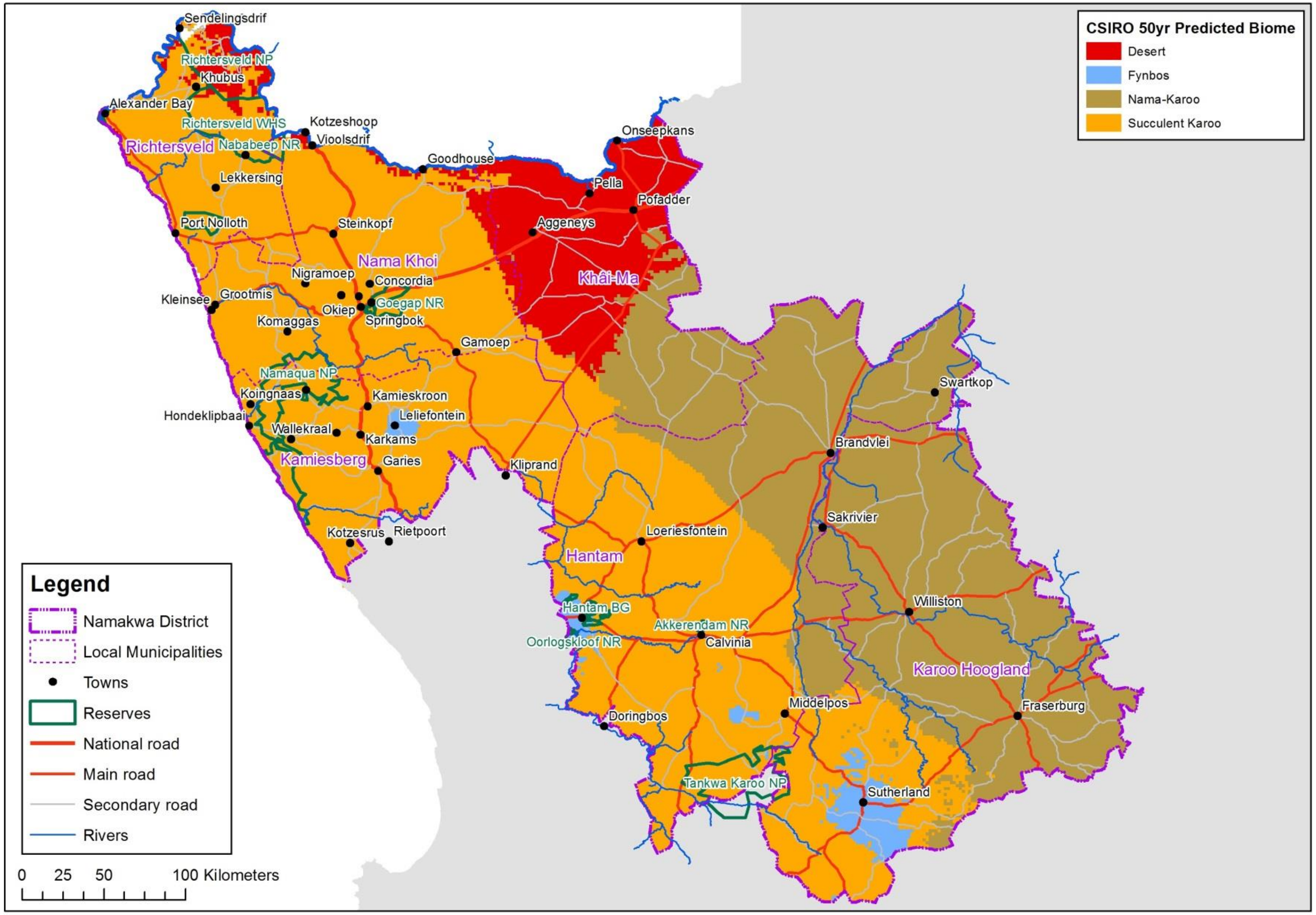

FIGURE 83: PREDICTIONS OF BIOME CLIMATE ENVELOPES UNDER THE CSIRO MODEL, FOR THE MEDIUM TERM (50 YEARS).

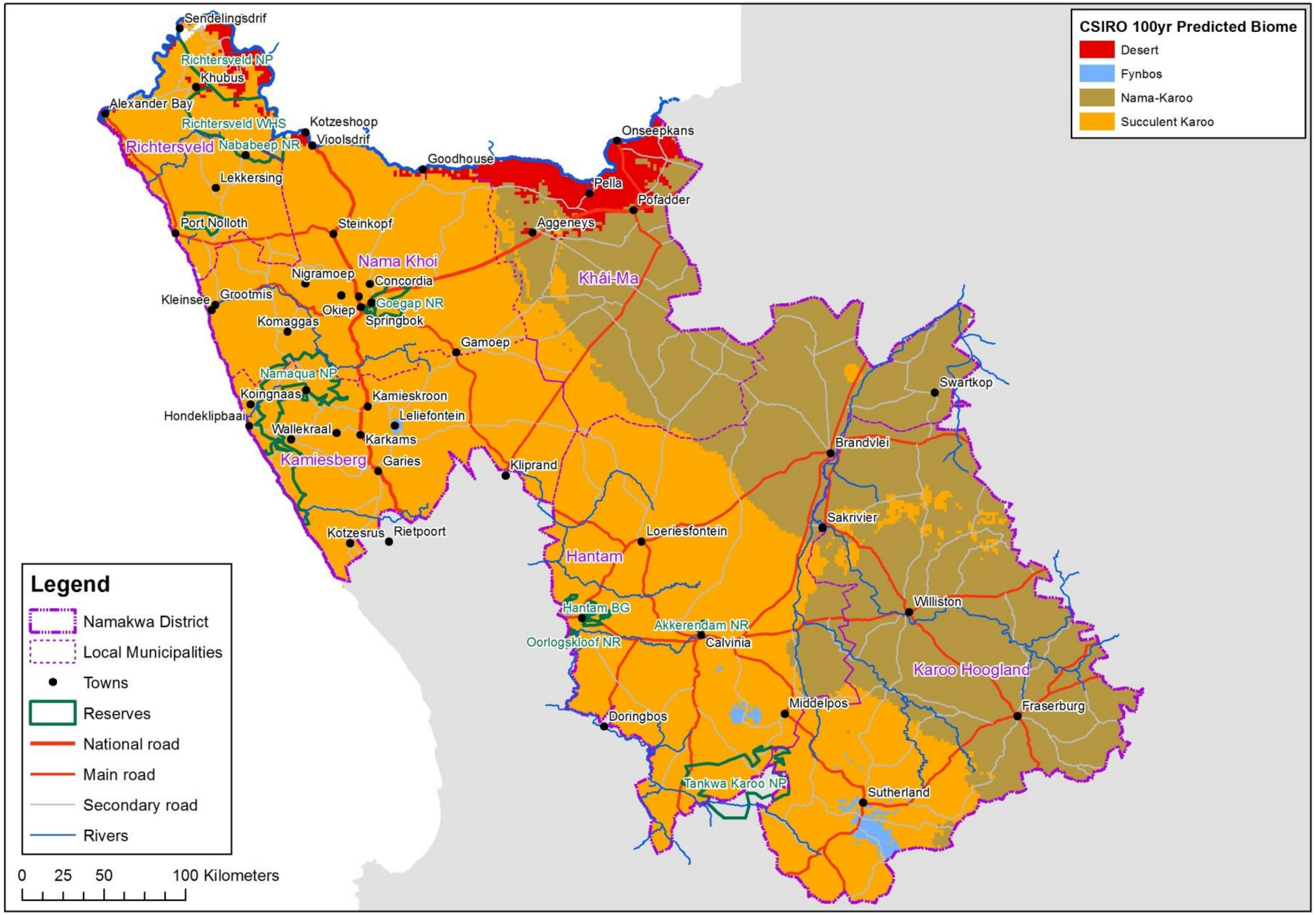

FIGURE 84: PREDICTIONS OF BIOME CLIMATE ENVELOPES UNDER THE CSIRO MODEL, FOR THE LONGER TERM (100 YEARS).

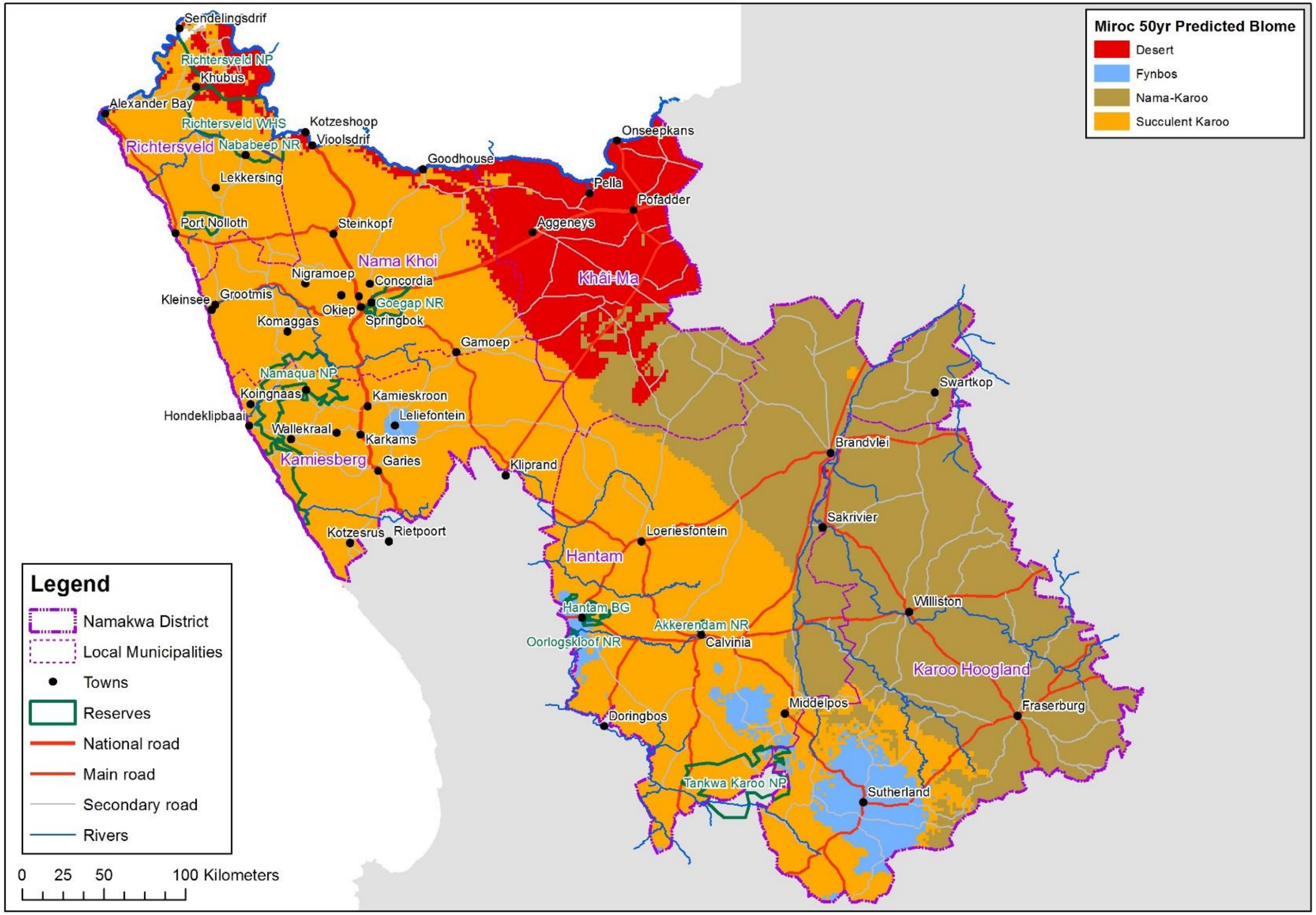

FIGURE 85: PREDICTIONS OF BIOME CLIMATE ENVELOPES UNDER THE MIROC MODEL, FOR THE MEDIUM TERM (50 YEARS).

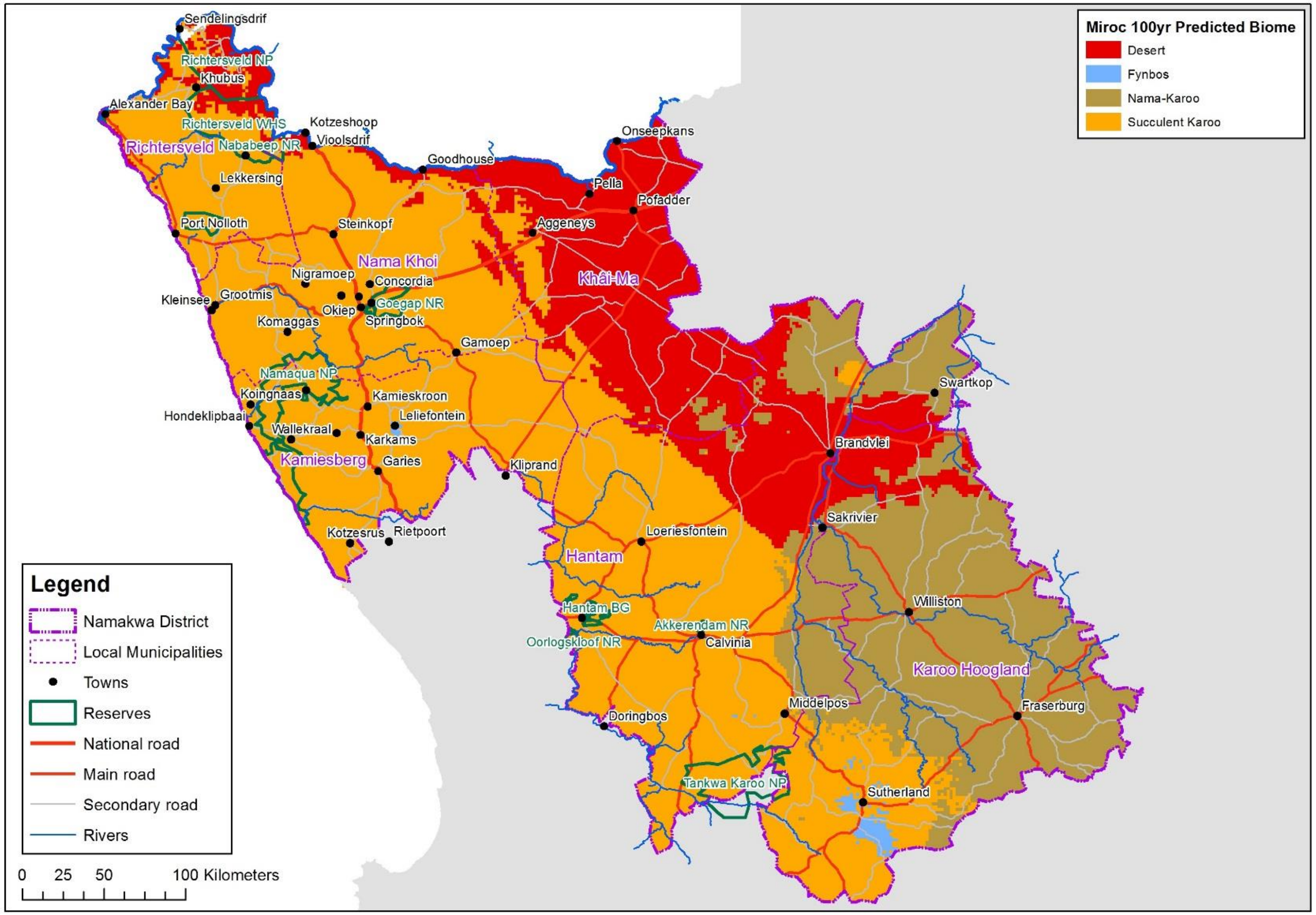

FIGURE 86: PREDICTIONS OF BIOME CLIMATE ENVELOPES UNDER THE MIROC MODEL, FOR THE LONGER TERM (100 YEARS).

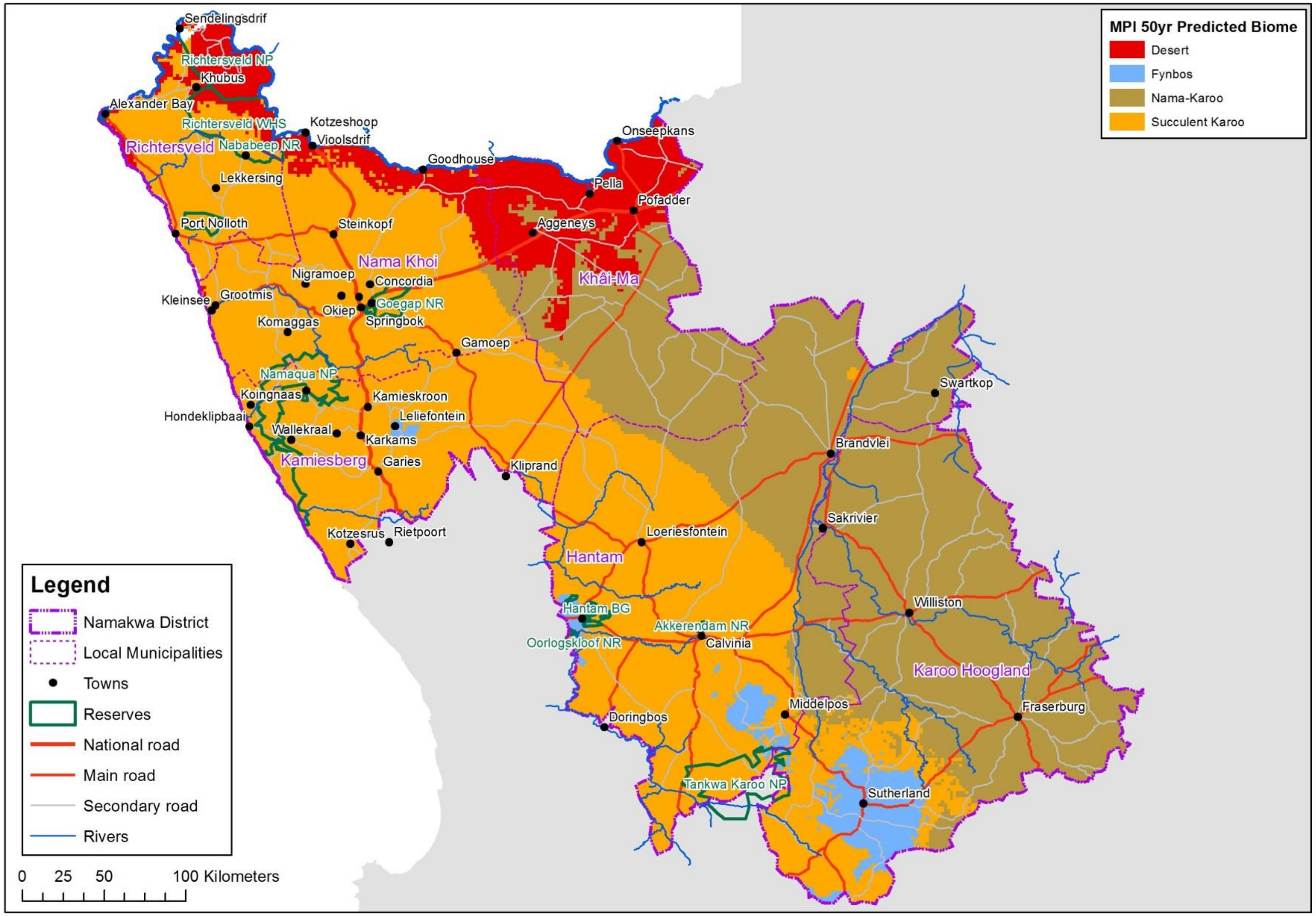

FIGURE 87: PREDICTIONS OF BIOME CLIMATE ENVELOPES UNDER THE MPI MODEL, FOR THE MEDIUM TERM (50 YEARS).

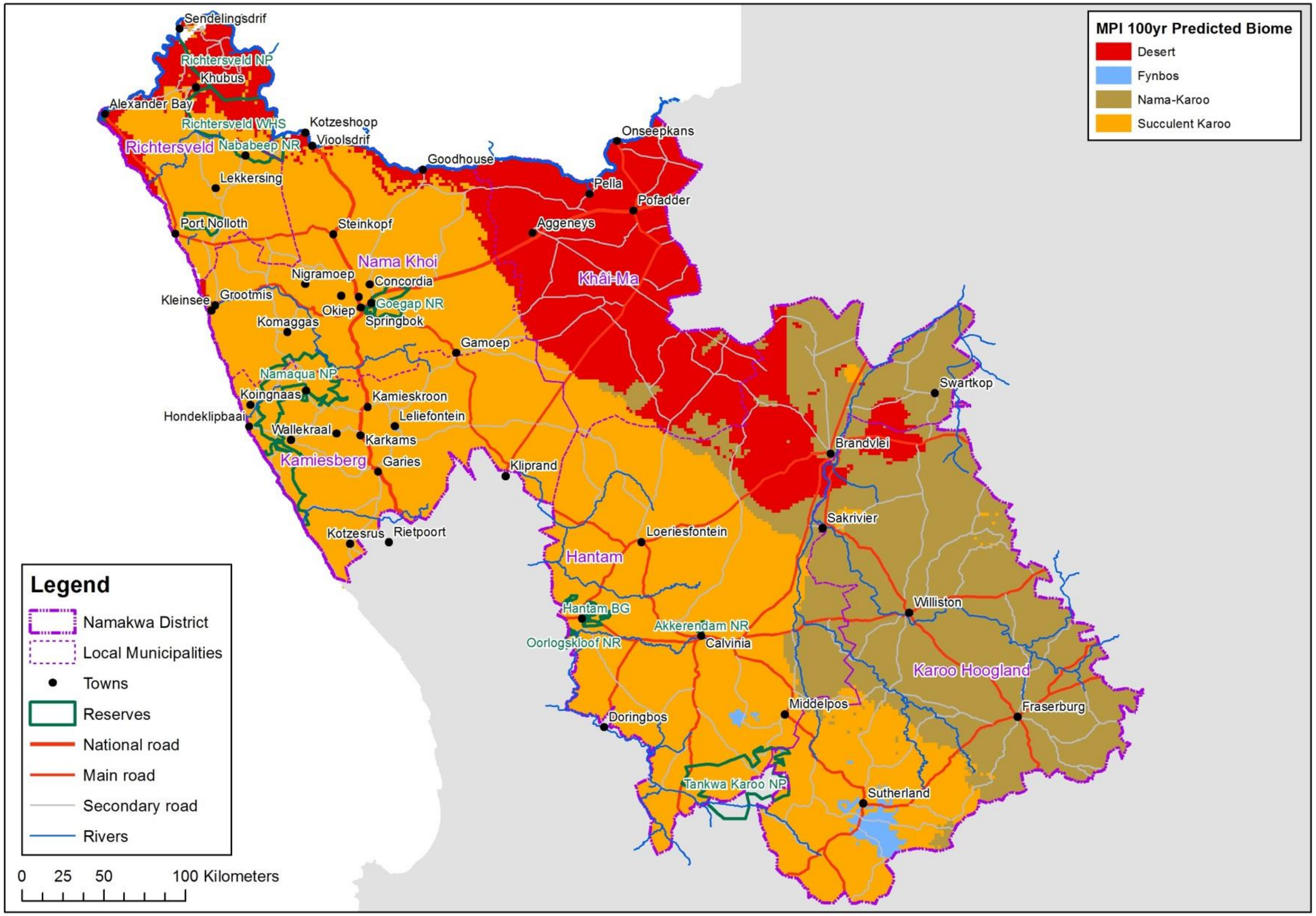

FIGURE 88: PREDICTIONS OF BIOME CLIMATE ENVELOPES UNDER THE MPI MODEL, FOR THE LONGER TERM (100 YEARS).

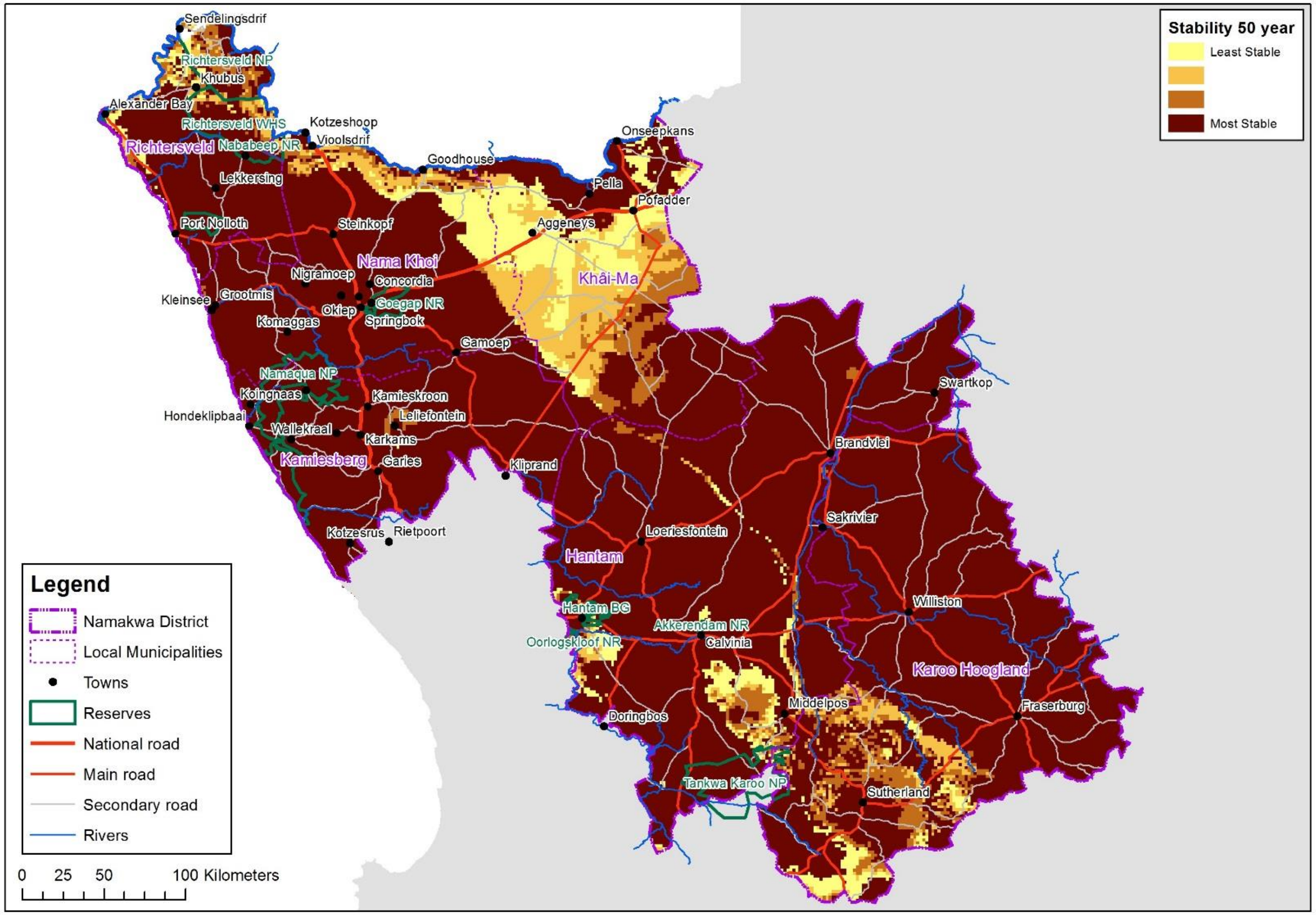

FIGURE 89: AREAS OF BIOME STABILITY IN THE FACE OF CLIMATE CHANGE, IN THE MEDIUM TERM, ACCORDING TO NICHE MODELLING RESULTS USING STATISTICALLY DOWNSCALED FUTURE CLIMATE SCENARIOS. THE DARKEST AREAS ARE PREDICTED TO STAY WITHIN THEIR CURRENT CLIMATE ENVELOPES UNDER ALL THREE MODELS, AND HENCE ARE MOST LIKELY TO MAINTAIN A STABLE ECOLOGICAL COMPOSITION AND STRUCTURE. THE LIGHT AREAS ARE AREAS WHERE BIOMES ARE MOST AT RISK OF ECOLOGICAL COMPOSITION AND STRUCTURAL CHANGE IN THE FACE OF CLIMATE CHANGE IN THE MEDIUM TERM.

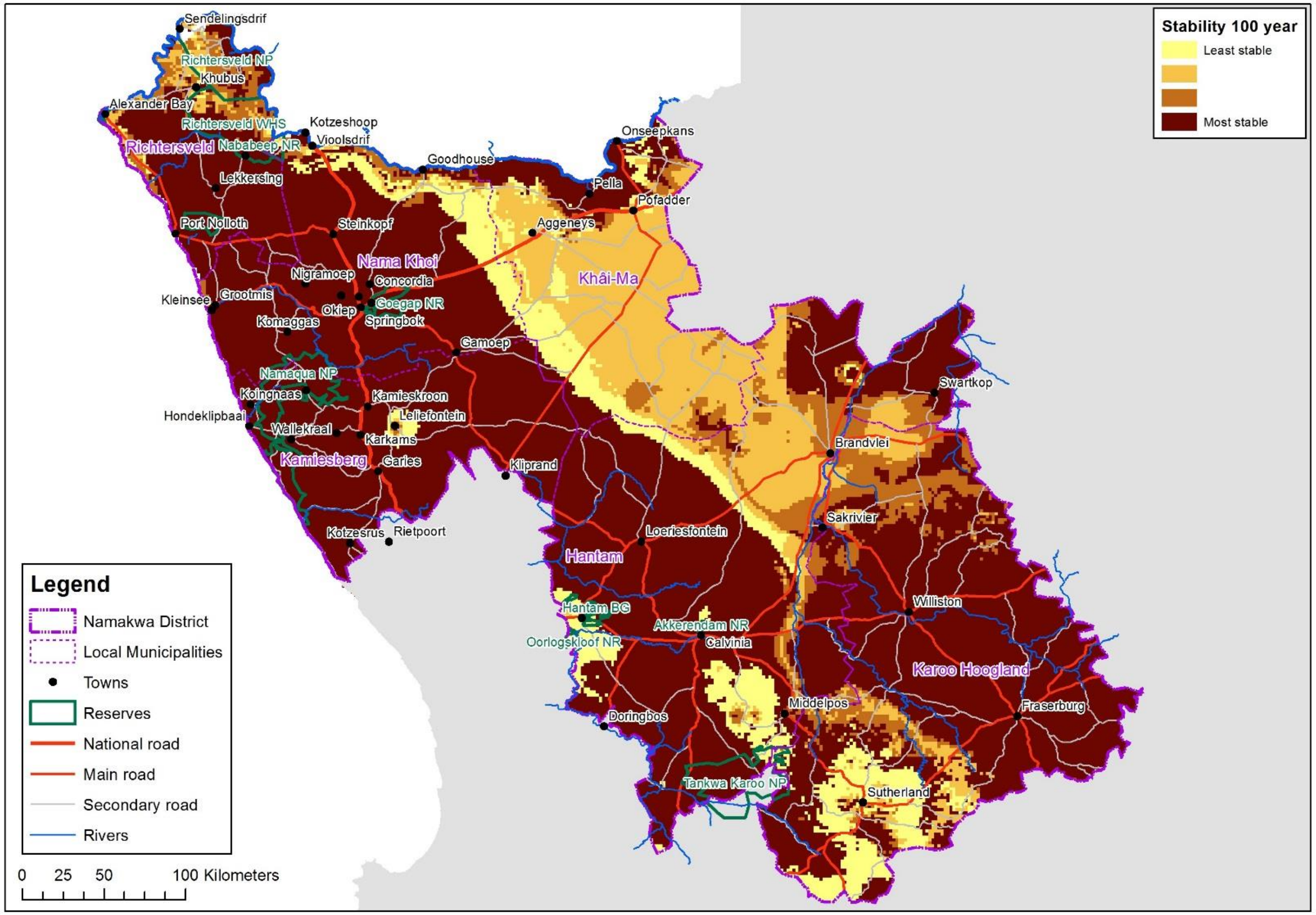

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FIGURE 90: AREAS OF BIOME STABILITY IN THE FACE OF CLIMATE CHANGE, UNDER A RANGE OF CLIMATE SCENARIOS, ACCORDING TO NICHE MODELLING RESULTS FOR THE LONGER TERM (100 YEARS) USING STATISTICALLY DOWNSCALED FUTURE CLIMATE SCENARIOS. THE DARKEST AREAS ARE PREDICTED TO STAY WITHIN THEIR CURRENT CLIMATE ENVELOPES UNDER ALL THREE CLIMATE MODELS, AND HENCE ARE MOST LIKELY TO MAINTAIN A STABLE ECOLOGICAL COMPOSITION AND STRUCTURE. THE LIGHT AREAS ARE AREAS WHERE BIOMES ARE MOST AT RISK OF ECOLOGICAL COMPOSITION AND STRUCTURAL CHANGE IN THE FACE OF CLIMATE CHANGE.

Water related ecological infrastructure maps

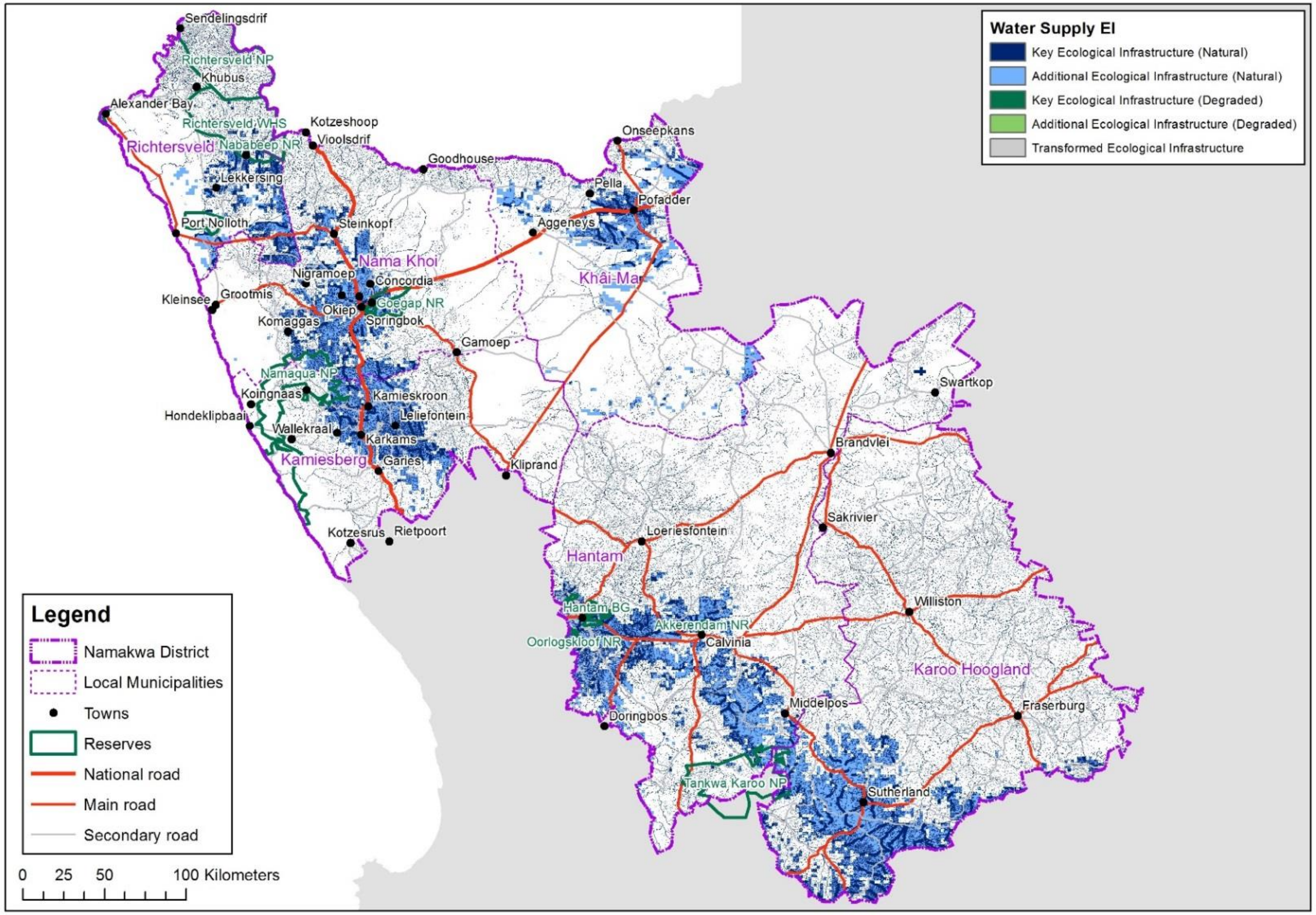

FIGURE 91: AREAS OF ECOLOGICAL INFRASTRUCTURE IMPORTANT FOR IMPORTANT FOR WATER PRODUCTION AND STREAM FLOW AUGMENTATION.

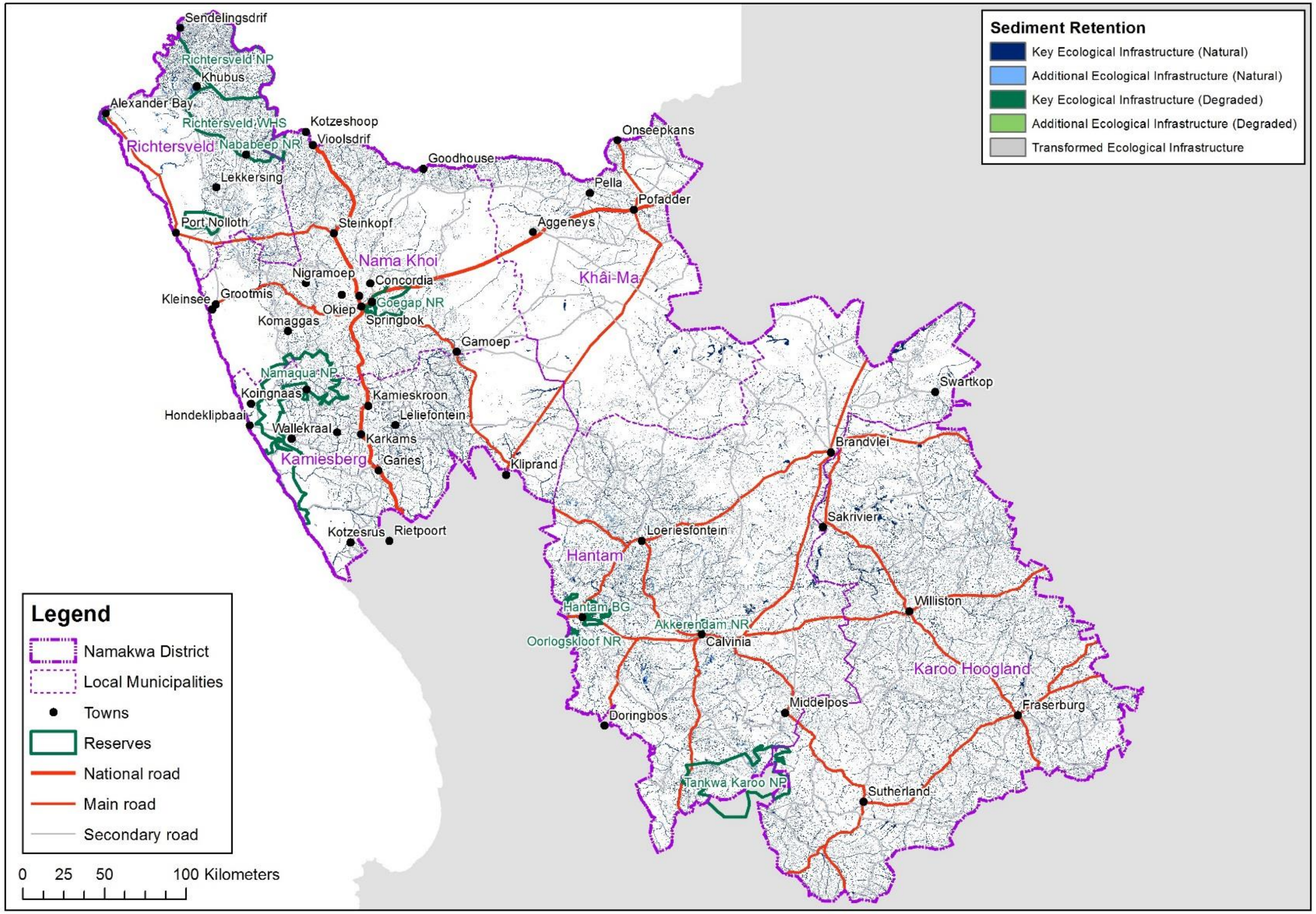

FIGURE 92: AREAS OF ECOLOGICAL INFRASTRUCTURE IMPORTANT FOR EROSION CONTROL AND SEDIMENT RETENTION.

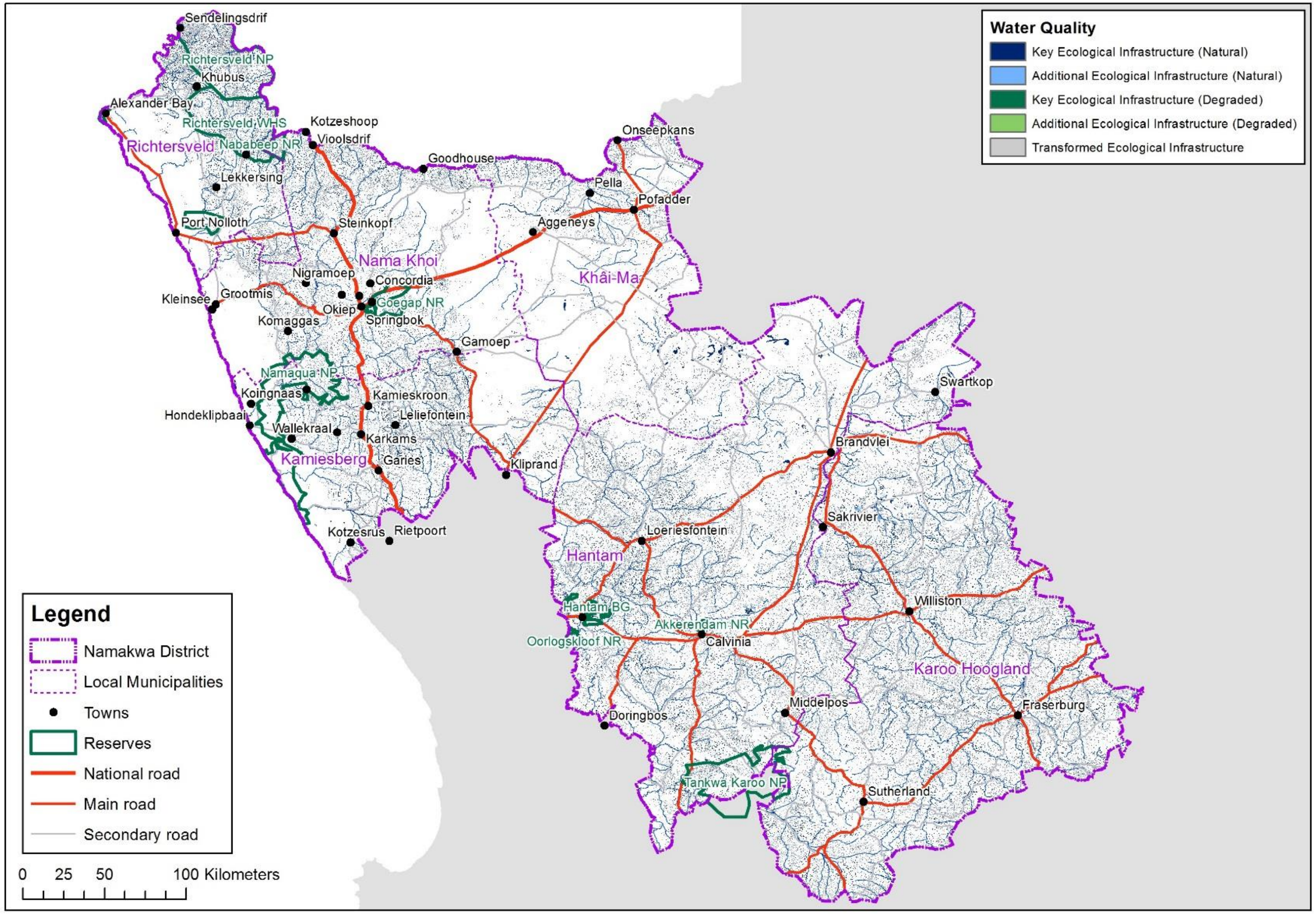

FIGURE 93: AREAS OF ECOLOGICAL INFRASTRUCTURE IMPORTANT FOR IMPORTANT FOR MAINTAINING OR ENHANCING WATER QUALITY.

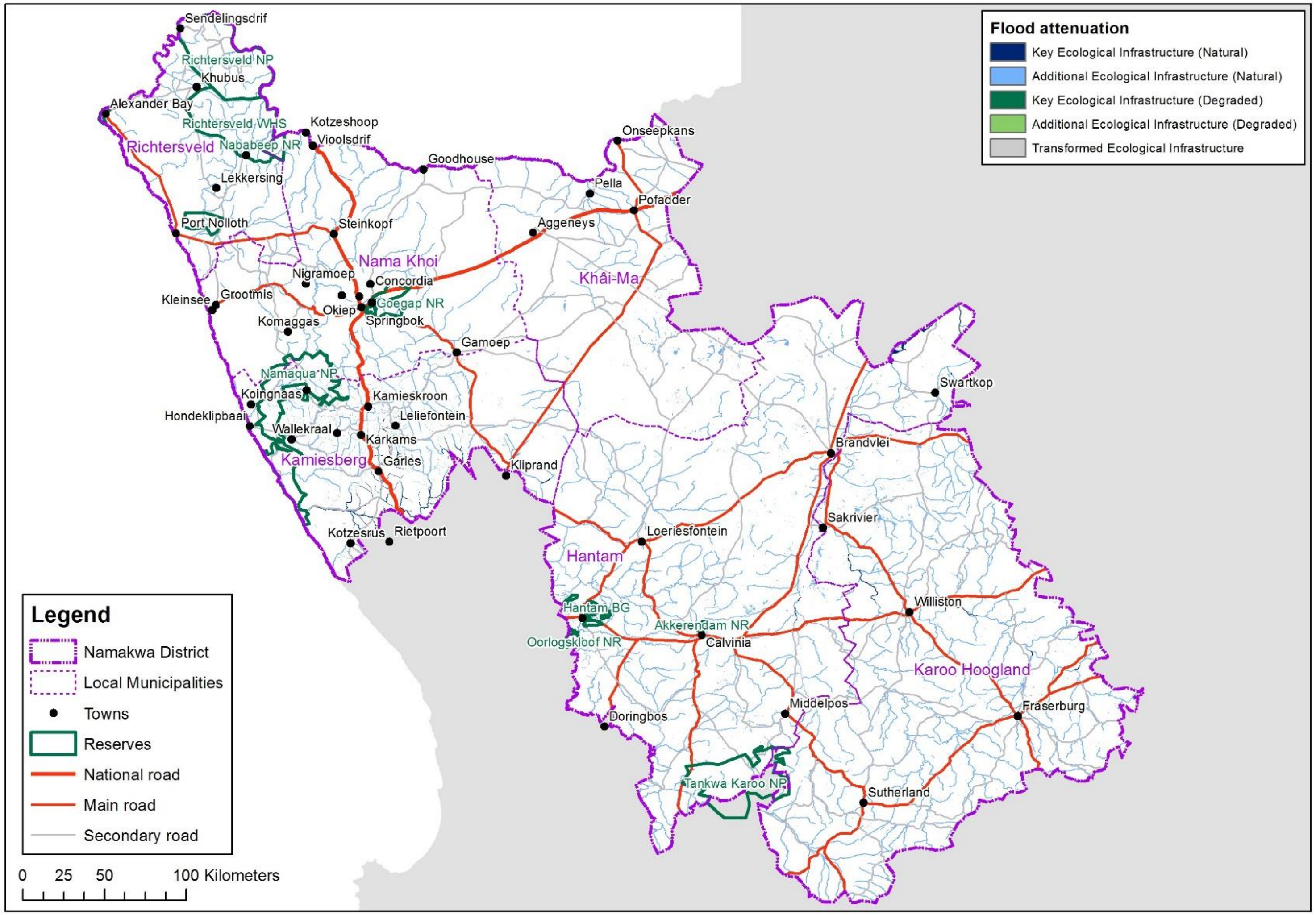

FIGURE 94: AREAS OF ECOLOGICAL INFRASTRUCTURE IMPORTANT FOR IMPORTANT FOR FLOOD ATTENUATION.

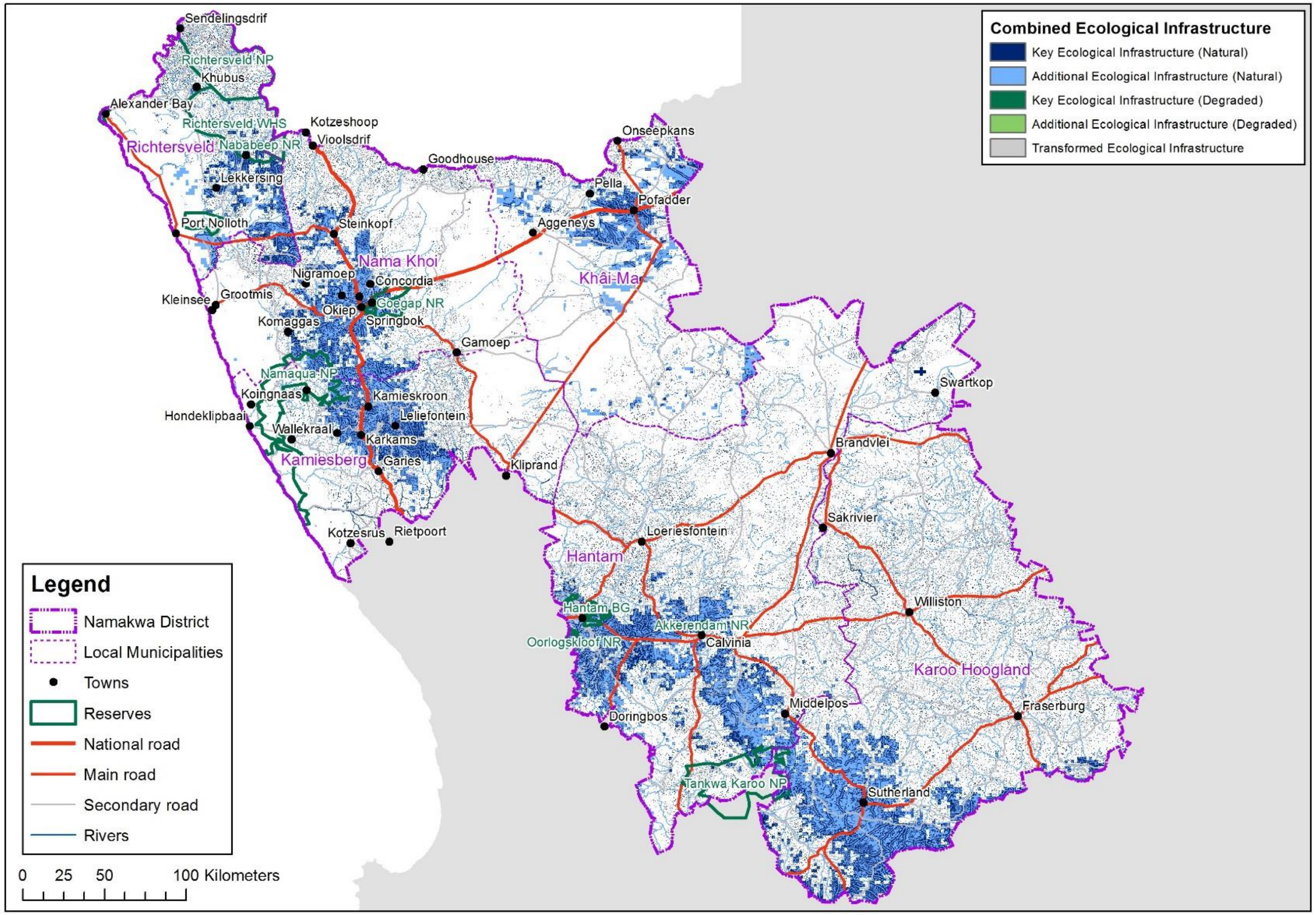

FIGURE 95: INTEGRATED MAP OF WATER RELATED ECOLOGICAL INFRASTRUCTURE IMPORTANT FOR THE NAMAKWA DISTRICT.

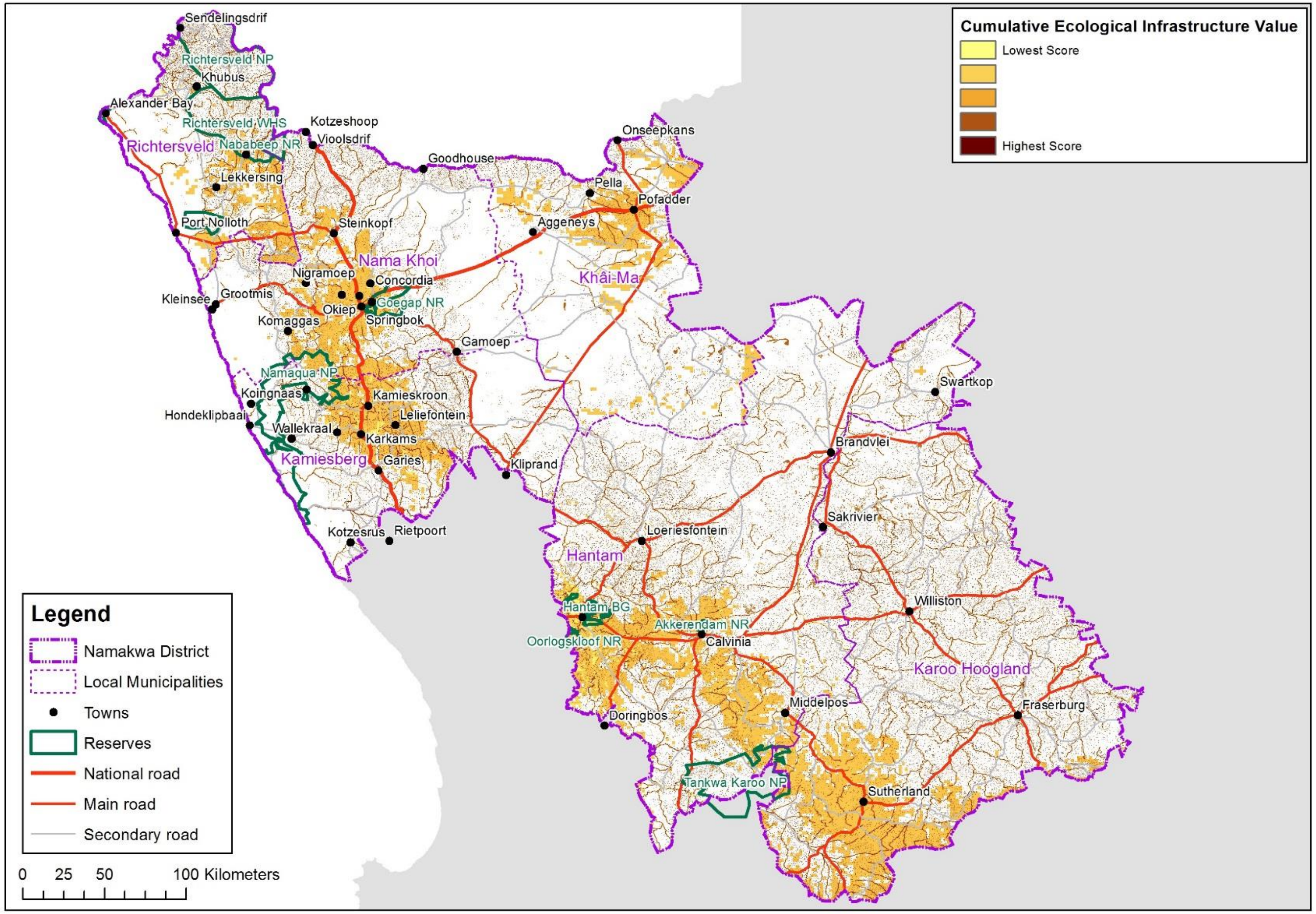

FIGURE 96: CUMULATIVE SCORE OF WATER RELATED ECOLOGICAL INFRASTRUCTURE VALUE FOR THE NAMAKWA DISTRICT.

Climate resilience ecological infrastructure maps

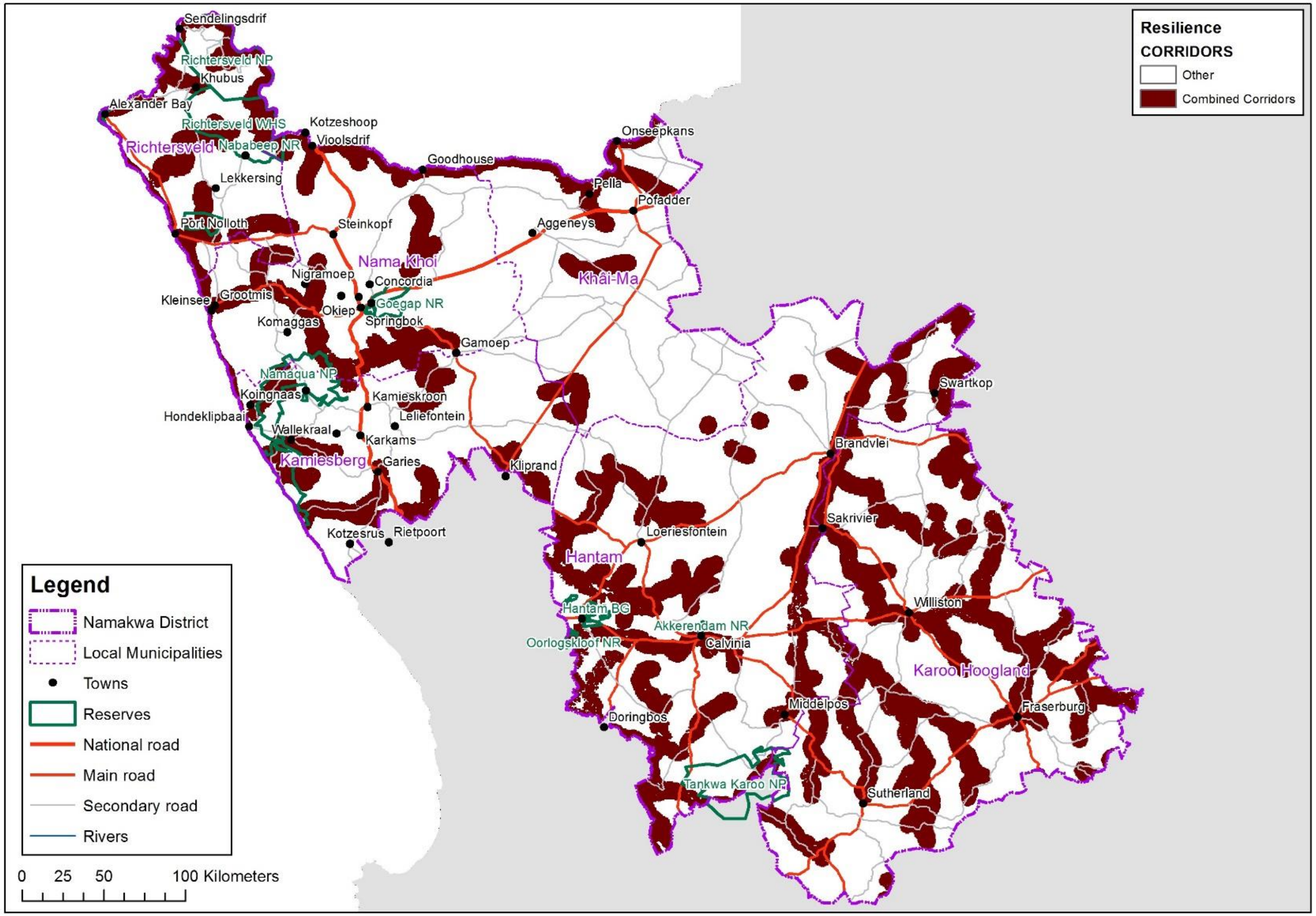

FIGURE 97: COASTAL AND RIPARIAN CORRIDORS LAYER FOR NAMAKWA DISTRICT.

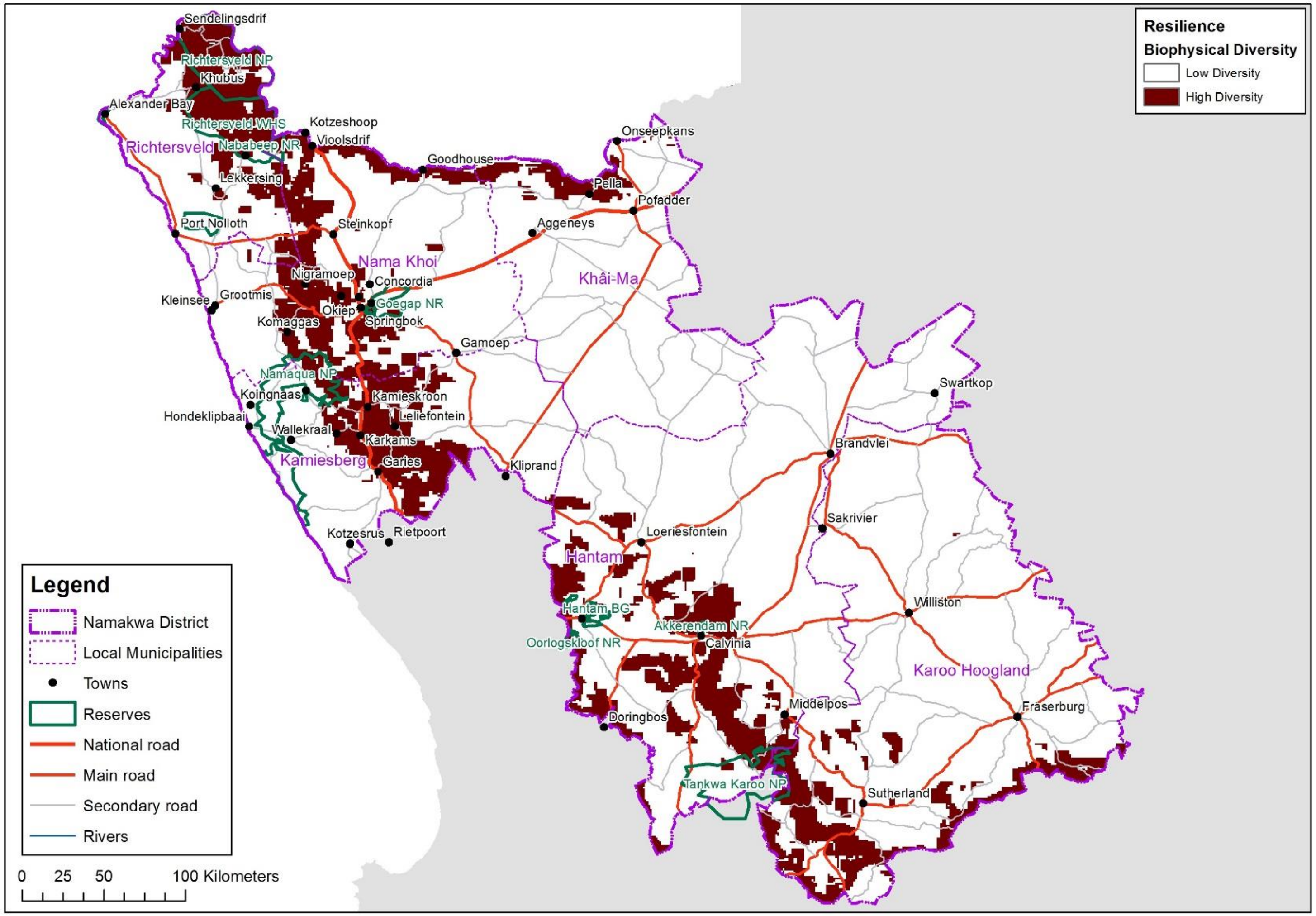

FIGURE 98: COMBINED AREAS OF STEEP ALTITUDE, TEMPERATURE AND PRECIPITATION GRADIENTS IN THE NAMAKWA DISTRICT.

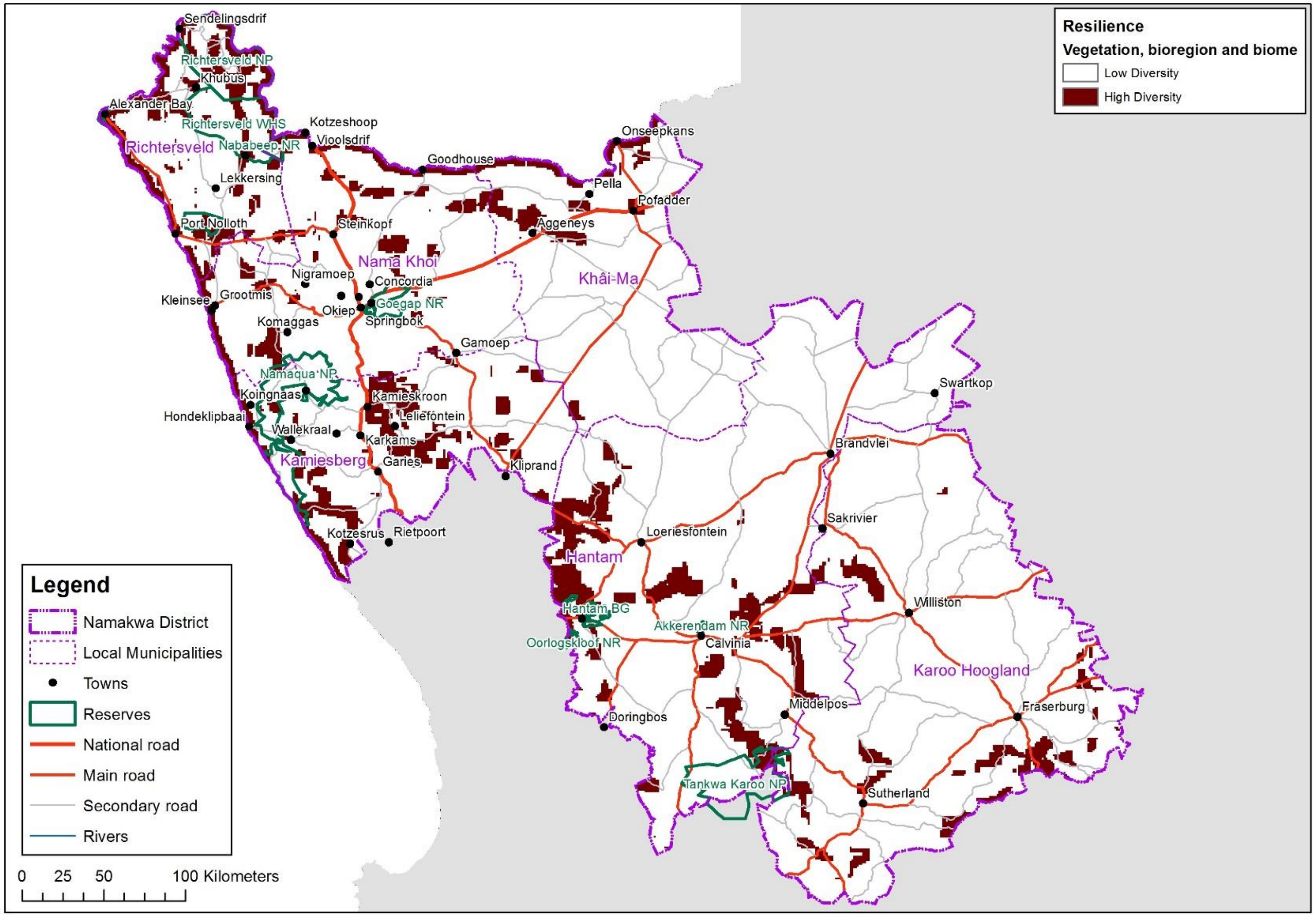

FIGURE 99: COMBINED AREAS OF HIGH HABITAT DIVERSITY IN THE NAMAKWA DISTRICT. THIS MAP IS COMPILED FROM THREE UNDERLYING MAPS OF HIGH DIVERSITY AT THE VEGETATION TYPE, VEGETATION GROUP AND BIOME LEVELS.

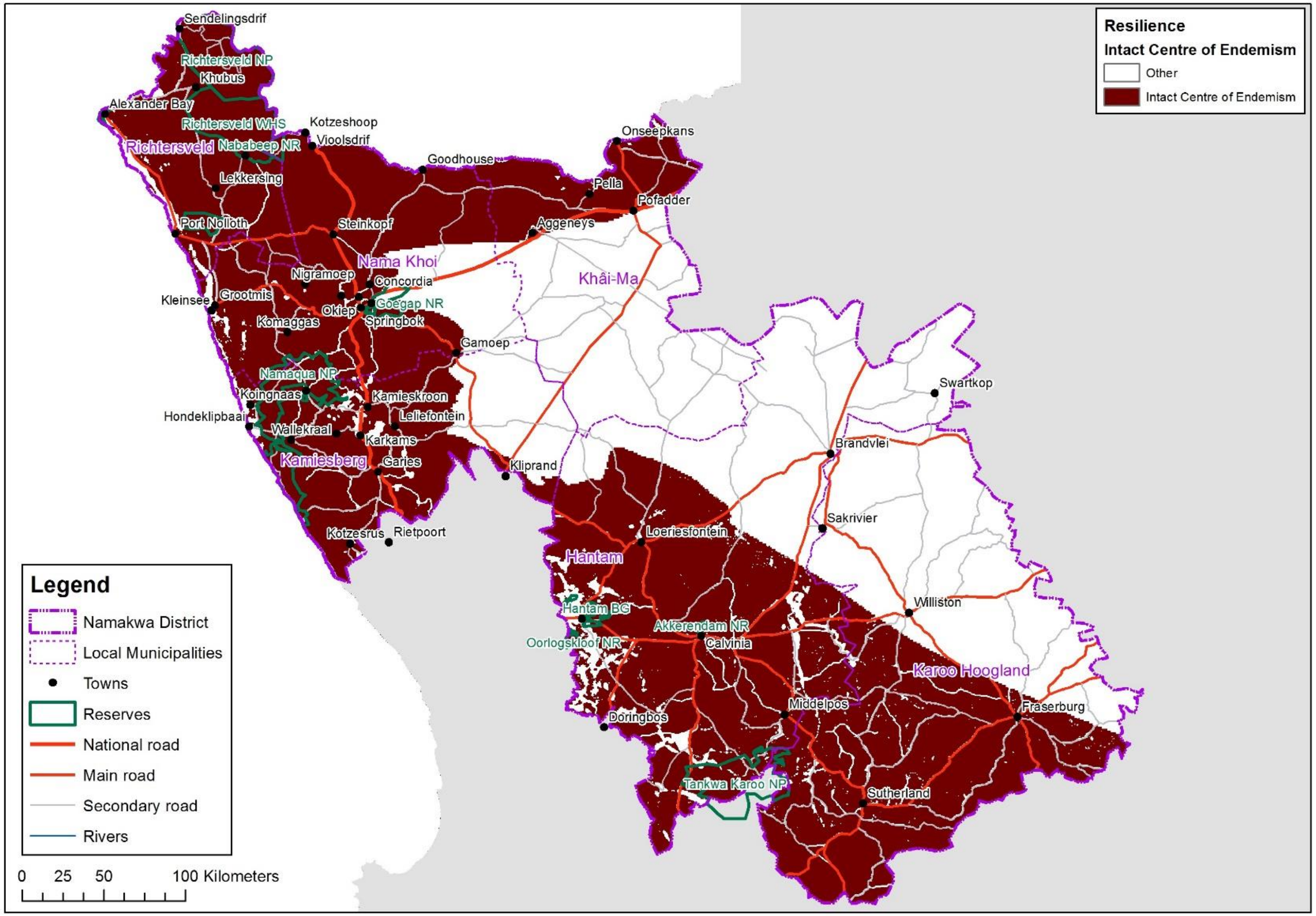

FIGURE 100: REMAINING INTACT AREAS OF CENTRES OF ENDEMISM IN THE NAMAKWA DISTRICT.

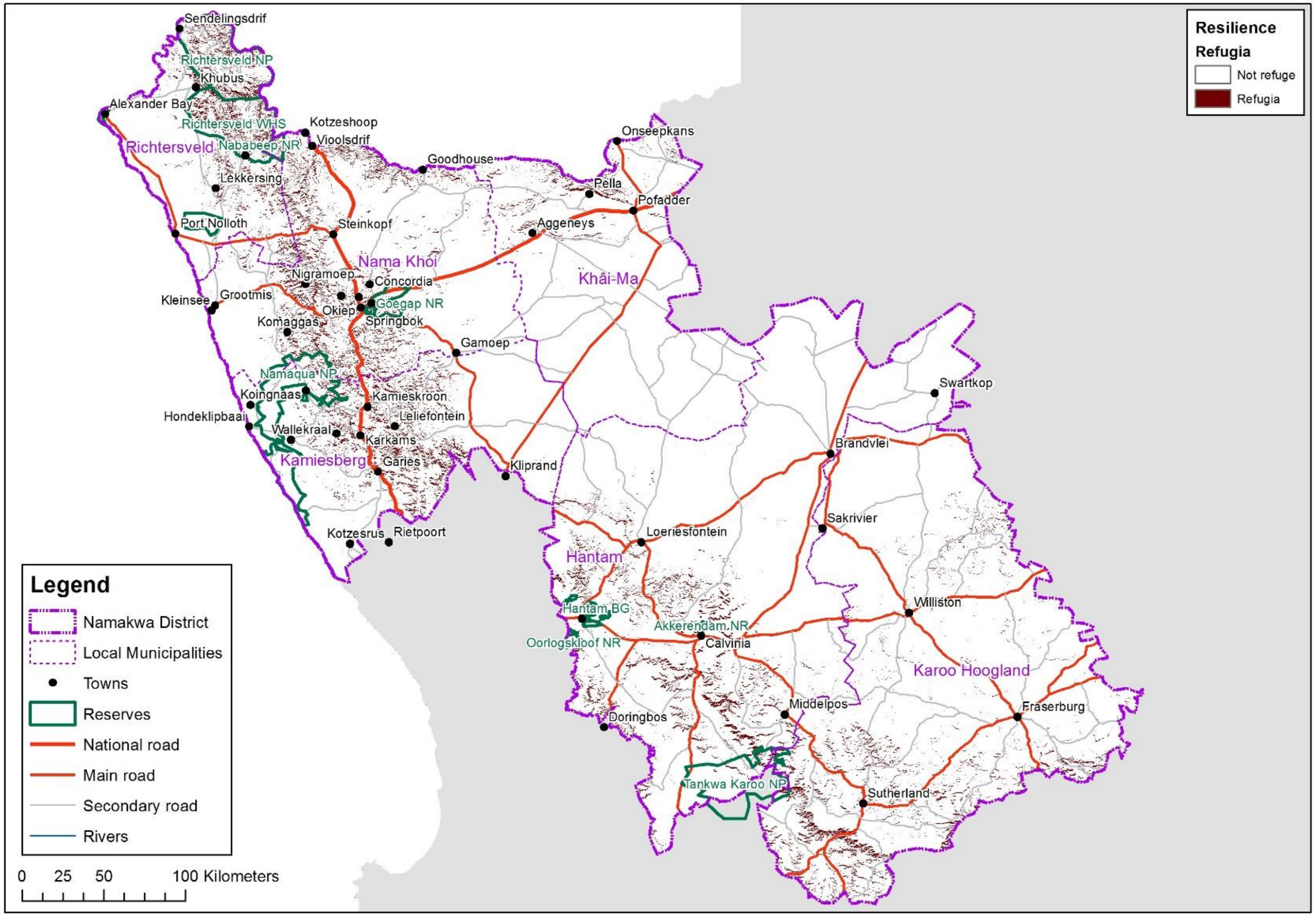

FIGURE 101: LOCAL REFUGIA CONSISTING OF A COMBINATION OF SOUTH FACING SLOPES AND GORGES IN THE NAMAKWA DISTRICT.

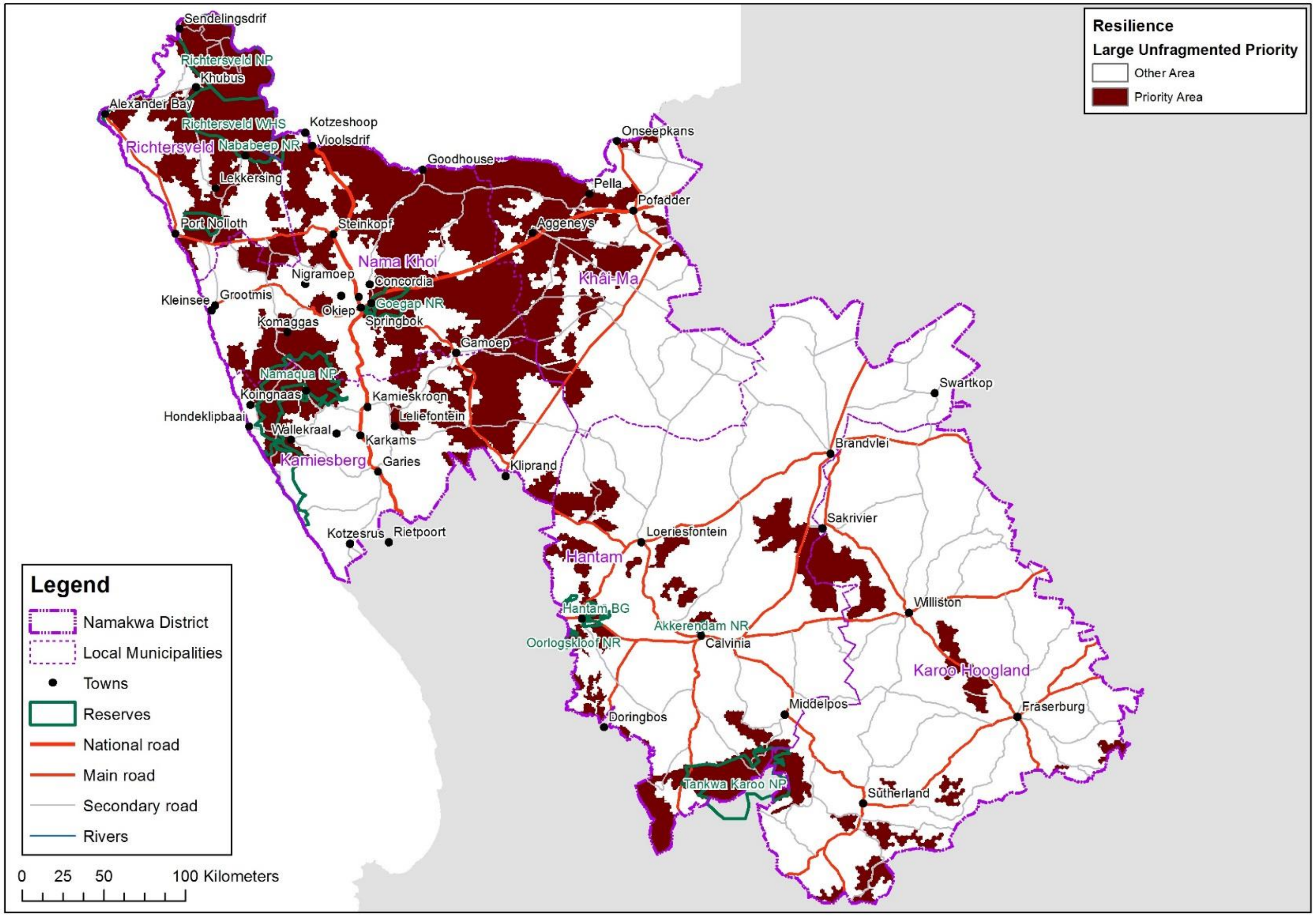

FIGURE 102: LARGE UNFRAGMENTED PRIORITY AREAS IN THE NAMAKWA DISTRICT.

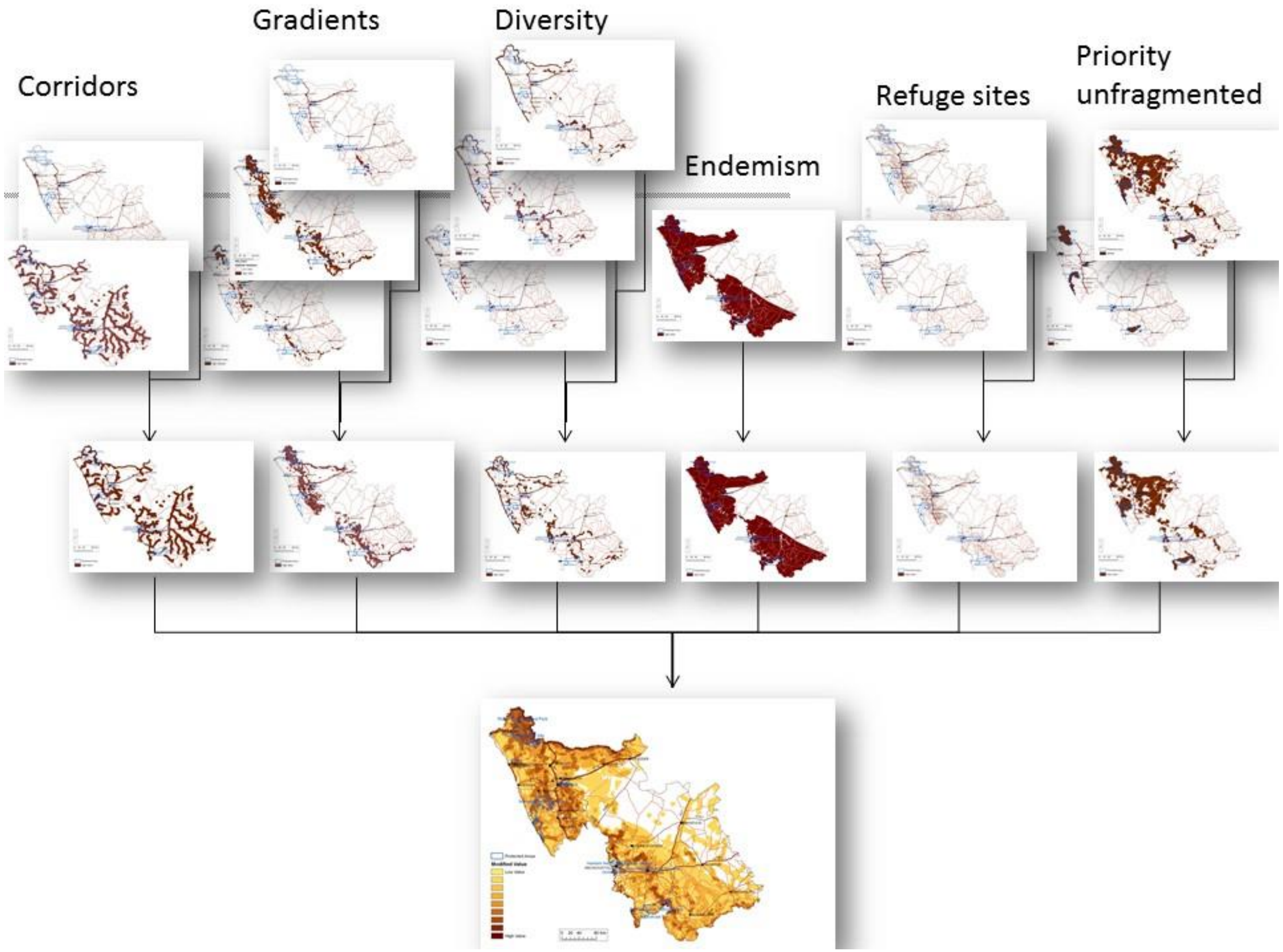

FIGURE 103: DIAGRAM ILLUSTRATING THE INTEGRATION METHOD USED TO IDENTIFY AREAS MOST IMPORTANT FOR SUPPORTING RESILIENCE TO CLIMATE CHANGE IMPACTS AT A LANDSCAPE SCALE.

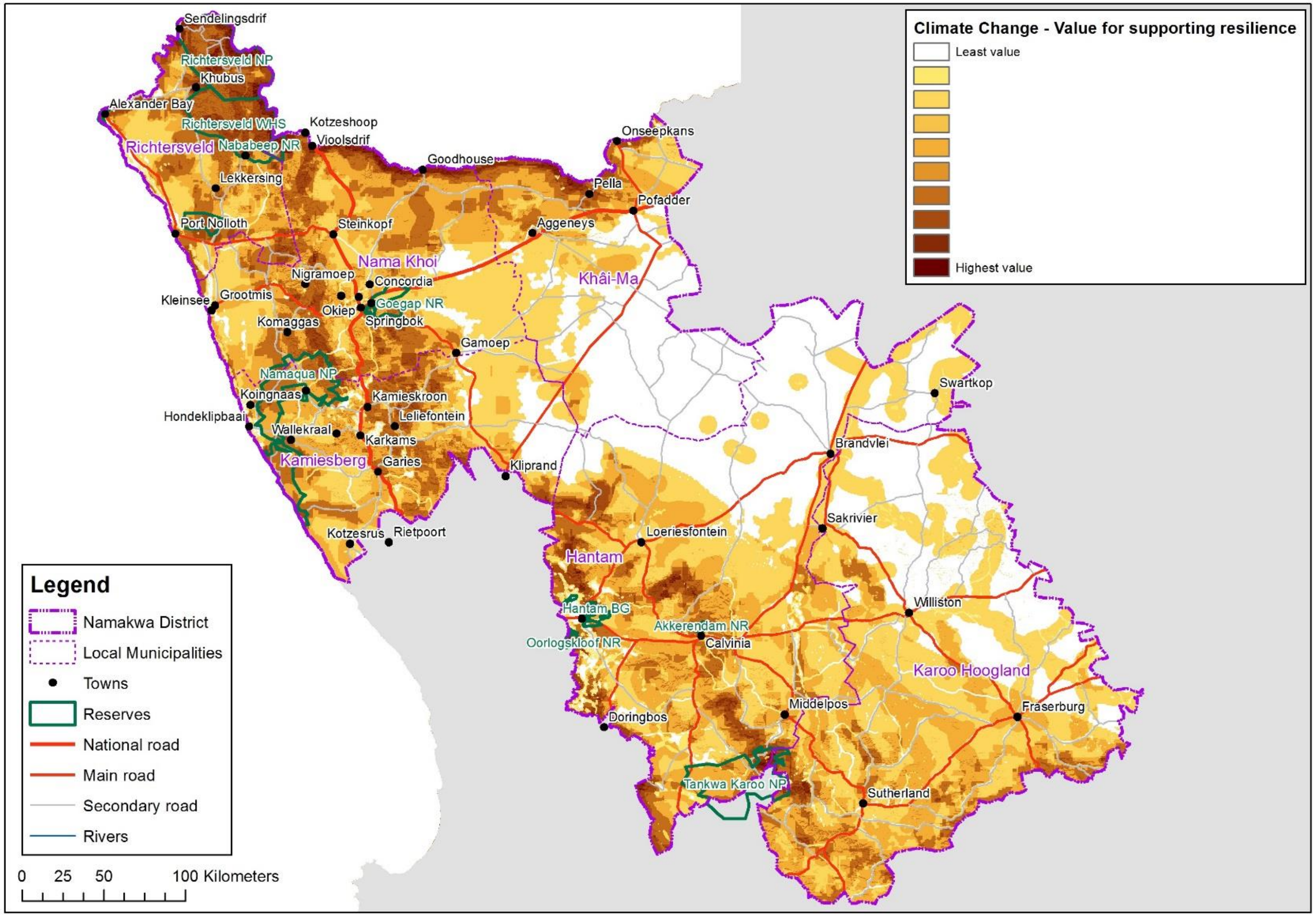

FIGURE 104: VALUE OF AREAS FOR SUPPORTING RESILIENCE TO CLIMATE CHANGE IMPACTS IN THE NAMAKWA DISTRICT. NOTE THAT ALTHOUGH THIS REPRESENTS AN OVERALL SUMMARY OF AREAS IMPORTANT FOR SUPPORTING RESILIENCE TO CLIMATE CHANGE IMPACTS, WHEN ONE IS FOCUSSING IN ON A PARTICULAR ISSUE (SUCH AS RIPARIAN CORRIDORS OR THREATENED SPECIES) THEN IT MAY BE MORE APPROPRIATE TO PRIORITIZE BASED ON THAT ISSUE ALONE.

Biodiversity ecological infrastructure maps

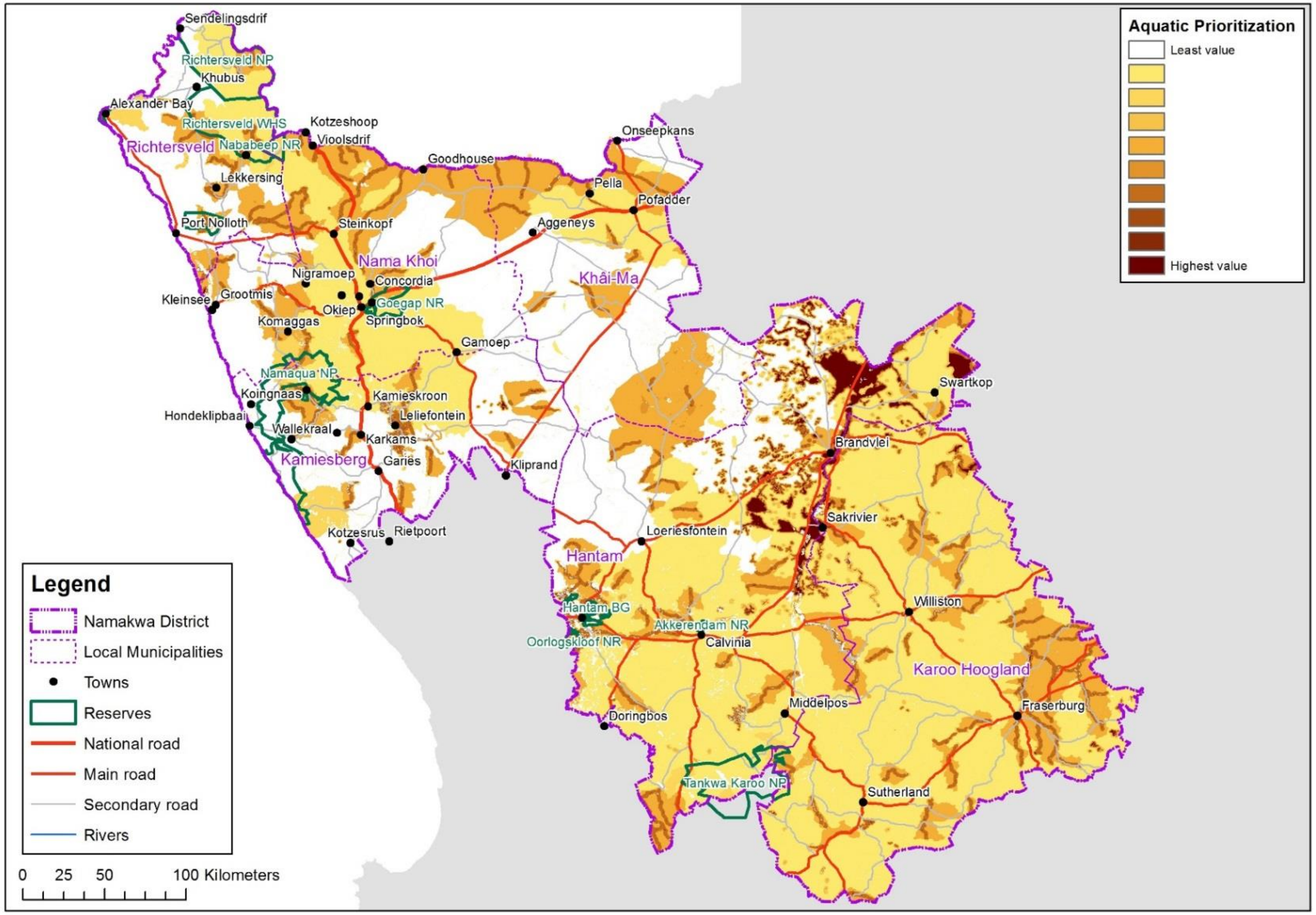

FIGURE 105: RESULTS OF THE AQUATIC PRIORITIZATION.

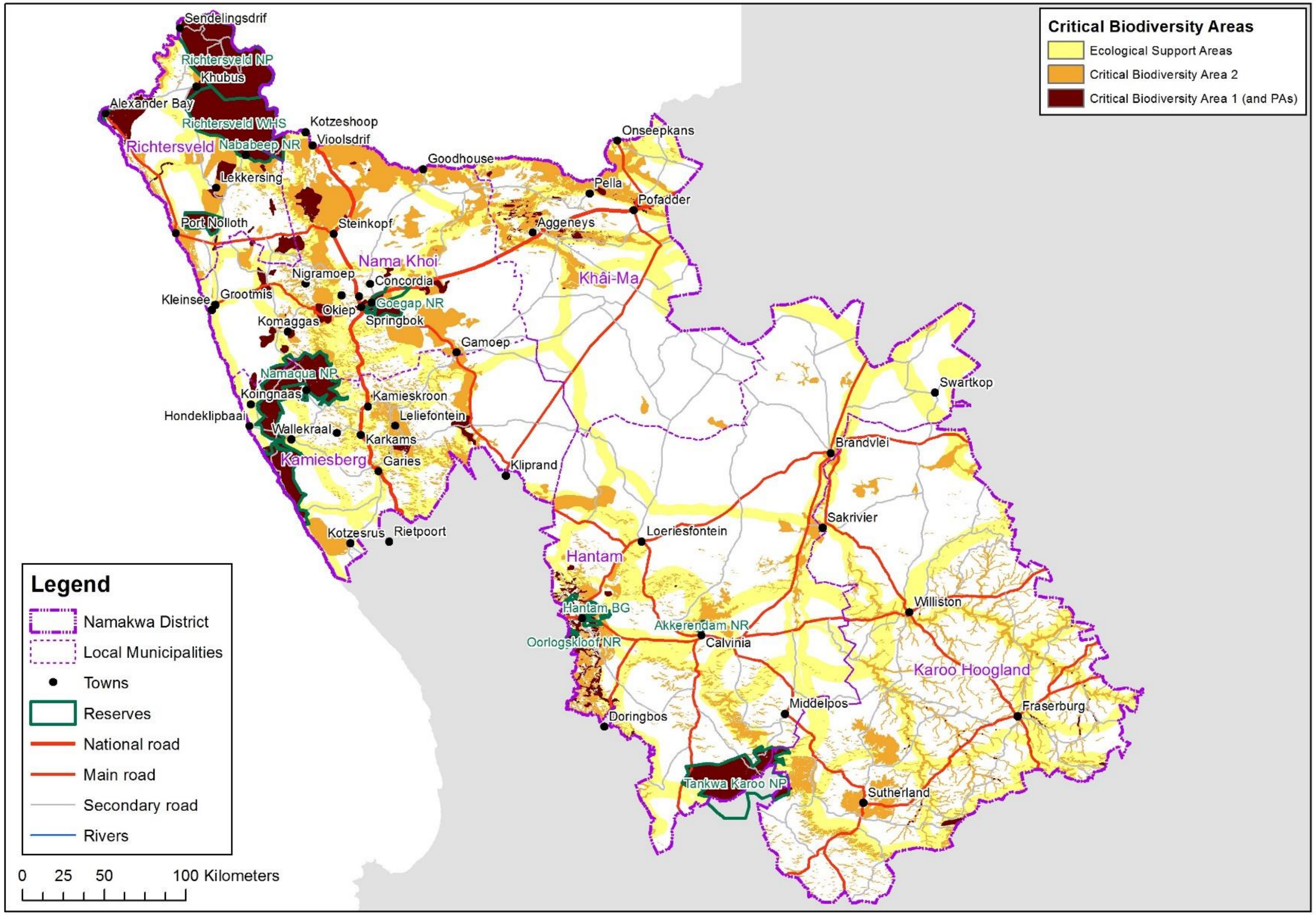

FIGURE 106: CRITICAL BIODIVERSITY AREAS AND OTHER PRIORITIES IDENTIFIED IN THE NAMAKWA DISTRICT CONSERVATION PLAN.

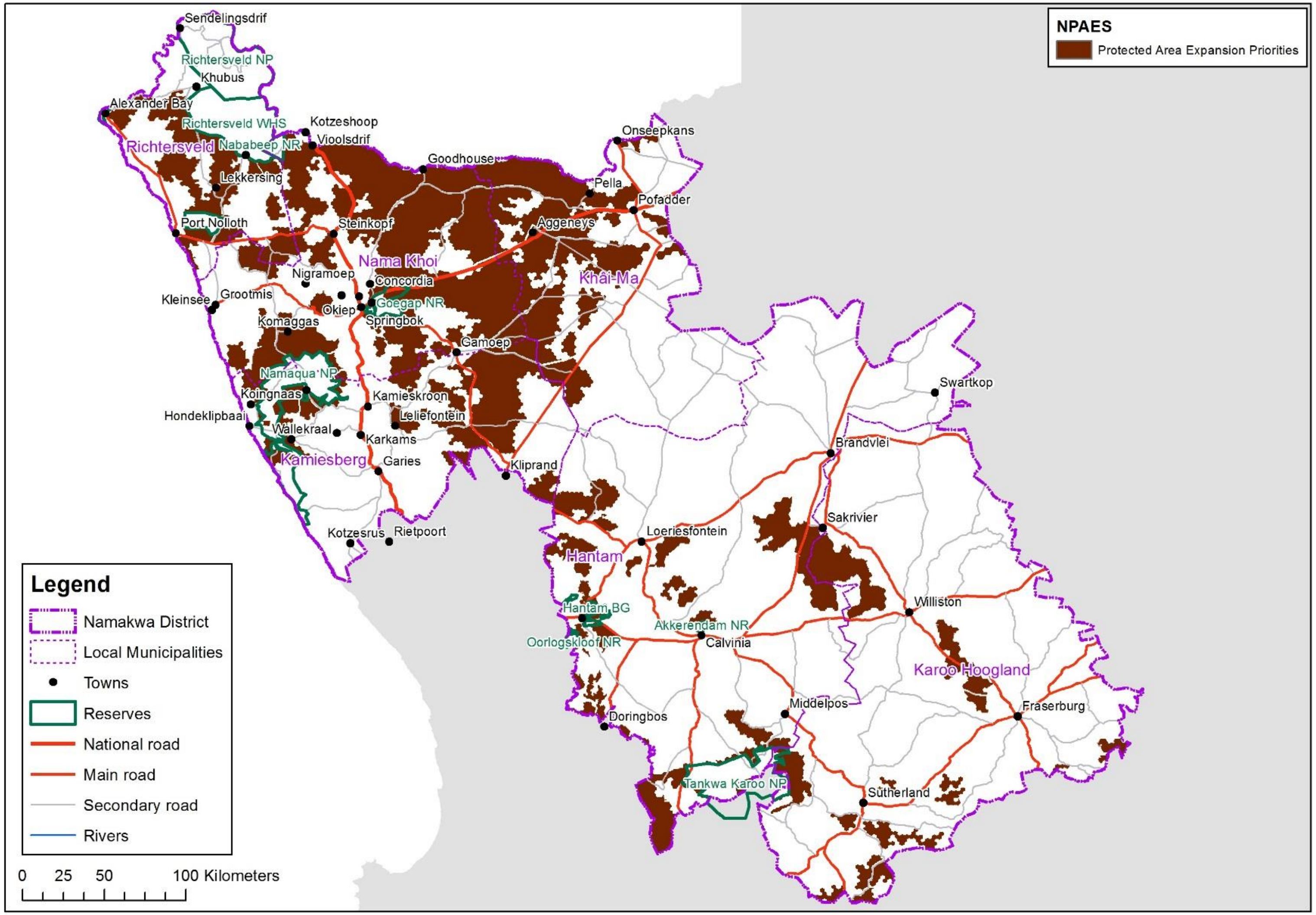

FIGURE 107: PROTECTED AREA EXPANSION PRIORITIES IN THE NAMAKWA DISTRICT.

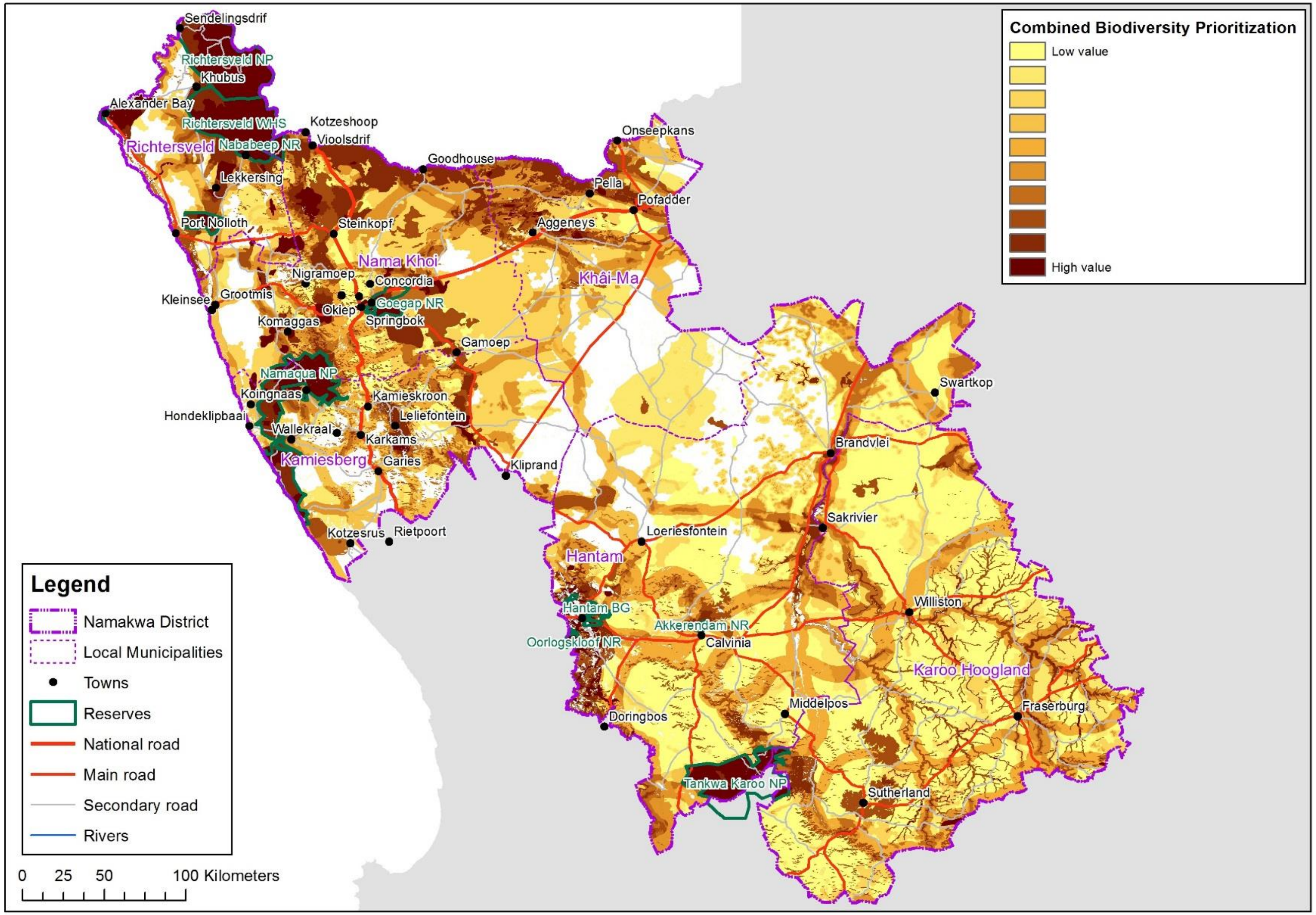

FIGURE 108: INTEGRATED MAP OF OVERALL BIODIVERSITY PRIORITIES IN THE NAMAKWA DISTRICT.

Socio-economic vulnerability maps

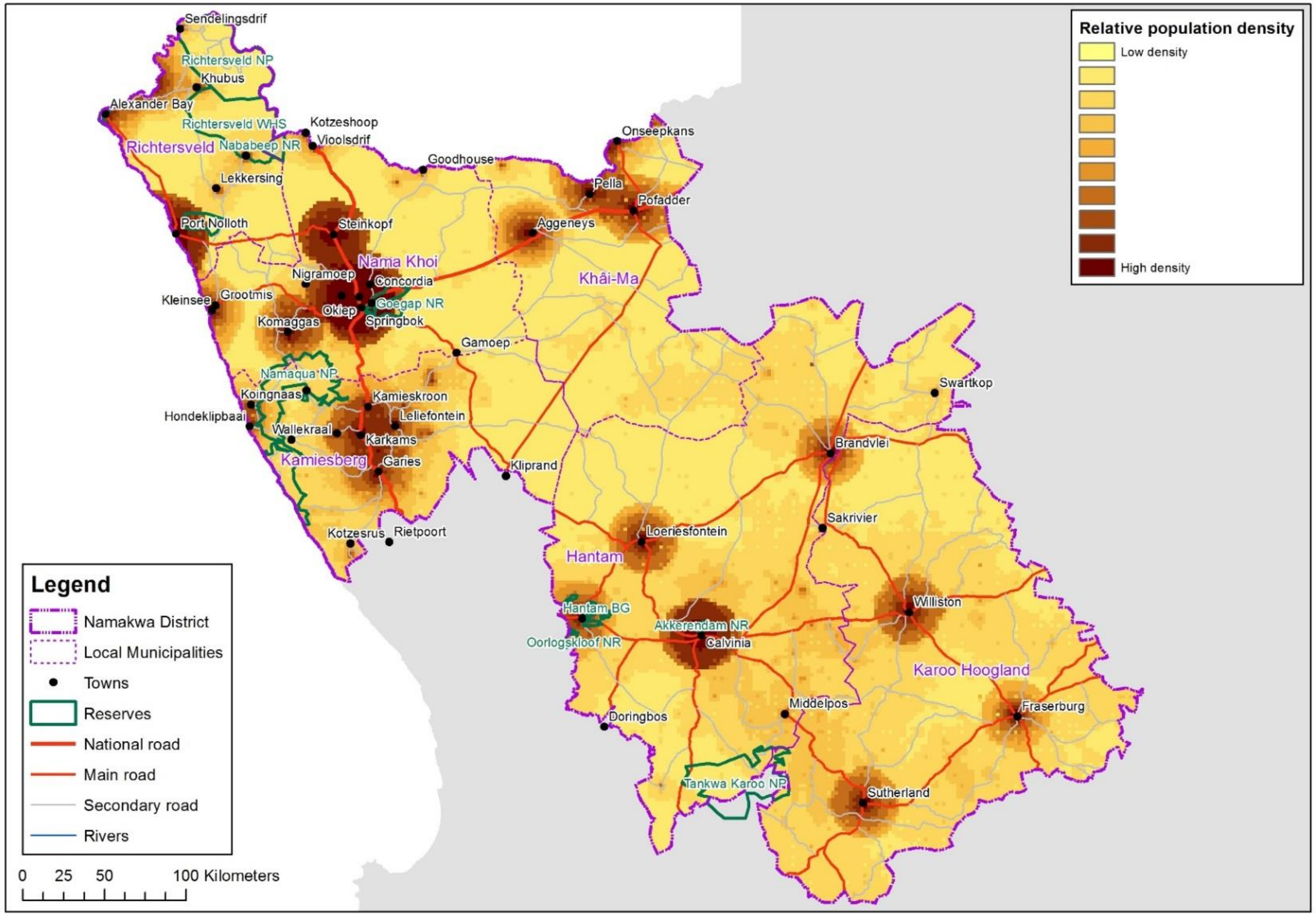

FIGURE 109: MAP SHOWING RELATIVE POPULATION DENSITY BASED ON AN ANALYSIS OF THE DISTRIBUTION OF BUILDINGS ACROSS NAMAKWA DISTRICT. SEE TEXT FOR DETAILS.

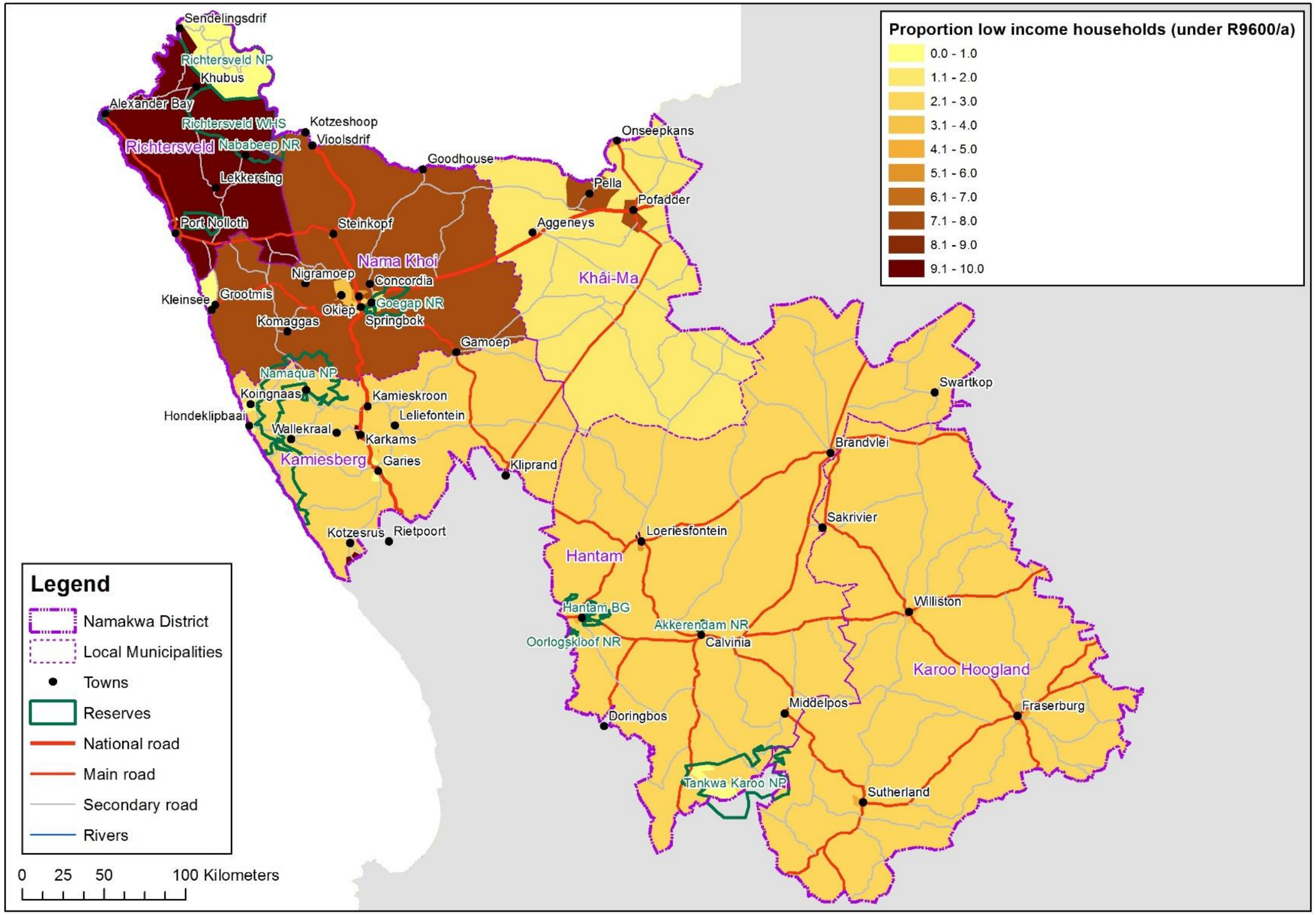

FIGURE 110: MAP SHOWING HOUSEHOLD INCOME DERIVED FROM THE CENSUS 2011 DATA FOR NAMAKWA DISTRICT. IT SHOWS AN INDEX BASED ON THE PROPORTION OF HOUSEHOLDS WITH INCOMES OF UNDER R9600/YEAR OR WITH NO INCOME AT ALL.

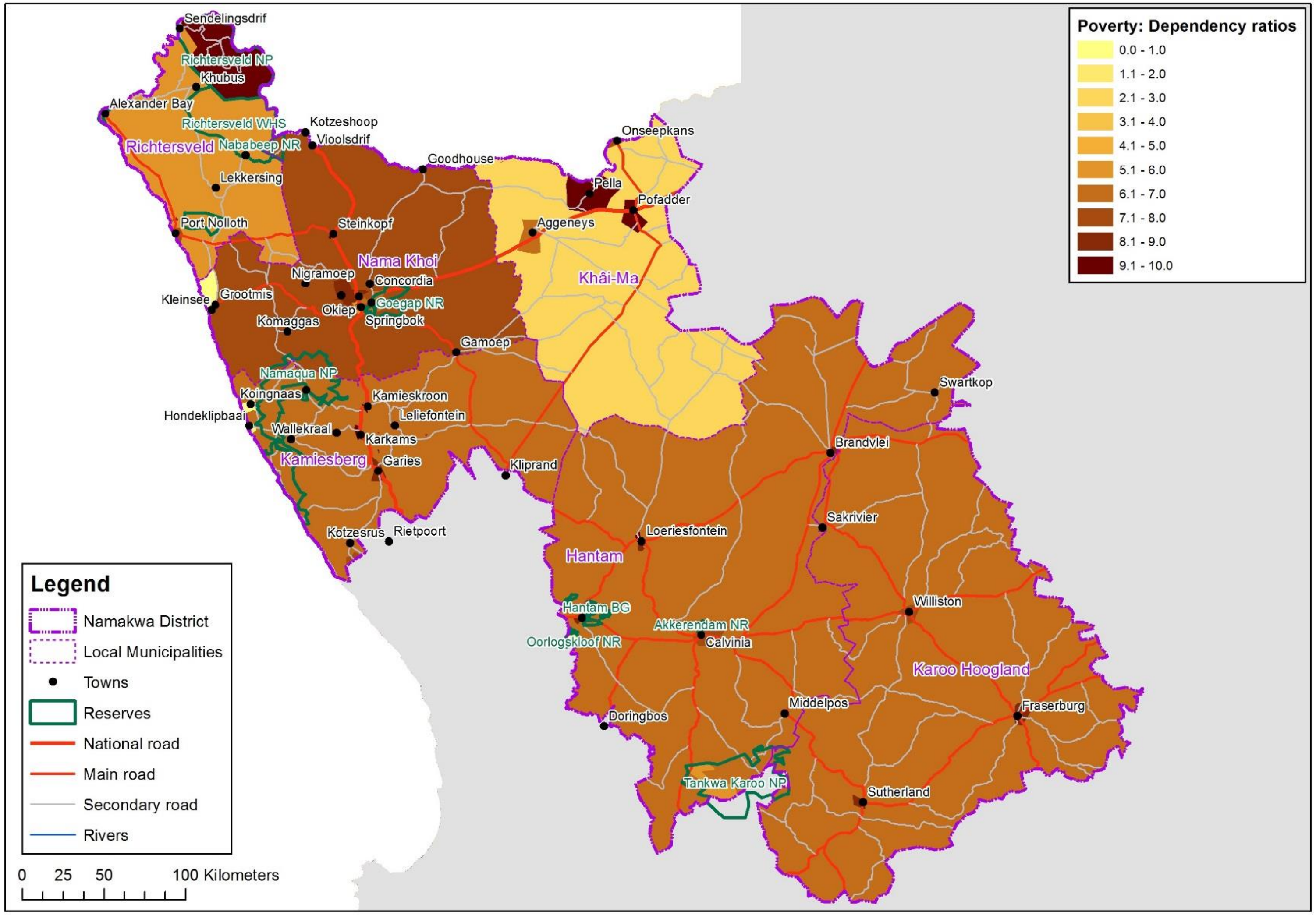

FIGURE 111: MAP SHOWS THE RATIO OF PEOPLE WHO ARE EMPLOYED TO PEOPLE WHO ARE UNEMPLOYED, DISCOURAGED WORK-SEEKERS, NOT ECONOMICALLY ACTIVE OR UNDER 15, BASED ON THE CENSUS 2011 DATA FOR NAMAKWA DISTRICT. IT ATTEMPTS TO IDENTIFY AREAS WHERE THERE ARE VERY HIGH DEPENDENCY LEVELS.

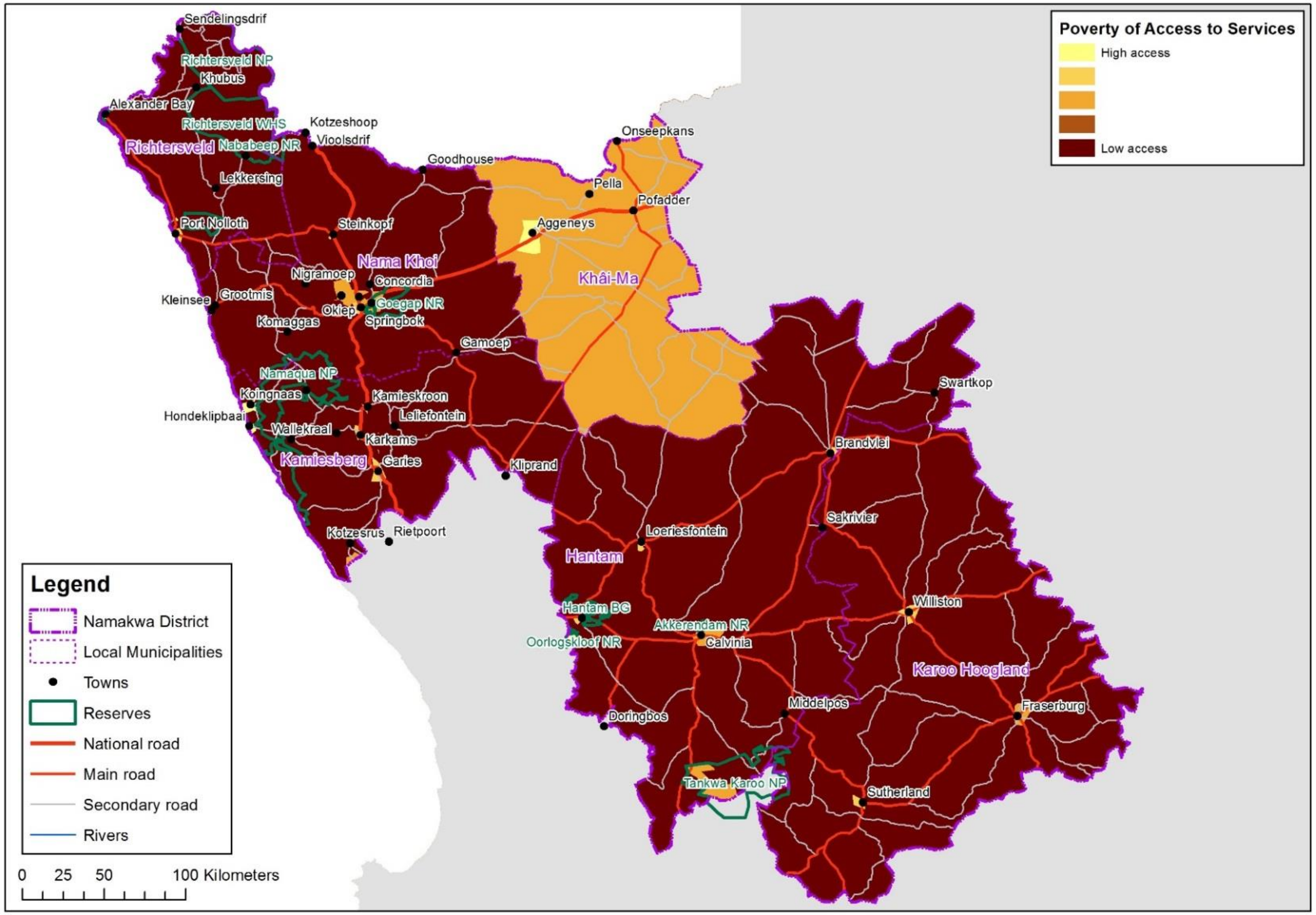

FIGURE 112: MAP SHOWS AN INDEX OF THE POVERTY MEASURED BY A LACK OF ACCESS TO SERVICES (NO DECENT ACCESS TO SANITATION, NO PIPED WATER WITHIN 200M, NO COLLECTION OF REFUSE, NO ACCESS TO ELECTRICITY FOR LIGHTING). THE INDEX RANGES FROM 0 TO 10 AND IS BENCHMARKED AGAINST THE LEVELS OF ACCESS TO SERVICES OF THE 90TH PERCENTILE OF VALUES FOR SUB-PLACES IN THE NAMAKWA DISTRICT. DERIVED FROM CENSUS 2011 DATA. NOTE THAT THE DARKEST COLOURS INDICATE AREAS WHERE PEOPLE HAVE THE LEAST ACCESS TO SERVICES.

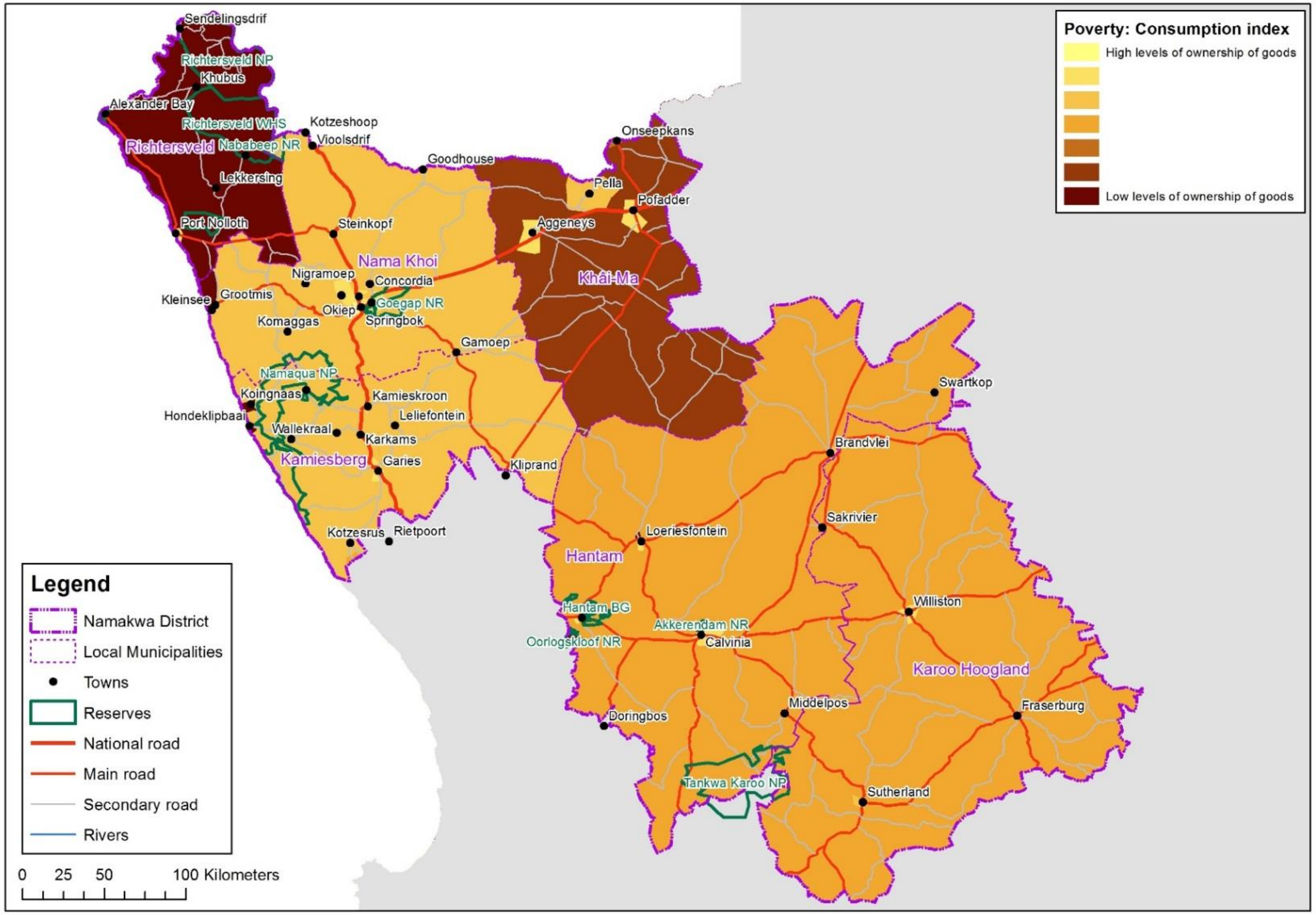

FIGURE 113: MAP SHOWS AN INDEX OF POVERTY AS MEASURED BY THE LACK OF OWNERSHIP OF ALL GOODS (I.E. CAR, CELL PHONE, COMPUTER, DVD PLAYER, REFRIGERATOR, RADIO, SATELLITE TELEVISION, ELECTRIC/GAS STOVE, TELEVISION, VACUUM CLEANER AND WASHING MACHINE). THE INDEX RANGES FROM 0 TO 10 AND IS BENCHMARKED AGAINST THE LEVELS OF POVERTY OF CONSUMPTION OF THE 90TH PERCENTILE OF VALUES FOR SUB-PLACES IN THE NAMAKWA DISTRICT. DERIVED FROM CENSUS 2011 DATA. NOTE THAT THE DARKEST COLOURS INDICATE AREAS WHERE PEOPLE HAVE THE LEAST POSSESSIONS.

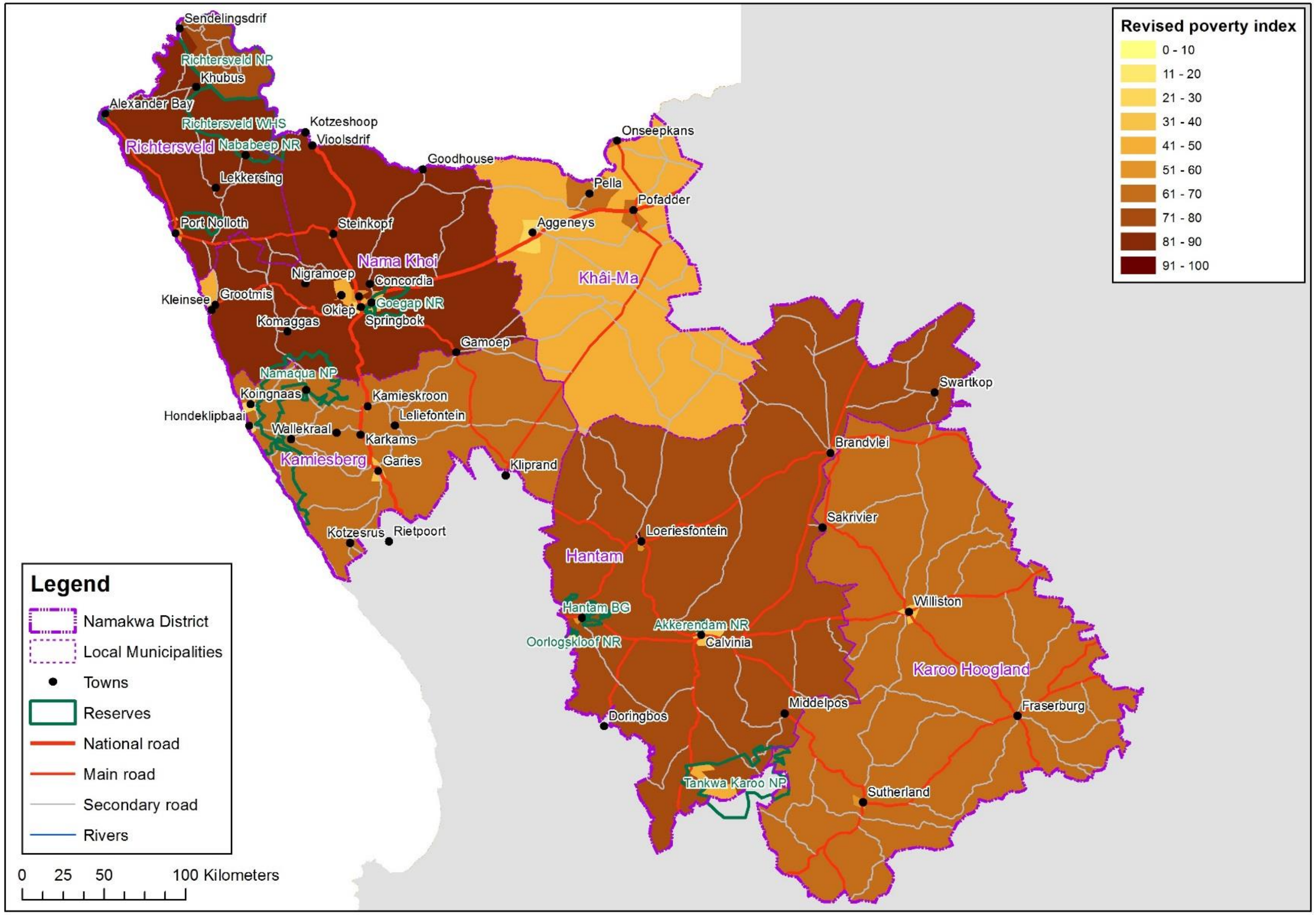

FIGURE 114: MAP SUMMARIZING THE REVISED POVERTY INDEX FOR NAMAKWA DISTRICT. THIS CONSISTS OF AN EQUAL WEIGHTED SUMMARY OF VALUES DERIVED FROM THE PROPORTION OF LOW INCOME HOUSEHOLDS, THE DEPENDENCY RATIO, THE LACK OF ACCESS TO SERVICES AND THE LACK OF ACCESS TO GOODS.

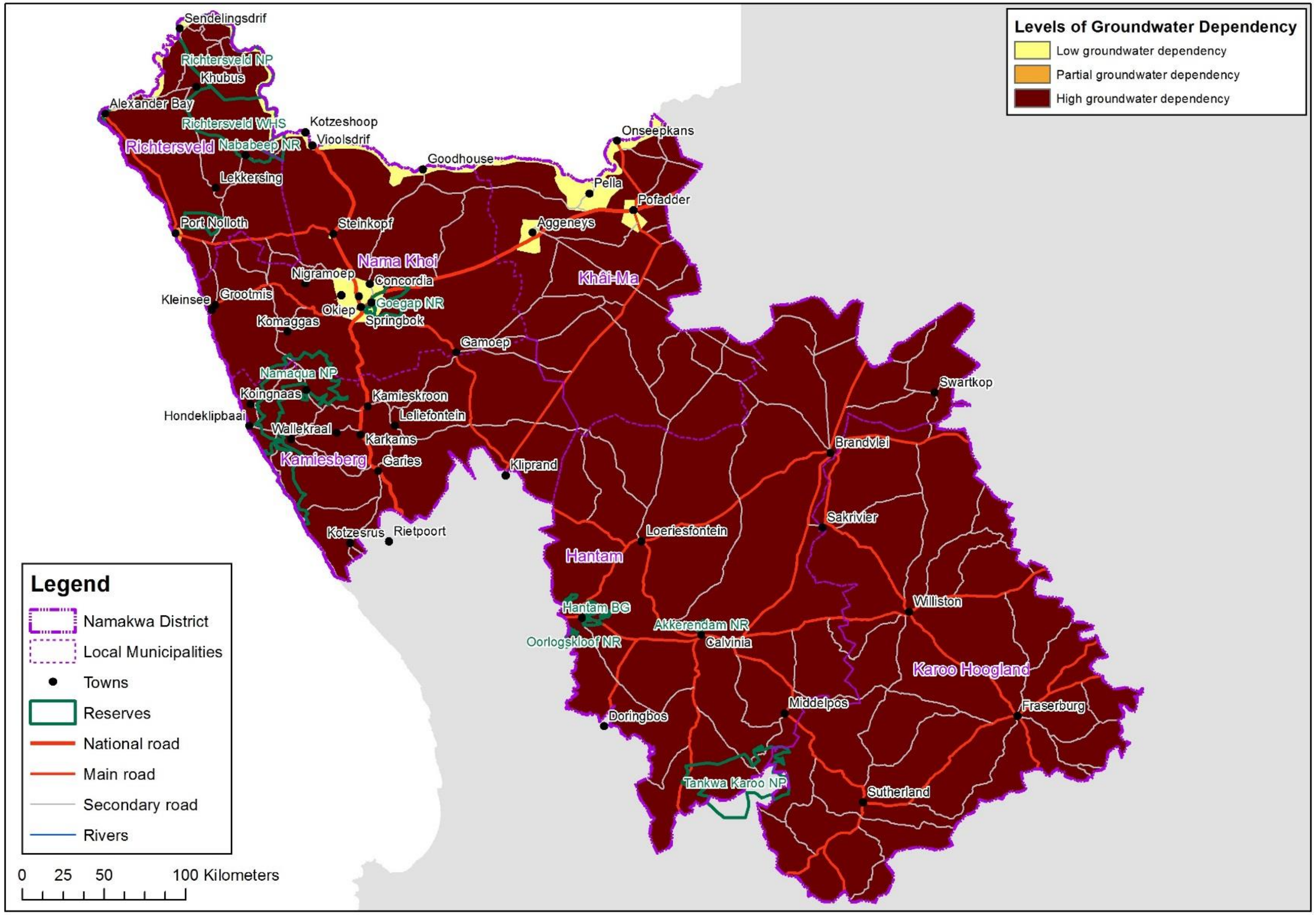

FIGURE 115: MAP SHOWING LEVELS OF GROUNDWATER DEPENDENCY IN THE NAMAKWA DISTRICT.

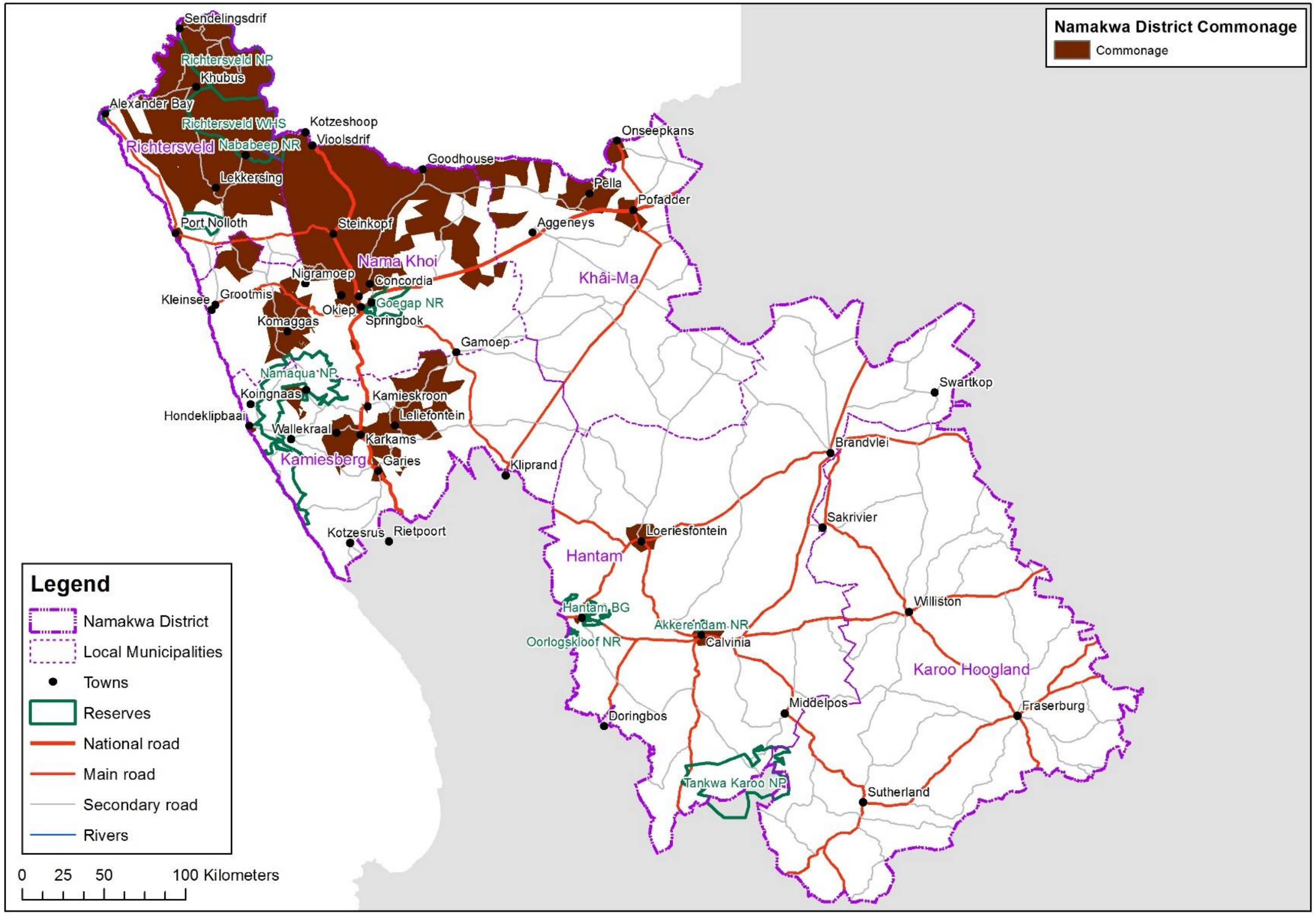

FIGURE 116: MAP SHOWING COMMUNAL GRAZING AREAS IN NAMAKWA DISTRICT.

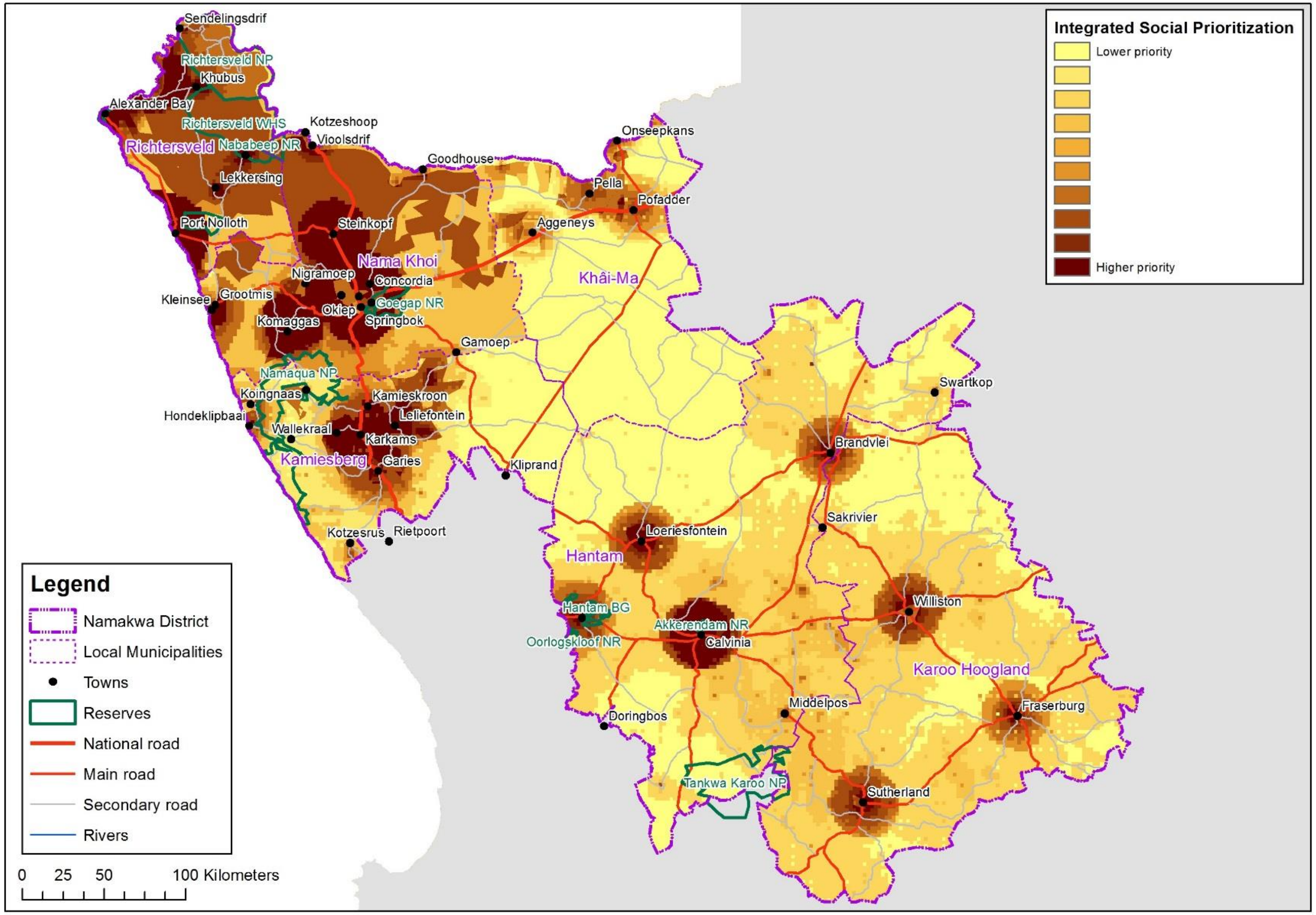

FIGURE 117: MAP SHOWING THE INTEGRATED SOCIAL PRIORITIZATION LAYER. THESE ARE THE AREAS WHICH NEED TO BE MOST CAREFULLY MANAGED TO ENSURE THE ONGOING SUPPLY OF GOOD QUALITY ENVIRONMENTAL GOODS AND SERVICES.

Ecosystem-based adaptation priority areas map

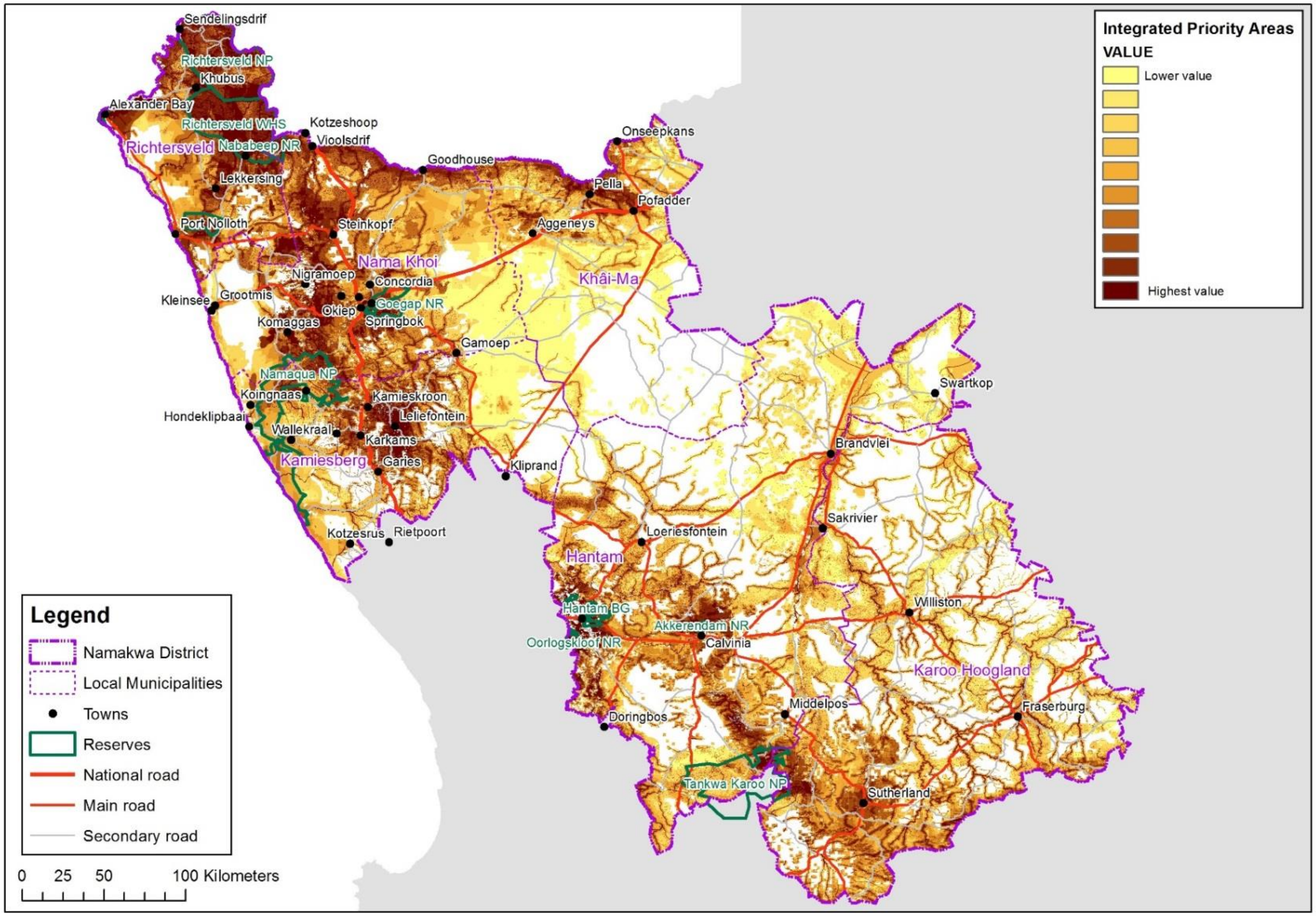

FIGURE 118: INTEGRATED SUMMARY OF AREAS IMPORTANT FOR ECOSYSTEM-BASED ADAPTATION TO CLIMATE CHANGE IMPACTS FOR NAMAKWA DISTRICT