



**AfCAP**  
Africa Community Access Partnership



## Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa

Management of Vulnerability and Adaptation to Climate Change: Mozambique



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## **Abstract**

The African Development Bank states that Africa is one of the most vulnerable regions in the world to the impacts of climate change. The majority of both bottom up and top down studies suggest that damages from climate variability and change, relative to population and Gross Domestic Product, will be higher in Africa than in any other region in the world.

In order to help address this significant threat to Africa's development, the Africa Community Access Partnership, a research programme funded by UK Aid, commissioned a project that started in April 2016 to produce regional guidance on the development of climate-resilient rural access in Africa through research and knowledge sharing within and between participating countries. The output will assist the development of a climate resilient road network that reaches fully into and between rural communities.

The study focusses on: (a) demonstrating appropriate engineering and non-engineering adaptation procedures; (b) sustainable enhancement in the capacity of three AfCAP partner countries; (c) sustainable enhancement in the capacity of additional AfCAP partner countries; and (d) uptake and embedment across AfCAP partner countries.

This document is a Country Report on Mozambique on the Management of Vulnerability and Adaptation to Climate Change using the principles and recommendations set out in the AfCAP Climate Adaptation Handbook and the relevant associated Guidelines. This report concludes with final actions flowing from an embedment workshop and engagements held in April 2018.

## **Key words**

Capacity Building; Change Management; Climate Adaptation; Climate Change; Climate Impact; Climate Resilience; Climate Threat; Climate Variability; Risk; Rural Accessibility; Vulnerability.

## **AFRICA COMMUNITY ACCESS PARTNERSHIP (AfCAP)**

### ***Safe and sustainable transport for rural communities***

AfCAP is a research programme, funded by UK Aid, with the aim of promoting safe and sustainable transport for rural communities in Africa. The AfCAP partnership supports knowledge sharing between participating countries in order to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources. AfCAP is brought together with the Asia Community Access Partnership (AsCAP) under the Research for Community Access Partnership (ReCAP), managed by Cardno Emerging Markets (UK) Ltd.

**See [www.research4cap.org](http://www.research4cap.org)**

## Glossary

Adaptation	Adjustments in natural and human systems in response to changing conditions or their effects with the aim of reducing harm or taking advantage of positive opportunities. Adjustments may be autonomous, anticipatory or policy-driven.
Adaptive Capacity	The degree to which adjustments in practices, processes and structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change [in climate].
Adaptation Needs	The circumstances requiring actions to ensure safety of populations and security of assets in response to climate impacts.
Adaptation Options	The array of strategies and measures that are available and appropriate for addressing adaptation needs. They include a wide range of actions that can be characterised as structural, institutional, or social.
Capacity Building	The ability of enhancing strengths and attributes of, and resources available to, an individual community, society, or organisation to response to change.
Change Management	A collective term for all approaches to preparing and supporting individuals, teams and organisations in making organisational or institutional changes in order to equip them to address and resolve new or recurring challenges impacting on them and their stakeholders (e.g. impacts of climate variability and change on their operations)
Climate Change	Change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity.
Climate Variability	Variations in the mean state and other statistics of the climate on all spatial and temporal scales beyond those of individual weather elements. Variability may be due to natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external forcing (external variability).
Disaster	Severe alterations in the normal functioning of a community or a society due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to widespread adverse human, material, economic, or environmental losses and impacts that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.
Early Warning Systems	The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities, and organisations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss.
Embedment	To incorporate the results of research in policy and practice within an institution. The results and related processes of analysis becomes part of the internal work processes of an institution.
Exposure	The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.
Extreme Weather Events	An event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is in itself extreme (e.g., drought or heavy rainfall over a season).

Flood	The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods, and glacial lake outburst floods.
Geographic Information System	GIS or Geographic Information System describes any information system that integrates, stores, edits, analyses, shares, and displays geographic information. Used in this case to spatially analyse data related to climate change.
Hazard (or Threat)	The potential occurrence of a natural, human-induced or socionatural process, phenomenon or activity that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related events or processes or their physical impacts. Climate change is a socionatural hazard in that it is associated with a combination of natural and human-induced factors.
Impacts (Consequences, Outcomes)	Effects on natural and human systems. In this report, the term <i>impacts</i> is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.
Impact Assessment	The practice of identifying and evaluating, in monetary and/or nonmonetary terms, the effects of [climate] change on natural and human systems.
Likelihood	The chance of a specific outcome occurring, where this might be estimated probabilistically.
Mitigation	The lessening of the potential adverse impacts of physical hazards (including those that are human-induced) through actions that reduce hazard, exposure, and vulnerability.
Representative Concentration Pathways	Representative Concentration Pathways (RCPs) are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014.
Resilience	The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognising the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term 'risk' is used primarily to refer to the risks of climate impacts.
Risk Assessment	The qualitative and/or quantitative scientific estimation of risks.
Risk Management	Plans, actions, or policies to reduce the likelihood and/or consequences of risks or to respond to consequences.
Stressors	Events and processes, often not climate-related, that have an important effect on the system exposed and can increase vulnerability to climate related risk.

<b>System Sensitivity</b>	The degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise).
<b>Vulnerability</b>	The propensity or predisposition to be adversely affected by hazards. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
<b>Vulnerability Assessment</b>	Process which attempts to identify the root causes for a system's vulnerability to hazards (e.g. climate variability and change).



## Acronyms, Units and Currencies

\$	United States Dollar
°C	Degrees Celsius
yr	Year
ADB	Asian Development Bank
AfCAP	Africa Community Access Partnership
AfDB	African Development Bank
ANE	Administração Nacional de Estradas (National Roads Administration, Mozambique)
AsCAP	Asia Community Access Partnership
CC	Climate Change
CCTAP	World Bank's Climate Change Technical Assistance Project
CCA	Climate Change Adaptation
CFMP	Cenário Fiscal de Médio Prazo (Medium-Term Fiscal Framework)
CGCMC	Centre for the Management of Climate Change
CRED	Centre for Research on the Epidemiology of Disasters
CSIR	Council for Scientific and Industrial Research, South Africa
DFID	Department for International Development, UK
DRFI	Disaster Risk Financing and Insurance
DMC	Developing Member Country
EM-DAT	Emergency Events Database
GCM	Global Climate Model
GDP	Gross Domestic Product
GIS	Geographic Information System
IFAD	International Fund for Agricultural Development
ITCZ	Inter Tropical Convergence Zone
MCA	Multi-Criteria Analysis
MCT	Ministry of Science and Technology
MDA	Ministries, Departments, Agencies/Authorities
MDG	Millennium Development Goal
MICOA	Ministry for the Coordination of Environmental Affairs
MITADER	Ministry of Land, Environment and Rural Development
NGO	Non-Governmental Organisation
NPV	Net Present Value
PMS	Pavement Management System
PQG	Plano Quinquenal do Governo
RAI	Rural Access Index
RAMS	Road Asset Management System
RCM	Regional Climate Model
ReCAP	Research for Community Access Partnership
SADC	Southern African Development Community
SCS	Soil Conservation Service
SMS	Slope Management System
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, DFID)
UN ESA	United Nations, Department of Economic and Social Affairs
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reconstruction



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## Summary

In order to help address a significant threat to Africa's development through climate change, the Africa Community Access Partnership (AfCAP), a research programme funded by UKAid, commissioned a project in April 2016 to produce regional guidance on the development of climate-resilient rural access in Africa through research and knowledge sharing within and between participating countries. The output will assist the development of a climate resilient road network that reaches fully into and between rural communities.

The study covers threats and adaptation for both existing and new infrastructure. It addresses the issues of appropriate and economic methodologies for vulnerability and risk assessments; prioritisation of adaptation interventions; and optimisation of asset resilience in the context of low volume rural access roads. In addition, evidence of cost, economic and social benefit links to rural communities arising from more resilient rural access will be provided to support wider policy adoption across Africa.

A **Climate Adaptation Handbook** has been developed to provide a methodology for carrying out a climate adaptation assessment for rural access to assist socio-economic development (Climate Adaptation Handbook, Head *et al.*, 2018). It is supported by three separate Guideline documents and a Manual covering the following:

- Change Management<sup>1</sup>
- Climate Threats and Vulnerability Assessment<sup>2</sup>
- Engineering Adaptation<sup>3</sup>
- Visual assessment Manual<sup>4</sup>

This document is a Country Report on the Management of Vulnerability and Adaptation to Climate Change using the principles and recommendations set out in the Handbook and the relevant Guidelines. It features issues specific to Mozambique, dealing with the issues of adaptation, incorporation of climate risk information into systems, and actions to put in place a policy that specifically deals with incorporating Climate Change Adaptation (CCA) into the National Roads Administration of Mozambique (ANE) and its operations.

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<sup>1</sup> Head, M., Verhaeghe, B. and Maritz, J. (2018). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Change Management Guidelines*, GEN2014C. London: ReCAP for DFID.

<sup>2</sup> Le Roux, A., Makhanya, S., Arnold, K., Roux, M., & Mwenge Kahinda, J.M. (2018). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Climate Threats and Vulnerability Assessment Guidelines*, GEN2014C. London: ReCAP for DFID.

<sup>3</sup> Paige-Green, P., Verhaeghe, B. & Head, M. (2018). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Engineering Adaptation Guidelines*, GEN2014C. London: ReCAP for DFID.

<sup>4</sup> Paige-Green, P., Verhaeghe, B. (2018). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Visual Assessment Manual*, GEN2014C. London: ReCAP for DFID.

## 1 Introduction

### 1.1 Climate variability and change within the context of rural accessibility

Africa has experienced dramatic changes to the continent's climate, which is causing widespread damage to road infrastructure and its associated assets. Rural accessibility is being compromised in a number of countries for increasing proportions of the year, creating both direct and indirect adverse effects on livelihoods and associated socio-economic development.

In the past four decades (1975-2015) African countries have experienced more than 1 400 recorded weather-related disasters, each having direct effects on rural accessibility. These disasters impact on affected countries' economies and, in particular, on rural communities and their livelihoods. The impacts of these natural hazards (floods, storms, droughts, extreme temperature, landslides and wildfires) were also felt across all economic sectors and infrastructure. Many communities and countries are socially and economically vulnerable to extreme climate events. Low adaptive capacity, as well as their high exposure to natural hazards, has resulted in the death of more than 600 000 people (the majority due to droughts), left 7.8 million people homeless (99 % due to flooding and storms) and affected an estimated 460 million people over the past four decades (CRED, 2016).

The predominant types of recorded weather-related disasters and the amount of people that have historically been affected in each country are illustrated in scaled pie charts presented in Figure 1.

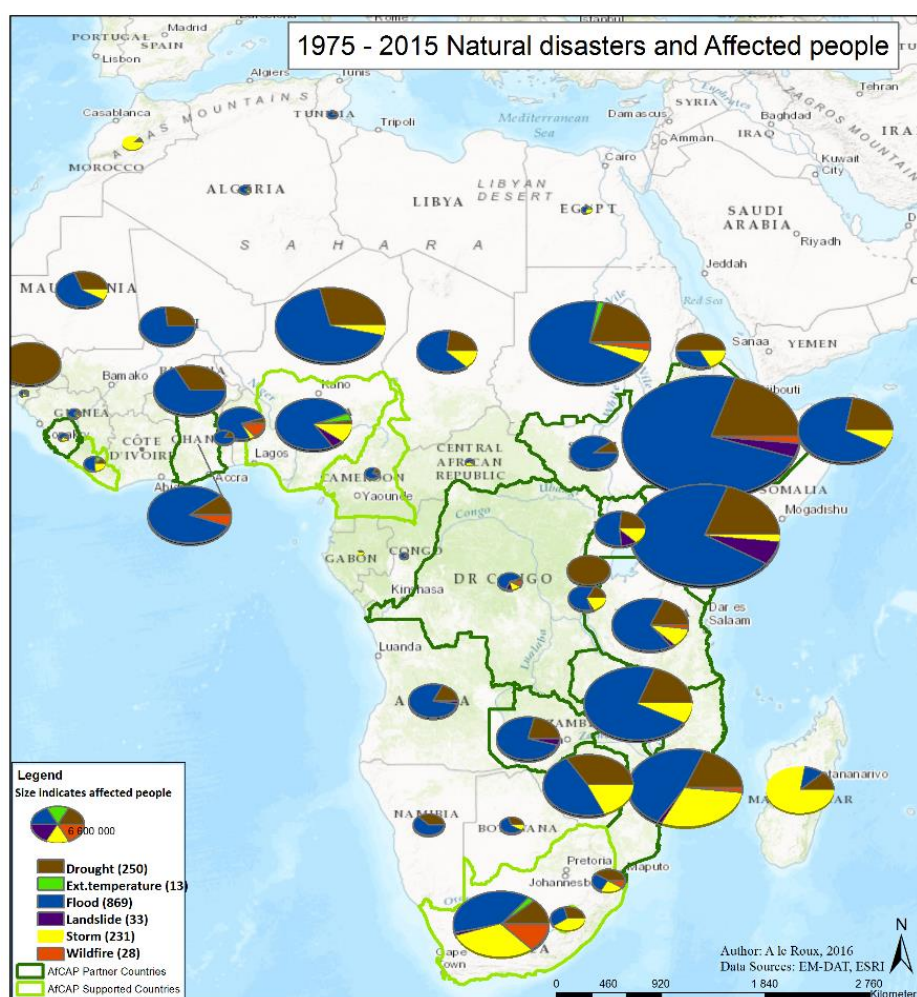


Figure 1: Recorded weather-related disasters and affected populations

The African continent is facing a potential direct liability of over \$ 150 billion to repair and maintain existing roads damaged from temperature and precipitation changes directly related to projected climate change. The liability does not include costs associated with impacts to critically-needed new roads, nor does it include indirect socio-economic effects generated from dislocated communities and from loss of rural access (Chinowsky *et al.*, 2014). It is estimated that an additional 230 million people will live in rural areas in the 15 AfCAP supported and partner countries by 2050, making rural accessibility a high priority in Africa (UN-ESA, 2014).

## 1.2 Climate effects in Mozambique

The effects of changes in climate can be observed through the increased frequency and intensity of extreme climatic events in Mozambique such as droughts, floods, tropical cyclones, changes in the temperature and precipitation patterns, and in other phenomena, such as rising sea levels, saltwater intrusion and the spread of the forest wildfires. Many of these events are already occurring in Mozambique and, during the last decade, have caused the loss of thousands of human lives and the destruction of public and private infrastructure, including schools, hospitals, access routes, houses and tourist facilities. These losses negatively impact the growth of the country's GDP, and the achievement of the Government's national objectives for poverty reduction and wealth creation. The records of extreme events for the period between 1956 and 2007 indicate that for events lasting less than a year, the floods of 2000 appear to be the event that caused the highest number of casualties, with 699 dead and 4.5 million affected (NCCAMS, 2012).

Mozambique is situated in the subtropics along the east coast of southern Africa that regularly experiences intense weather related natural hazards; of note is the high exposure to intense droughts, floods and tropical cyclones. Thirty-nine percent of its population live in coastal areas below 100 m elevation (Van Niekerk & le Roux, 2017), exposing a vast number of economic activities, people and livelihoods to the risks associated with cyclones. In the past four decades alone, 66 weather-related natural disasters have killed more than 100 000 people (98 % due to droughts), left more than 600 000 people homeless (90 % due to tropical cyclones) and affected an estimated 30 million people (CRED, 2016).

Mozambique experiences the highest frequency of land-falling tropical cyclones and pressure-lows of any African country, often in association with widespread and catastrophic floods. Contributing to flooding is the fact that Mozambique shares nine river basins with neighbouring countries, with streamflow originating from these countries contributing to 50% of the country's total volume of runoff. Rainfall occurs mostly during the warmer months from October to April and is influenced by the warm Mozambique current, meridional displacements in the Inter-Tropical Convergence Zone (ITCZ), easterly waves (including tropical cyclones) and tropical-temperate troughs. Well-defined sea-breeze circulations also frequently develop on the coast during days when the synoptic-scale forcing is weak (le Roux *et al.*, 2018b).

## 1.3 Socio-economic overview

Mozambique is one of the world's poorest countries and the vast majority (70 %) of poor households are located in the rural areas (IFAD, 2011). Mozambique has a human development index (HDI) of 0.416 (UN, 2015) and is ranked 180<sup>th</sup> out of 188 assessed countries in terms of its human development measures. It is estimated that 18.4 million people (68%) of Mozambique's 27 million people live in rural areas (UN ESA, 2014). Rural isolation, poor infrastructure, high subsistence rain-fed agriculture and frequent exposure to intense weather-related hazards make Mozambique one of the SADC countries' most vulnerable to weather-related disasters (Van Niekerk & le Roux, 2018). The majority of Mozambique's population lives along the coast (Figure 2) – where floods, cyclones, erosion and sea level rise pose serious risks. As many as 39% of the population lives in coastal



regions below 100 m elevation (Van Niekerk & Le Roux, 2018). Climate projections indicate potential increases in the number of cyclones, flooding, storm surges as well as drought events, increasing the country's overall vulnerability to climate change (UN-Habitat, 2013; UN-Habitat, 2014; MER, 2015).

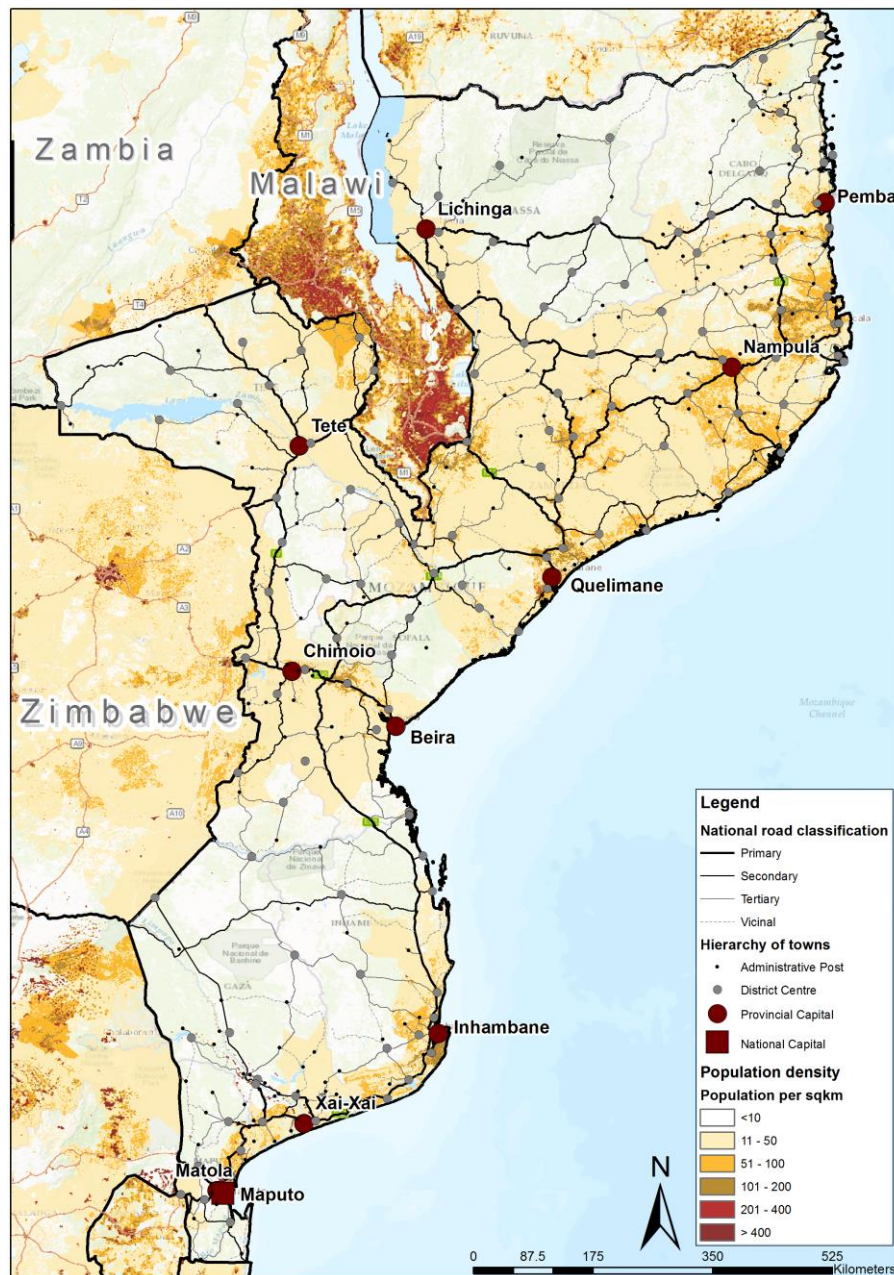
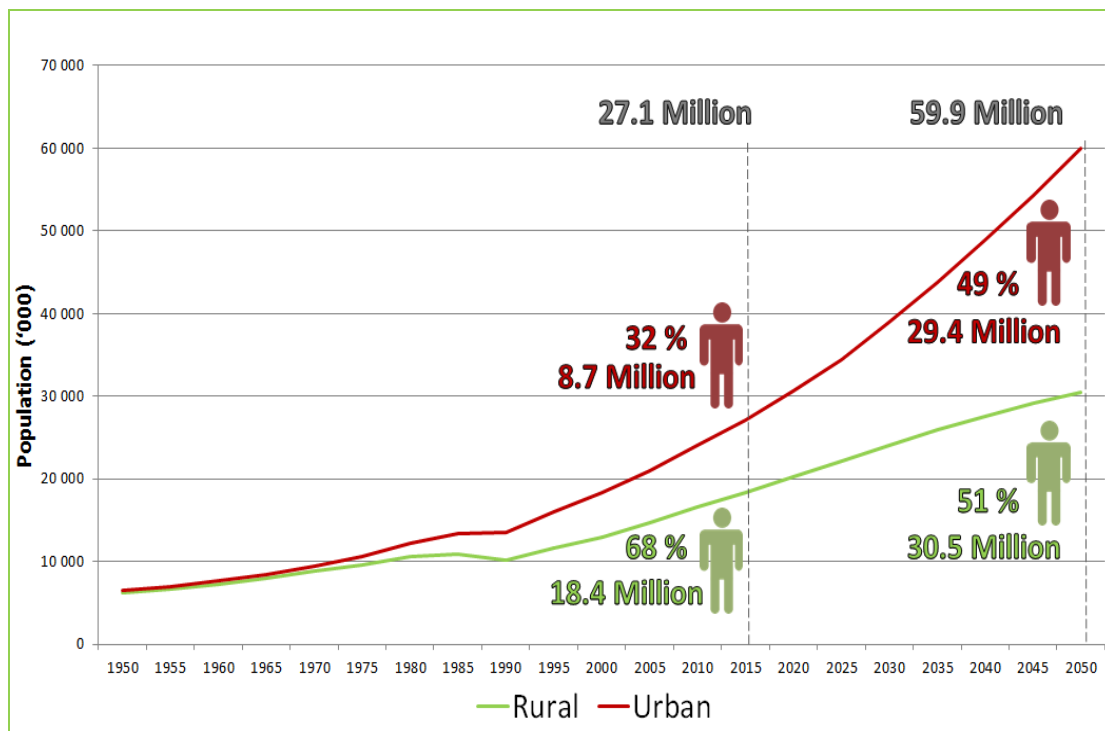


Figure 2: The current population distribution in Mozambique

Source: National Roads Administration (ANE) Mozambique, WorldPop, Diva-GIS and ESRI

Mozambique is projected to experience rapid urbanisation and a substantial urban growth rate in the coming three decades (UN ESA, 2014). The country is projected to become 49% urbanised by 2050 (up from 32% in 2015), as illustrated in Figure 3. The rural population is expected to grow to 30.5 million people adding 12 million additional people in rural areas by 2050. This will place substantially more pressure on land and natural resource management as well as exposing more people, livelihoods and economic activity to weather-related hazards. Failure to adapt to climate can result in a GDP reduction of between 4% and 14% in the decade between 2040 and 2050 (DRFI, 2012).



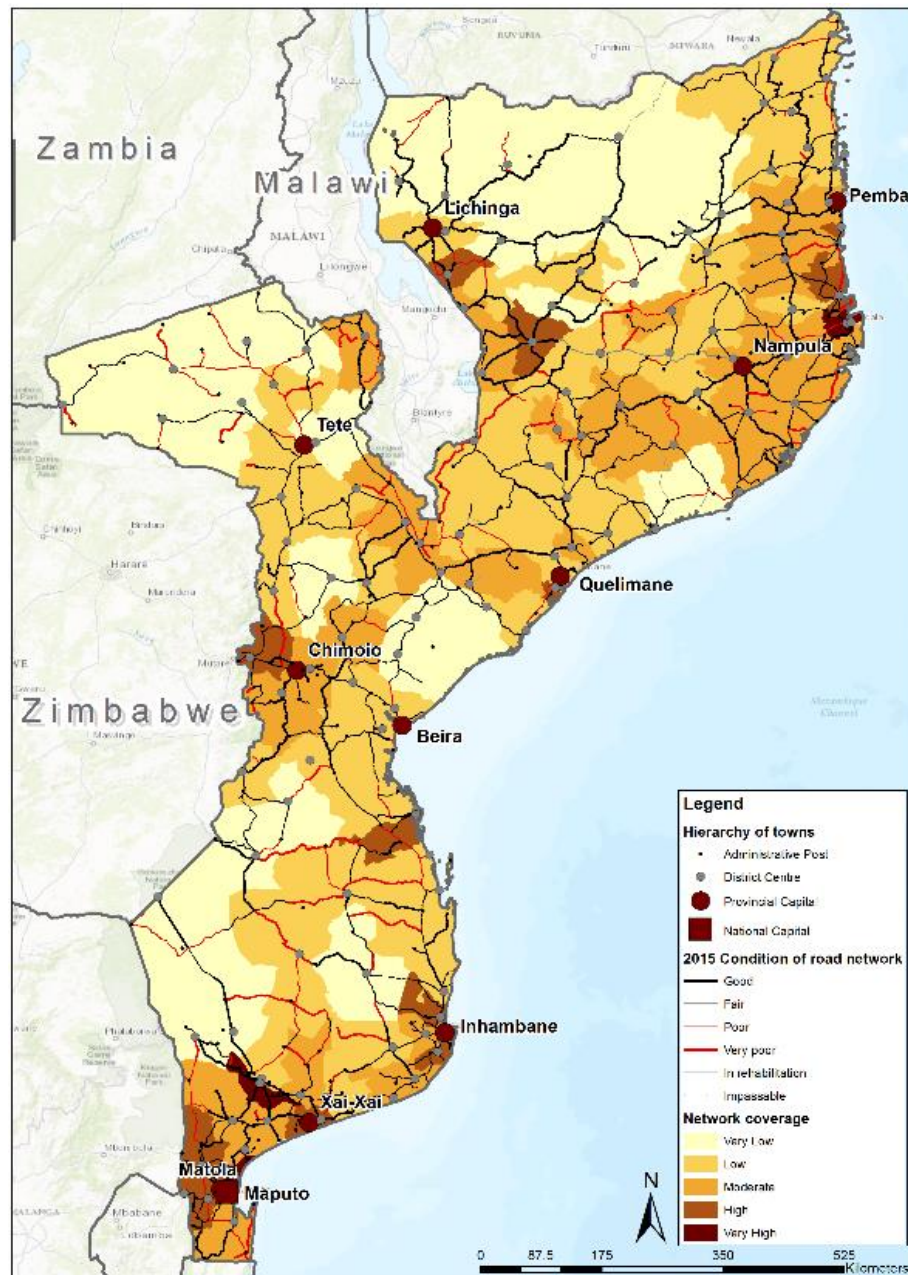


**Figure 3: Projected changes in Urban and Rural Population Distribution (2015 – 2050)**

It is not only the physical effects of climate change that render Mozambique highly vulnerable, but it is also a myriad of development challenges faced by the country that increase Mozambique's vulnerability and decrease the population's capacities to adapt. Poverty and weak institutional development, coupled with the increasing frequency of extreme weather events put Mozambique especially at risk (Netherlands Commission for Environmental Assessment, 2015). High poverty and low literacy rates for the vast majority of the population limit the options the rural communities have for making agricultural activities more climate-resilient and for finding alternative livelihoods. A projected drop of 4% to 14% in GDP or costs of up to \$ 7.6 billion by 2050 are projected due to climate change, seriously hampering the country's economic development. Poor infrastructure (only 6% of the primary road network are paved nationally (Netherlands Commission for Environmental Assessment, 2015) also limits people's mobility and increases the vulnerability of remote rural communities in case of extreme weather events. Furthermore, the high population growth rate (2.5% per year) additionally places pressure on Mozambique's natural resources (Netherlands Commission for Environmental Assessment, 2015).

#### 1.4 Road network overview

The map in Figure 4 depicts the condition of Mozambique's road network as at 2015 and provides an overview of the density of roads within each district (Length of roads per district/Total area of district). Mozambique has a very low overall road network density, which is considered to be amongst the lowest in Africa (DRFI, 2012). The road network is particularly vulnerable to rainfall events associated with cyclones and it is estimated that Cyclones Eline, Favio and Jokwe affected 11 400 km of secondary roads and 3 400 km of primary highways (DRFI, 2012).



**Figure 4: Mozambique road network overview 2015 (density and condition)**

**Source:** National Roads Administration (ANE) Mozambique, CSIR, Worldpop 2010 & DIVA-GIS

Thirty percent of Mozambique's current classified road network is considered to be in a poor, very poor or impassable condition. This includes eight percent of surfaced roads compared to thirty eight percent of unsurfaced roads (ANE, 2017).

### 1.5 Overview of the AfCAP Climate Adaptation Project

The overall aim of the AfCAP Climate Adaptation Project (AfCAP Project) is to deliver sustainable enhancement in the capacity of AfCAP partner countries to reduce current and future climate impacts on vulnerable rural road infrastructure. The approach taken is circular (Quinn et al., 2018), where science-based research undertaken to identify climate hazards, vulnerability and impacts on rural road infrastructure is integrated with decision-centric processes of prioritizing adaptation options, implementation through demonstration sections and both policy and practical embedment

of pragmatic, cost-beneficial engineering and non-engineering procedures. Core to this approach is extensive engagement of stakeholders based on the recognition of the importance of appraising locally-specific current and future climate threats, and organizational pathways for the uptake of engineering and non-engineering recommendations.

The fundamental research objective is to identify, characterise and demonstrate appropriate adaptation procedures that may be implemented to strengthen long-term resilience of rural access based on a logical sequence of guidance covering:

- Climate threats;
- Climate impacts;
- Vulnerability to impacts (risk);
- Non-engineering adaptations (referred to as Change Management adaptations here);
- Engineering adaptations; and
- Prioritisation.

The second objective, which focusses on capacity building and knowledge exchange, is to meaningfully engage with relevant road and transport Ministries, Departments and Agencies/ Authorities in a knowledge dissemination and capacity-building programme based on the outputs from the research.

The third objective is to ensure that there is focus on the uptake and subsequent embedment of the outcomes aimed at a range of levels; from informing national policies, through regional and district planning, down to practical guidance on adaptation delivery at rural road level.

The purpose of this document is to summarise relevant information from the AfCAP programme on rural access road climate adaptation, namely, the methodology and findings for Mozambique. It includes an analysis of the current and projected climate situations and the impacts on rural road infrastructure, as well as a summary of Mozambique's socio-economic and policy environments. Finally, Change Management options to reduce risk in order that agreed actions can be implemented are identified.

## 2 Current Climate and Climate Change Impacts on Road Infrastructure in Mozambique

The first research objective as explained in Section 1.5 is concerned with gathering the scientific evidence which informs the proposal and appraisal of engineering and non-engineering adaptation options. The scientific evidence consists of identifying climate threats (or hazards) and their impacts on road infrastructure in rural areas.

This chapter begins with the definition of disaster risk in the context of climate events and processes and their impact of road infrastructure. Climate modelling outputs and climate impacts on Mozambican rural roads for both current and future time periods will be discussed. A detailed description of climate models and downscaling can be found in the “Climate Threats and Vulnerability Assessment Guidelines” (Le Roux, *et al.*, 2018).

### 2.1 Defining disaster risk for road infrastructure

Within the context of this work, disaster risk is defined as a function of hazards, exposure and vulnerability of rural access roads. The focus is primarily on climate induced hazards (or threats), and in terms of vulnerability, an additional aspect is considered, namely rural community access (Le Roux, *et al.*, 2018). Therefore, the definition is adapted from the concept shown in Figure 5 that was framed by the International Panel on Climate Change Working Group 2 - Fifth Assessment Report (Niang *et al.*, 2014) by considering the physical and some of the functional aspects of road infrastructure. In particular, the following definitions apply:

- **Hazards:** Climate-related events that can possibly cause damage to and/or interruption of service of rural low volume access road infrastructure as well as potential loss of life (e.g. floods);
- **Exposure:** Location and condition of low volume road facilities, the associated structures and road environment as well as rural communities in places that could be adversely affected (within the hazard footprint); and
- **Vulnerability:** Propensity of road infrastructure to be adversely affected by hazards, considering also the dependence of rural communities on these low volume access roads.

Disaster risk is determined by the occurrence of hazards (e.g. floods), which may impact exposed populations and assets (e.g. rural communities and rural access roads located in flood-prone areas). Vulnerability is an inherent condition of the population or asset that makes it particularly susceptible to the damaging effects imposed by the hazard (i.e. rural access roads in poor condition). Poorly planned development, socio-economic vulnerability, environmental degradation and climate change are all pressures that increase the damaging effects of hazards (World Bank, 2013).

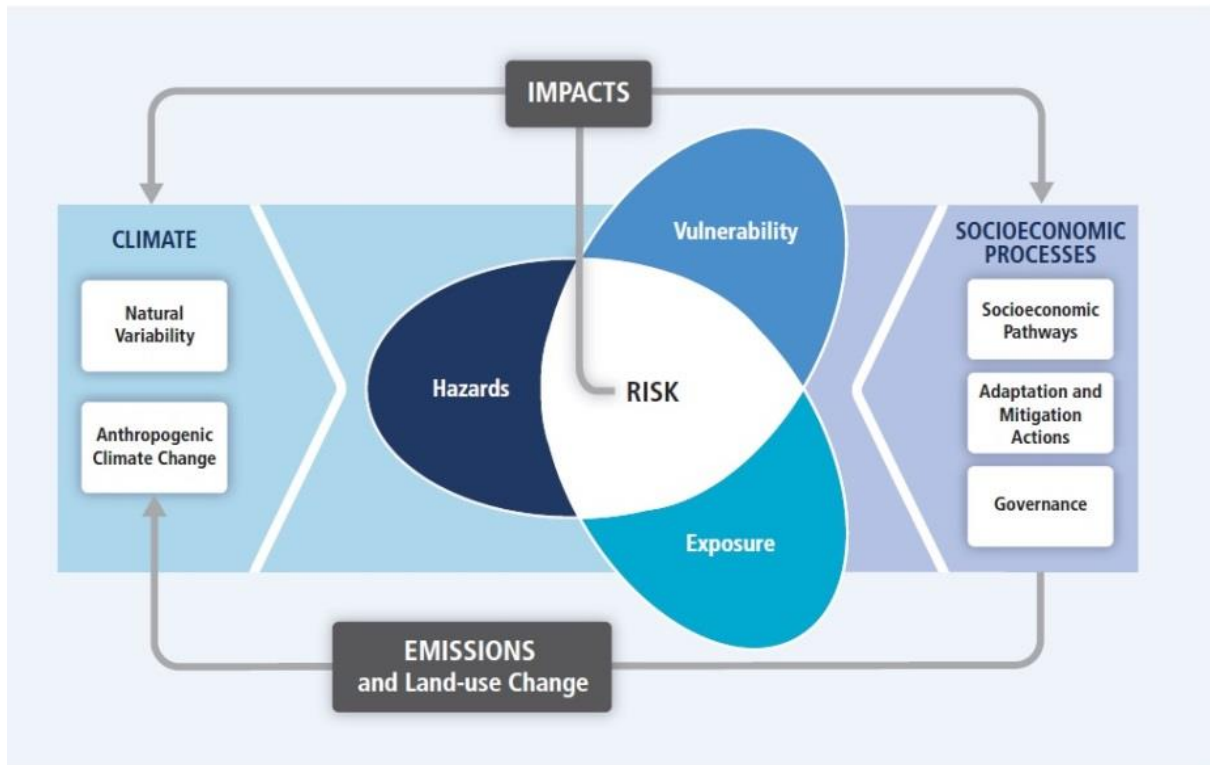


Figure 5: A conceptual framework for climate-related risk as an interaction between climate-related hazards, exposure and vulnerability of human and natural systems.

Source: Niang *et al.* (2014)

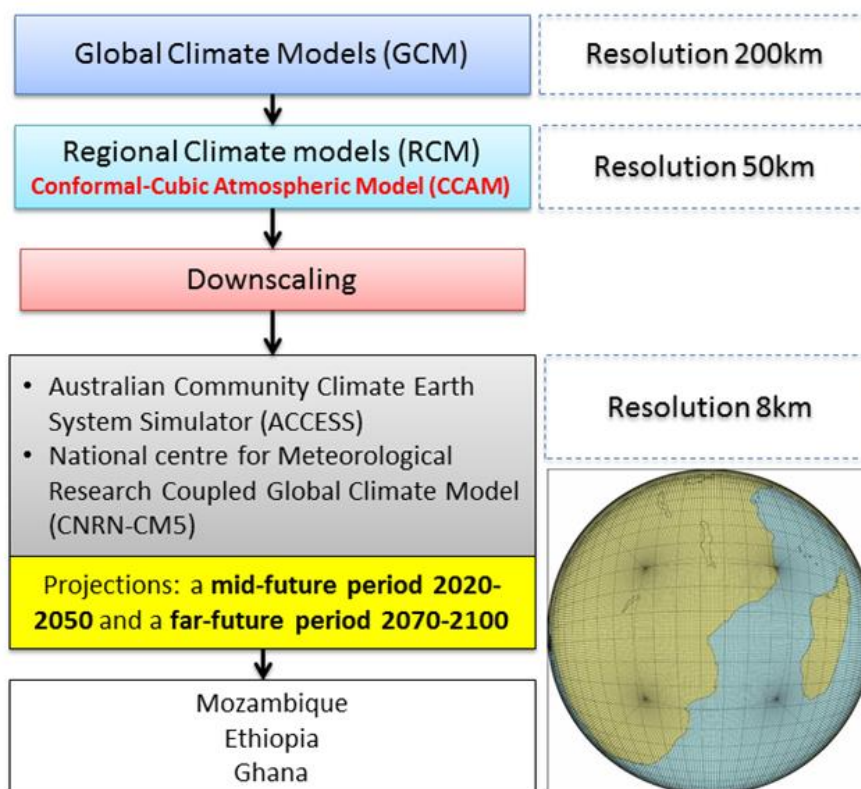
## 2.2 Downscaling of climate projection models

In order to project future climate scenarios for Mozambique (until 2100), detailed projected changes in climate were obtained by downscaling the output of two global climate model simulations (GCMs), namely the Australian Community Climate and Earth System Simulator (**ACCESS1-0**) and the French National Meteorology Research Centre Model Version 5 (**CNRM-CM5**). The output of both the **ACCESS1-0** and **CNRM-CM5** models, corresponding to the low mitigation greenhouse gas emission scenario (RCP8.5<sup>5</sup>), were selected for further downscaling to a very high resolution over three AfCAP countries, including Mozambique (see Figure 6). The regional climate model used was the Conformal-Cubic Atmospheric Model (**CCAM**), a variable-resolution GCM developed by the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) (McGregor & Dix, 2001; McGregor 2005; McGregor & Dix, 2008).

To reflect the current climate variability for Mozambique and surrounding region, a **Conformal-Cubic Atmospheric Model (CCAM)** was created to produce downscaled climatologies, where for each grid cell values were averaged over the ACCESS1-0 and CNRM-CM5 downscalings for the periods 1971 to 2000, 2021-2050 and 2071-2100.

<sup>5</sup> Representative Concentration Pathways (RCP)





**Figure 6: Climate model downscaling.**

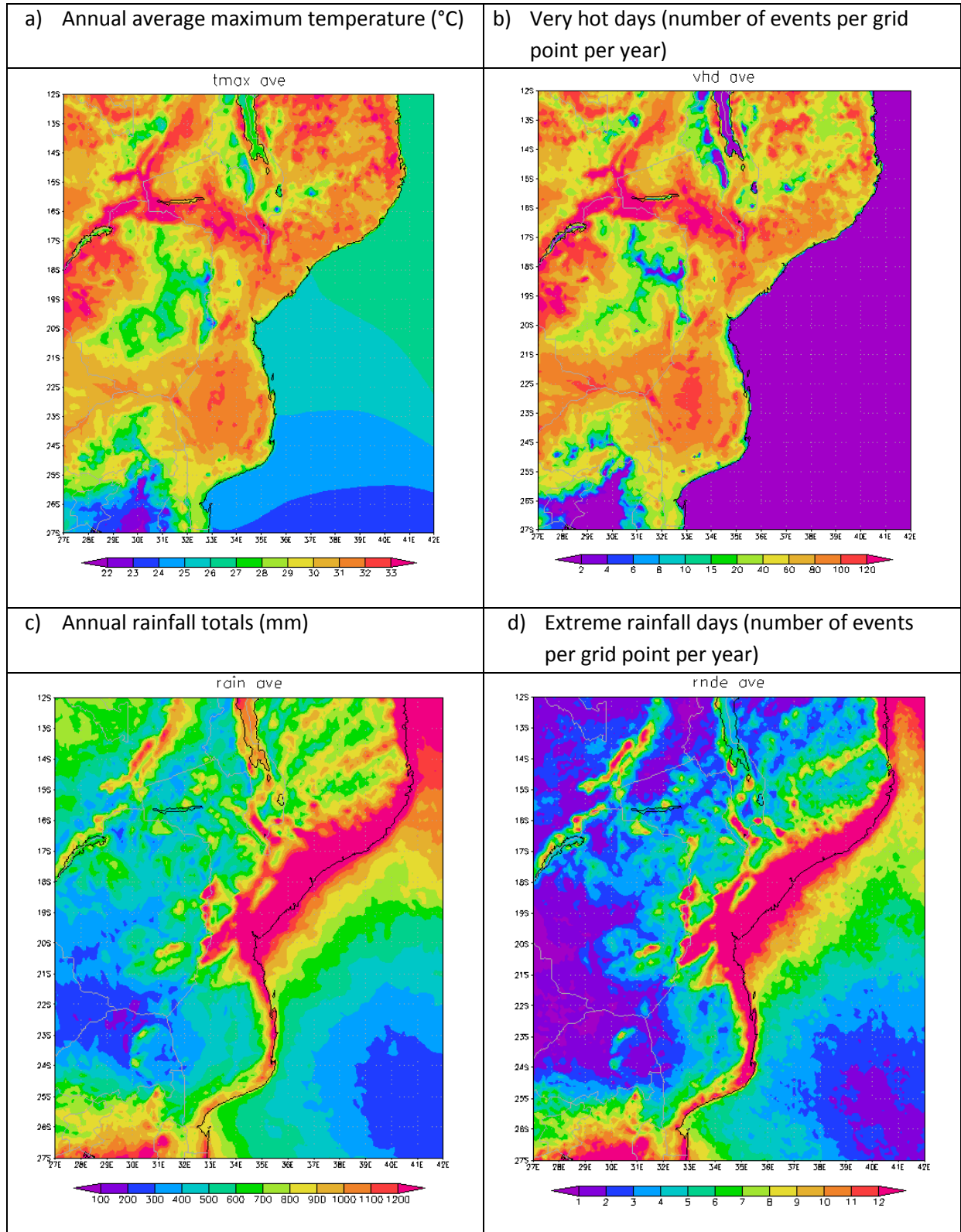
The stretched conformal-cubic grid used to obtain the 8 km resolution model projections of future climate change over Mozambique is displayed in Figure 6 (every second grid-point is shown), also showing the model domain stretching about 1 500 km from the south to the north, and 1 500 km from the west to the east to cover the entire country. Four climate variables were included for the analyses, namely:

- Average annual rainfall (mm);
- The annual number of extreme rainfall events (defined as the occurrence of more than 20 mm of rain over a period of 24 hours);
- Annual average temperature (°C); and
- The annual number of very hot days (defined as days when the maximum temperature exceeds 35 °C).

The simulations described here are of the highest resolution ever obtained for relatively large sub-regions of the African continent.

### 2.3 Current climate variability and observed trends

Annual average maximum temperatures of over 30°C are projected across Mozambique, which matches on-ground observations (Figure 7 – top-left). More than 100 very hot days are simulated to occur annually over parts of the Limpopo river basin in the south, and also over a larger area in the Zambezi river basin in the north (Figure 7 – top-right). The bottom of Figure 7 shows high average annual rainfall totals of more than 1 000 mm per year are modelled to occur along the coastline, exhibiting a pronounced sea-breeze pattern. The southern part of the country, located in the Limpopo river basin, is semi-arid. The simulated pattern in annual average numbers of extreme rainfall events over the area of interest closely follows that of the simulated rainfall totals. More than 12 extreme rainfall events are simulated to occur annually at many locations along the coast.

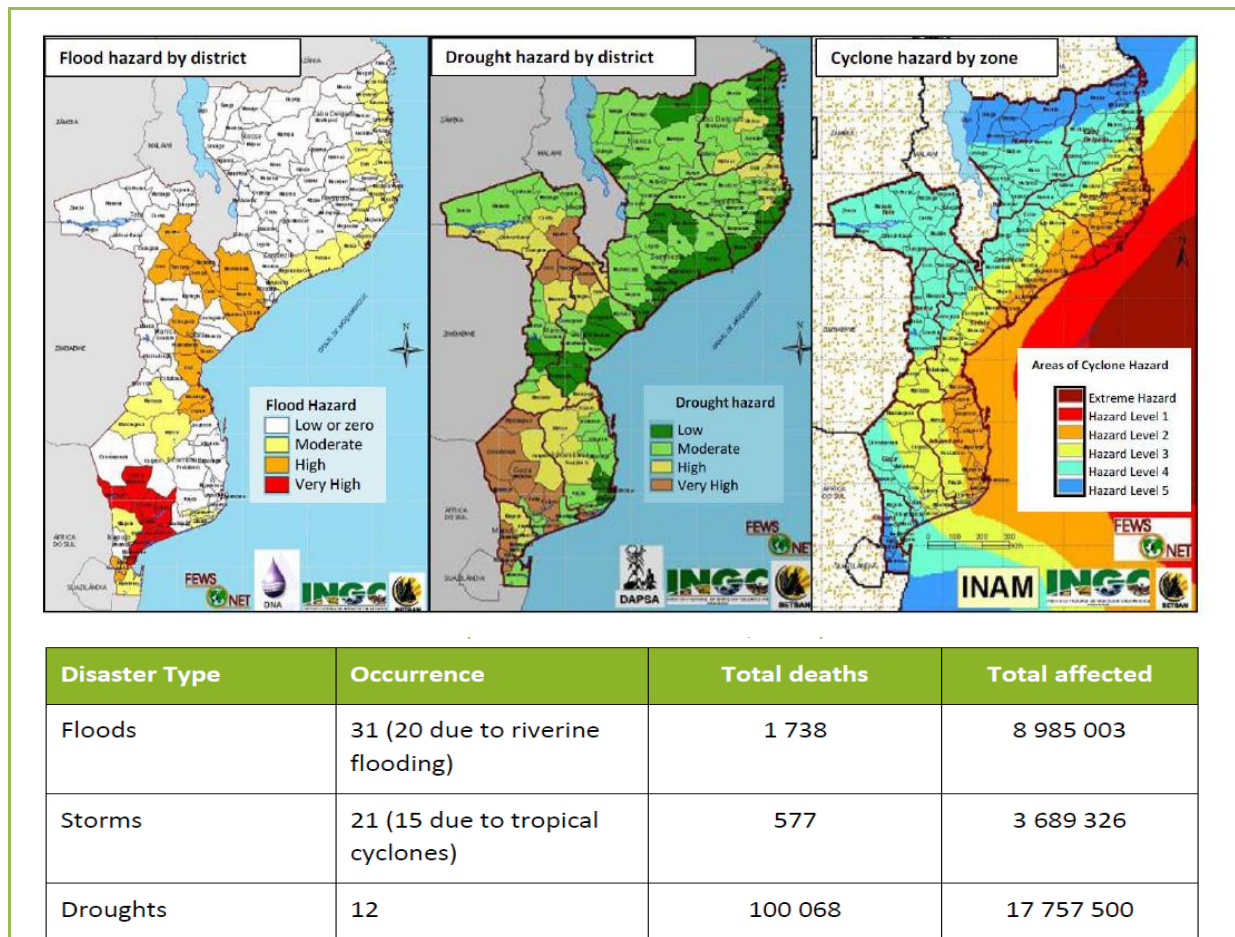


**Figure 7: Present-day climatology (1971-2000) over Mozambique**

Source: CCAM downscaled climatology from ACCESS1-0 and CNRM-CM5 (CSIR)



Mozambique regularly experiences intense **weather related natural hazards**, particularly high exposure to frequent and intense droughts, floods and cyclones, many of which affects the country simultaneously in given years (Figure 8). Flooding and storms are the most frequent type of weather related hazards posing significant risks to rural settlements, infrastructure and rural accessibility.



**Figure 8: Mozambique current situation: Weather related hazards and impacts (1975-2015)**

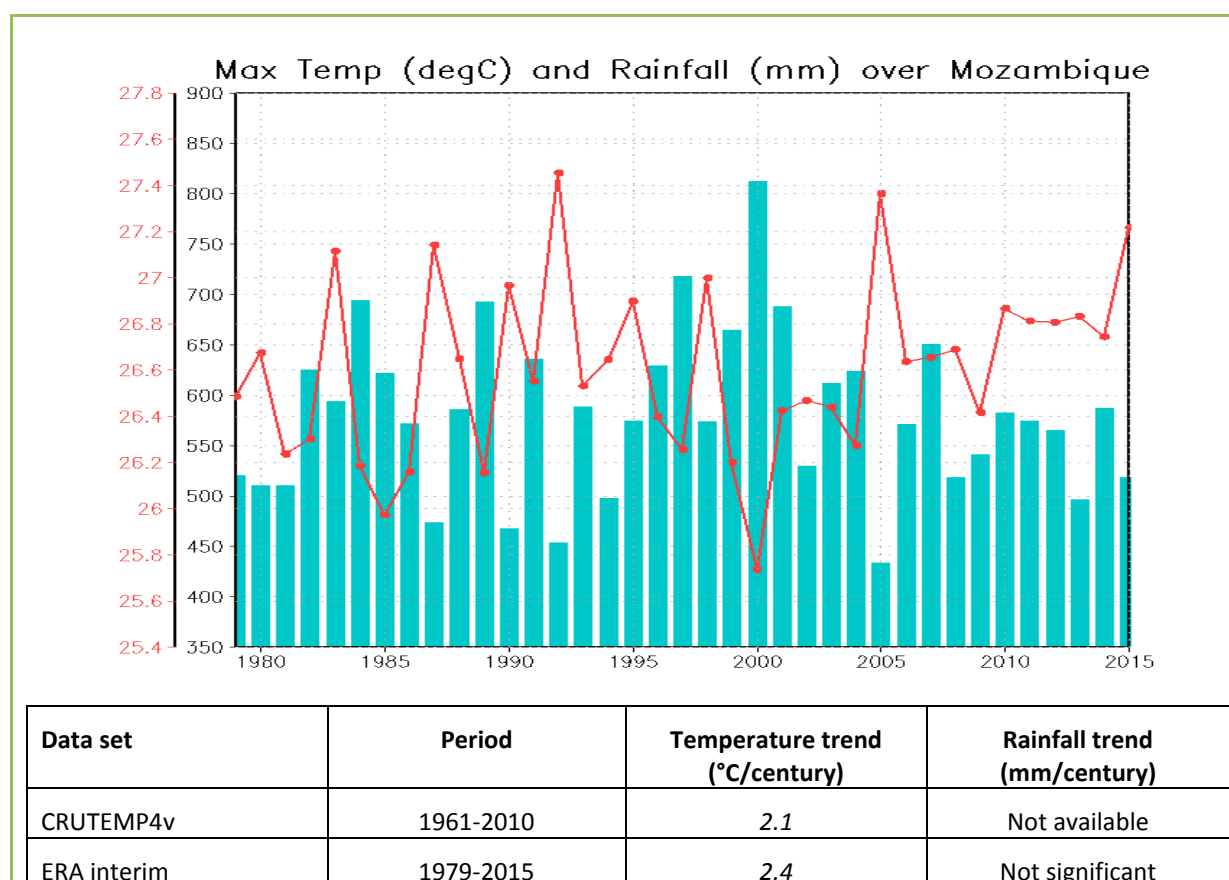
Source: DFRI Country notes, p.6 and custom data acquired from EM-DAT, 2016

Tropical cyclones that reach Mozambique often cause widespread and catastrophic floods. Contributing to the flooding is the fact that Mozambique also shares nine river basins with neighbouring countries that contributes 50 % of the country's total volume of runoff. Rainfall occurs mostly during the warmer months from October to April and is influenced by the warm Mozambique ocean current, meridional displacements in the Inter-Tropical Convergence Zone (ITCZ), easterly waves (including tropical cyclones) and tropical-temperate troughs.

Due to its high dependency on natural resources (and the environment), and its low capacity to adapt to intense weather related hazards, Mozambique is vulnerable (endangering loss of life, livelihoods and economic activity). Current trends and modelled climate indicates that the weather related hazards are increasing. Considering the importance of transport infrastructure to sustain livelihoods and the economy, it is vital to protect and improve rural accessibility especially in areas where vulnerable communities are.

Over northern Mozambique, the rate of temperature increase is more than 2.5°C per century, with smaller increases (in the order of 2°C per century) recorded over the central and southern parts (Engelbrecht *et al.*, 2015). Rainfall trends recorded over Mozambique over the last five decades have been largely negative - but are also statistically insignificant (Niang *et al.*, 2014). The variability in

maximum temperature and rainfall over northern Mozambique (defined as the region north of Beira) as represented in ERA-interim data is displayed in Figure 9 for the period 1979 to 2015.



**Figure 9: Mozambique current situation: Weather variability and trends**

**Source:** ERA-interim and CRUTEMP4v

Over the past 50 years, an increasing trend in temperature is observed over northern Mozambique, with the period 2000 to 2015 showing the strongest upward trend in observed maximum temperatures. No trend could be determined from the rainfall signal over the past half century. However, it is observed that the amplitude from the annual rainfall time series (1980-2015) is lower for the past decade (2005-2015) in comparison to the earlier period. Lastly, the peaks (or high values) in annual maximum temperatures coincide with lower average annual rainfall observations.

## 2.4 Projected climate change

Using projected climate change for two futures periods, namely a **mid-future period 2020-2050** and a **far-future period 2070-2100**, projected climate data was produced. This was compared to the current baseline period 1996-1990 and the from these comparisons it could be deduced that the southern African region is likely to become generally drier under low mitigation (Christensen *et al.*, 2007; Niang *et al.*, 2014; Engelbrecht *et al.*, 2015). Drastic temperature increases are projected to occur in conjunction with the rainfall decreases, approaching values of 6°C in the far-future over the subtropical interior regions. Over Mozambique, far-future increases are projected to range between 3°C and 4°C over the eastern coastal areas, with larger increases projected for the western interior regions (Niang *et al.*, 2014; Engelbrecht *et al.*, 2015).

For southern Mozambique, rainfall decreases are consistently projected across the majority of CMIP5 GCMs, with a mixed signal of rainfall increases and decreases projected for the northern parts (Niang *et al.*, 2014). Very few Regional Climate Model projection studies have to date been obtained

for Mozambique. A northward shift in tropical cyclone tracks is projected by the ensemble of RCM downscalings generated by Malherbe *et al.* (2013), with implications of general rainfall increases and more flood events for central to northern Mozambique, with an associated decrease in such events projected for southern Mozambique.

#### 2.4.1 Mid-future projected climate changes (period of 2021-2050)

The projected mid-future climate (see Figure 10) reflects projected changes in annual average maximum temperatures (°C, top) and the annual number of very hot days (number of events per grid point per year, bottom) over Mozambique, for the ACCESS1-0 (left) and CNRM-CM5 (right) downscalings. The projections are for the period 2021 to 2050 relative to 1961 to 1990 under low mitigation scenario. For the mid-future period of 2021 to 2050, the ACCESS1-0 and CNRM-CM5 downscalings are consistently indicating projected temperature increases of 1°C to 2°C in the southern parts of the country, with increases less than 1°C projected over the northern parts. The number of very hot days is projected to increase by 20 to 40 days per year across the country, with the largest increases projected for the Limpopo river basin in the south (Niang *et al.*, 2014; Engelbrecht *et al.*, 2015).

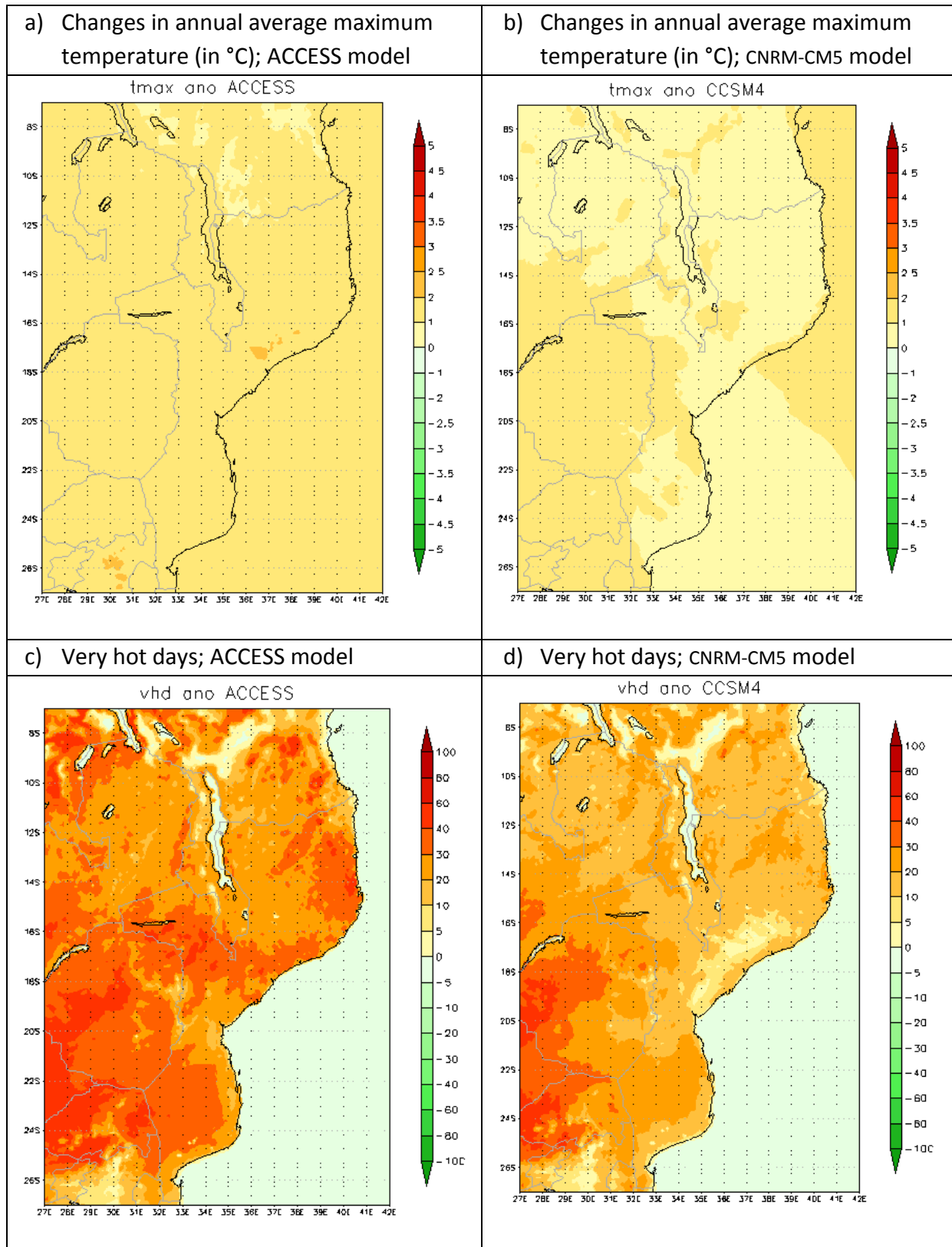
CCAM projected changes in annual average rainfall totals (Figure 11, top) and the annual number of extreme rainfall days (number of events per grid point per year; Figure 11, bottom) over Mozambique, for the ACCESS1-0 (left) and CNRM-CM5 (right) downscalings. The projections are for the period 2021 to 2050 relative to 1961 to 1990 under low mitigation scenario. Both of the downscalings are indicative of pronounced rainfall increases as well as increases in extreme rainfall events over the far northern parts of Mozambique, spreading to the central parts in the CNRM-CM5 downscaling. Over the southern parts, the downscalings are indicative of rainfall decreases or smaller increases, consistent with the downscalings of Malherbe *et al.* (2013) and the GCM projections of AR5 (Niang *et al.*, 2014). The larger southern African region is likely to become generally drier under low mitigation (Christensen *et al.*, 2007; Niang *et al.*, 2014; Engelbrecht *et al.*, 2015). For southern Mozambique, rainfall decreases are projected by the majority of CMIP5 GCMs, with a minority of GCMs indicative of rainfall increases in the south. Very few regional RCM projection studies have to date been obtained for Mozambique. A northward shift in tropical cyclone tracks was projected by the ensemble of RCM downscalings described by Malherbe *et al.* (2013), with implications of general rainfall increases and more flood events for central to northern Mozambique.

#### 2.4.2 Far-future projected climate changes (period of 2071-2100)

CCAM projected changes in annual average maximum temperatures (Figure 12 - top) and the annual number of very hot days (number of events per grid point per year, Figure 12 bottom) over Mozambique, for the ACCESS1-0 (left) and CNRM-CM5 (right) downscalings. The projections are for the period 2071 to 2100 relative to 1961 to 1990 under low mitigation scenario. Temperature increases of about 4°C are projected for the far-future (2071-2100) over northern Mozambique by the ACCESS1-0 downscaling, with somewhat smaller increases projected by the CNRM-CM5 downscaling. Relatively smaller temperature increases are projected to occur over the southern parts of the country (Figure 12). More than 40 very hot days per year projected to occur in the far-future compared to the present-day baseline climatology, with increases of more than 80 days per year projected over northern Mozambique in the ACCESS1.0 downscaling.

CCAM projected changes in annual average rainfall totals (Figure 13 - top) and the annual number of extreme rainfall days (number of events per grid point per year; Figure 13 - bottom) over Mozambique, for the ACCESS1-0 (left) and CNRM-CM5 (right) downscalings. The projections are for the period 2071 to 2100 relative to 1961 to 1990 under low mitigation (RCP8.5). The downscalings are indicative of rainfall increases spreading to southern Mozambique by the far-future, with associated increases in extreme events. In the ACCESS 1.0 downscaling, however, it is projected that

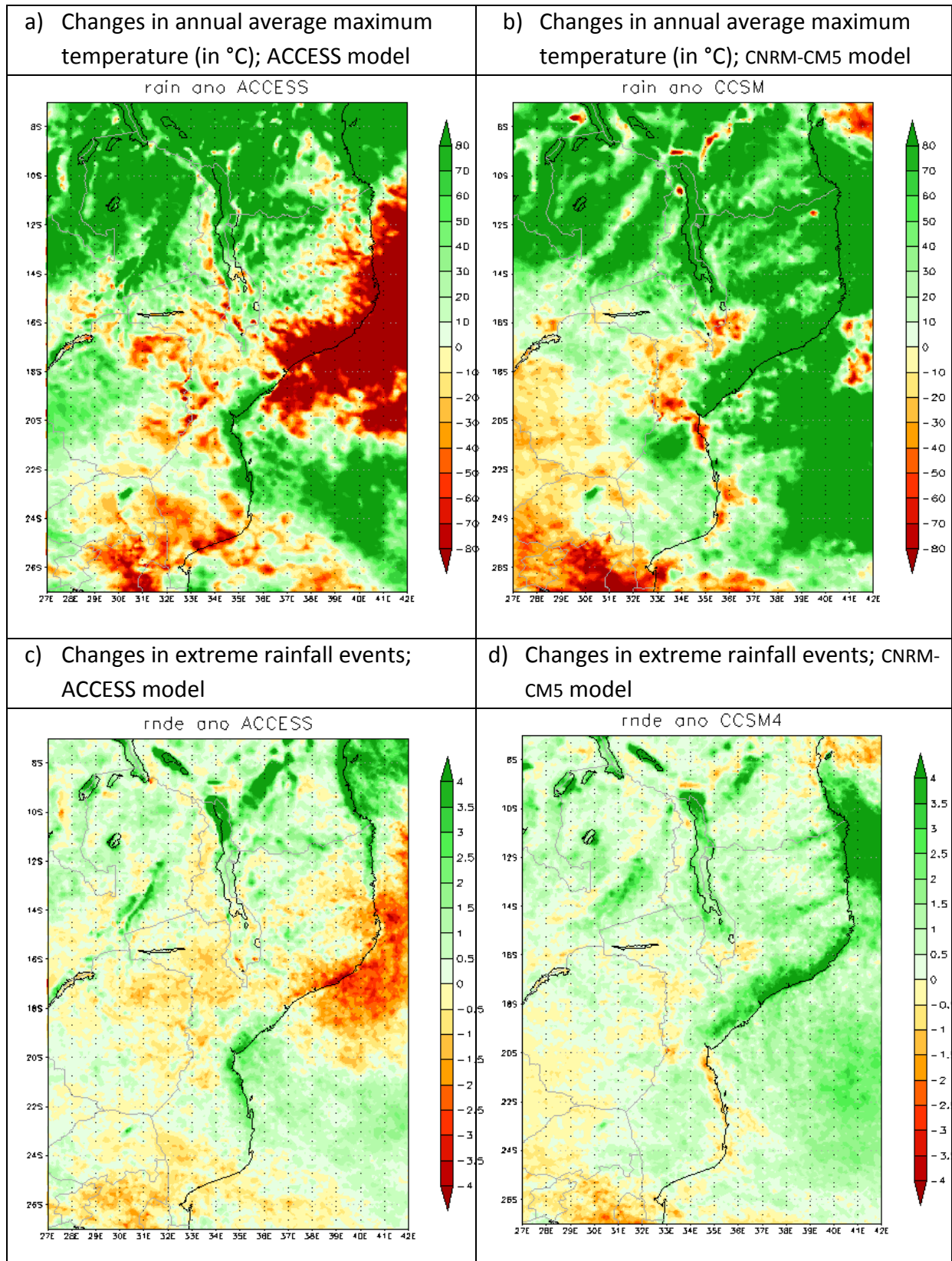
northern Mozambique will become drier under low mitigation for the far-future period (largely in contradiction with the CNRM-CM5 downscaling).



**Figure 10: Projected changes in annual average maximum temperatures**

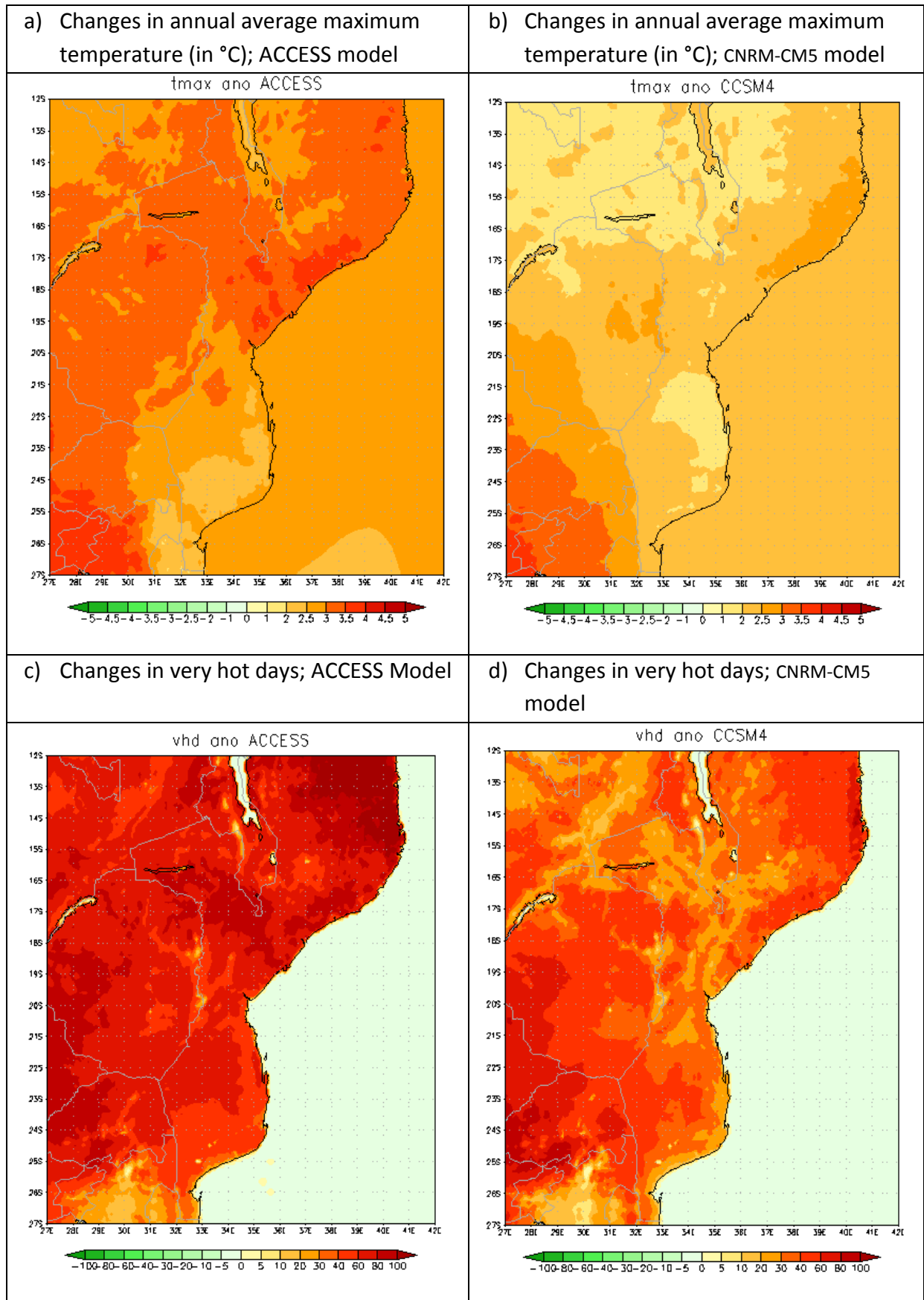
Source: CCAM downscaled climatology from ACCESS1-0 and CNRM-CM5 (CSIR)





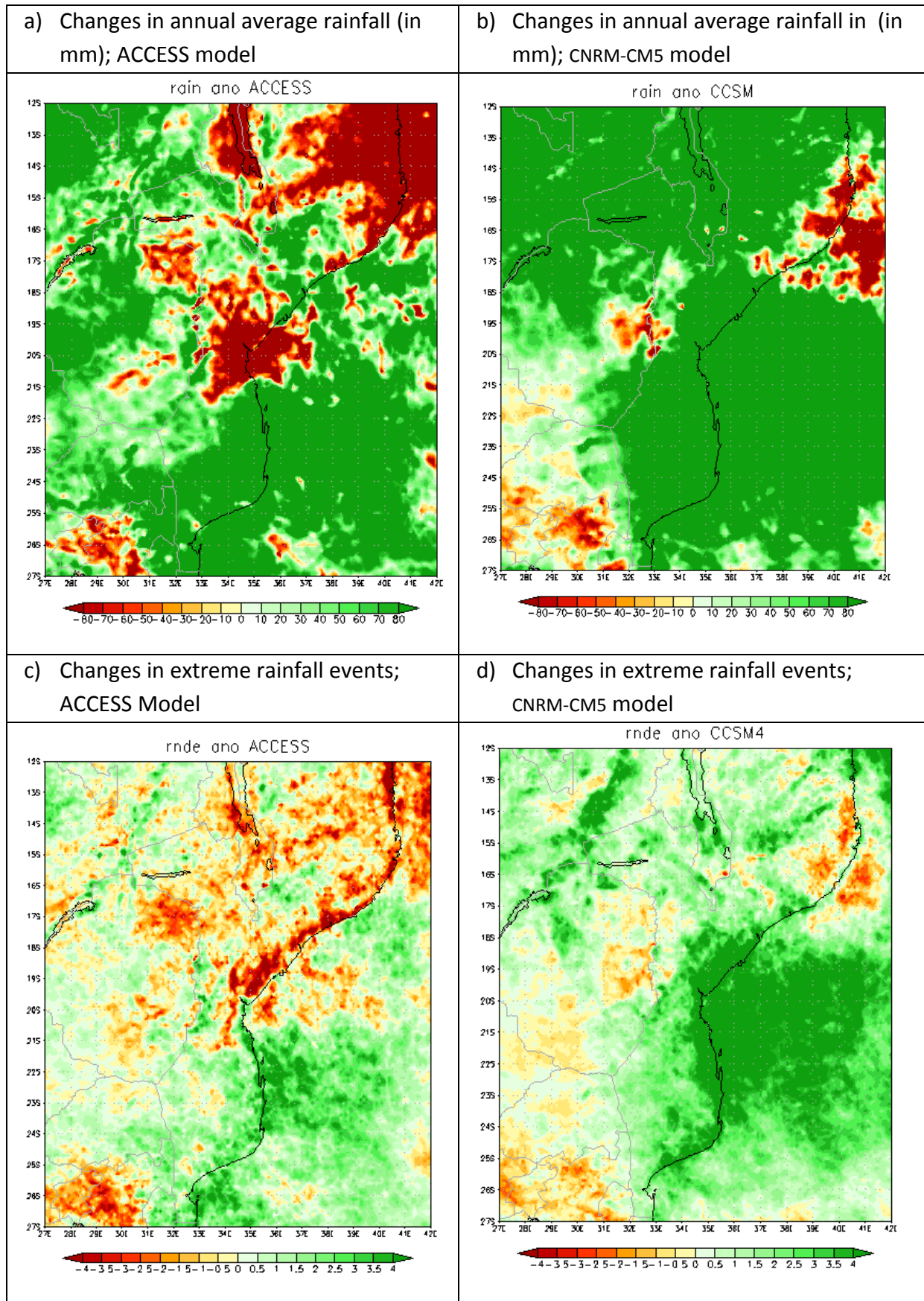
**Figure 11: Projected changes in average rainfall and changes in extreme rainfall events**

Source: CCAM downscaled climatology from ACCESS1-0 and CNRM-CM5 (CSIR)



**Figure 12: Projected changes in annual average maximum temperatures**

Source: CCAM downscaled climatology from ACCESS1-0 and CNRM-CM5 (CSIR)



**Figure 13: Projected changes in average rainfall and changes in extreme rainfall events**

Source: CCAM downscaled climatology from ACCESS1-0 and CNRM-CM5 (CSIR)



## 2.5 Impacts of current climate variability

Climate variability and the occurrence of extreme weather events annually pose a costly hazard to roads in terms of degradation, necessary maintenance, and potential decrease in lifespan due to climatic impacts. In Mozambique current climate variability often result in the degradation and damage of infrastructure, ecosystem destruction and loss of life and property.

- **Impact on critical infrastructure:**  
Climate variability has resulted in the destruction of critical infrastructure such as roads, bridges, culverts, schools, hospitals, power grids, property, crops and animals (NCCAMS, 2012).
- **Socio-economic Impact:**  
Communities exposed to extreme climate events are highly vulnerable. Mozambique's economy is largely based on agriculture, with as much as 70 % of the population who live in rural areas depending on subsistence agriculture for their livelihood. Floods, droughts and shifts in rainfalls patterns have led to periods of severe food and water insecurity in the country. In the past four decades 66 weather related natural disasters have killed more than 100 000 people (98 % due to droughts), left more than 600 000 people homeless (90 % due to tropical cyclones) and affected an estimated 30 million people (CRED, 2016).
- **Financial Impact:**  
Climate variability has also had massive financial implications on Mozambique's economy, where flooding impacts as much as a 100 km of roads with an estimated direct loss of \$ 700 000 every year (DRFI, 2012). Climate change is expected to cause a drop in GDP of 4% to 14% or costs of up to USD 7.6 billion dollars by 2050, seriously hampering the country's economic development (MER, 2015).
- **Ecosystem Impact:**  
Current climate variation of temperature and precipitation patterns and rising sea levels result in environmental degradation, loss of ecosystems and biodiversity and erosion, thereby endangering the livelihoods of communities that depend on subsistence agriculture as their primary source of income (NCCAMS, 2012).

## 2.6 Projected impacts of future climate change

Given the observed impacts that weather related disasters have had on communities, infrastructure and economies, it can be expected that climate change will impact drastically on the African continent during the 21st century under a low mitigation scenario future.

- **Changes in atmospheric and oceanic temperature patterns:**
  - Temperature increases of about 4°C are projected for the far-future (2071-2100) over northern Mozambique by the ACCESS1-0 downscaling, with somewhat smaller increases projected by the CNRM-CM5 downscaling. Relatively smaller temperature increases are projected to occur over the southern parts of the country. More than 40 very hot days per year projected to occur in the far-future compared to the present-day baseline climatology, with increases of more than 80 days per year projected over northern Mozambique in the ACCESS1.0 downscaling, and an increase in minimum and maximum temperatures; and
  - Sea-level rises as a result of increasing global temperature, changes in the distribution and availability of fish stocks and effects on temperature sensitive marine ecosystems such as coral reefs (NCCAMS, 2012).

- **Changes in national precipitation patterns (NCCAMS, 2012):**
  - with increases in erratic rainfall, extreme rainfall events and drought, changes in the length of the agricultural growing seasons are expected to shift, resulting in a drop in potential revenue of up to 25%; and
  - Further reductions in potential agricultural income of up to 20% for the main crops that form the basis of food security and are essential for improving per capita yield of Mozambican households.
- **Changes in the frequency and intensity of weather extremes, such as increases in (NCCAMS, 2012):**
  - Extraordinary floods in specific low-lying flood prone areas;
  - Land hitting cyclones and strong winds; and
  - Prolonged droughts.
- **Sea-level rises** –150 mm, 300 mm and 450mm resulting from thermal expansion, and a further 150 mm, 1 100 mm and 4 150 mm resulting from the melting of continental icecaps, by 2030, 2060 and 2100, respectively, resulting in (NCCAMS, 2012):
  - New areas facing increased risks due to the emergence of other adverse natural phenomena, such as the erosion and submergence of coastal areas, saltwater intrusion and desertification;
  - A reduction in arable land in green belts and flood plains; and
  - A further increase in the critically vulnerable situation due to climate change threats to human lives, property and infrastructure of many principal coastal urban centres, including Maputo, Beira and Quelimane.
- **Other projected impacts** of future climate change as described in the National Climate Change Adaptation and Mitigation Strategy include (extract from NCCAMS (2012)):
  - The reduction of soil fertility through erosion, deforestation, fires and saltwater intrusion;
  - Reduction in the availability of water with the necessary quality for various uses, including human and animal consumption, forestry, agriculture, energy production and industry, due to reduced rainfall, decreased recharge of aquifers, increased evapotranspiration, and saltwater intrusion;
  - Increased risk of wildfires due to lower atmospheric relative humidity; and
  - Greater risk of loss of life, crops, forests and natural heritage, soil erosion and damage to infrastructure associated with floods and inundation by rising seas, storm surge water and extreme precipitation events such as floods.

## 2.7 Climate-related geo-hazards and their significance to road construction and operation

Climate change is expected to have a significant impact on transportation, affecting the way transportation system are planned, designed, constructed, operated, and maintained. The potential impact of climate change on transport infrastructure was featured in a Transport Sector Research Strategy compiled by a Euronet Consortium in 2012 (Head, Agyekum, & Twerefou, 2012). It indicated that the projected increases in temperature and changes in the intensity of rainfall will widely impact on both transport infrastructure and operations. Table 1 reflects a range of climate drivers and associated geo-hazards. It also indicates the level of significance that each geo-hazard category has from a rural roads perspective. Obviously, most of these geo-hazards are topography-dependent and are likely to be more relevant to some parts of the region than others. The significance of these hazards was rated during a transport project meeting held in Addis Ababa in 2014 (Hearn, 2014).

Table 1: Climate-related geo-hazards and their significance to road construction and operation

Climate driver of geo-hazard	Geo-hazard sub-category	Impact type	Significance to rural road construction & operation in SSA (see explanation below)		
			Low	Moderate	High
Heavy/ prolonged precipitation	Direct rainfall/runoff	Surcharge of side drains	**	**	
		Raised water tables and surface ponding	*	**	*
		Raised water tables induce collapse in meta-stable soil structures	**	*	*
	Flooding in streams and rivers	Surcharge of drainage crossings	**		**
		Flood plain inundation	*	**	*
		Embankment overtopping		**	**
	Erosion	Slope erosion	*		***
		Scour in stream channels	**	*	*
		Scour beneath culverts		**	**
		Scour of embankments		**	**
		Erosion/scour contributes significant quantities of sediment to drainage system		*	***
		Erosion in streams and rivers triggers landslides		****	
		Seepage erosion in dispersive soils		*	**
	Sediment transport	Contributes to scour through abrasion	*	***	
		Raising of stream and river channel bed levels giving rise to reduced waterway and apparent increased flood stage			****
		Deposition of debris on fans causing bridge blockage and damage or inundation to other structures		**	**
	Landslides	Rock falls and soil falls in cut slopes and natural slopes	*	***	
		Blockage to road due to cut slope/natural slope failure		****	
		Subsidence/removal of road due to slope failure below		***	*
		Debris flows damage sections of road and drainage crossings	*	***	

Climate driver of geo-hazard	Geo-hazard sub-category	Impact type	Significance to rural road construction & operation in SSA (see explanation below)		
			Low	Moderate	High
		Landslides contribute significant quantities of sediment to drainage systems		***	*
Drought	Drying of soils	Desiccation of clay soils causes shrinkage and settlement. May enhance shrink-swell cycles in expansive soils	*	***	
	Die-back of vegetation	Increased potential for soil erosion during/ following rains	***	*	
		Increased potential for wind-blown/ Aeolian hazards	***		
Increased temperature	Drying out of soils	Desiccation of clay soils causes shrinkage and settlement. May enhance shrink-swell cycles in expansive soils	**	**	
	Higher construction material temperatures	Bleeding and melting/softening of asphalt road surfaces	*	**	*
		Thermal expansion and spalling of concrete	***	*	
		Embrittlement of bitumen		**	**
Sea Level Rise	Erosion of beaches protecting road infrastructure	Affecting coastal road condition and safety		**	
	Flooding and direct erosion of coastal roads	Scour of road and related infrastructure		**	
Storm surges	Coastal road flooding and damage	Overload drainage infrastructure		**	
		Road surface overtopping			**
Significance based on scoring by attendees of roads workshop in Addis Ababa in 2014					

## 2.8 Climate change and Land use impacts

“Human activities, especially in the last two centuries, have had a huge impact on the environment and landscape through industrialisation and land-use change, leading to climate change, deforestation, desertification, land degradation, and air and water pollution. These impacts are strongly linked to the occurrence of geomorphological hazards, such as floods, landslides, snow avalanches, soil erosion, and others” (Alcantara-Ayala & Goudie, 2010). Land use change often appears to have the effect of **accentuating the effects of climate extremes**, primarily through deforestation and changes to drainage patterns. Some river-specific studies conducted by several researchers over shorter time-frames (2012-13), however, suggest that flooding events have increased as a result of land use change and poor drainage management and not climate change per se. [See (DeDescroix, Genthon, Amogu, Rajot, & Sighomnou, 2012) (Cornelissen & Diekkrueger, 2013)]. Apparent increasing flood levels in streams and rivers might partly be due to the increase in bed levels due to sedimentation rather than increased flood discharges – as was the case in Ethiopia (Hearn, 2014). There may also have been an increase in the peakedness of stream and river flow due to a more rapid response of runoff to rainfall brought about by changing land use patterns and the effects of concentrated drainage along roads. Increased levels of sediment production as a result of natural, land use and engineering factors also significantly affect stream and river hydraulics. Combined, these factors lead to higher maximum flood stages for the same rainfall. When climate change effects of increased rainfall is then added, this places more pressure on river systems and infrastructure to cope with. Land use practices have also been identified as important pre-condition factors in land slide initiation. Land use practices such as agriculture, forestry; mining, human settlement can change soil surface stability making conditions more favourable for landslides. Land uses have to be considered carefully when in close proximity to roads. Some practices such as agriculture can have indirect impacts for example through the silting of river systems downstream. Greater consideration should in future be given in all land use planning to limit the negative impacts it can have on geo-hazards.

## 2.9 Reported problems in Mozambique resulting from climate change

Demographic studies show that the Mozambican population is expected to grow from 27.1 million in 2015 to an estimated 59.9 million by 2050 (le Roux et al., 2018a). Some 70% of the population lives in rural areas and is dependent on subsistence agriculture and the use of natural resources. Since agriculture is largely based on subsistence farming, droughts and shifts in rainfall patterns can lead to severe food and water insecurity. Mozambique is a country with a history of conflict and insecure land tenure and this is likely to lead to resource conflicts (Van Niekerk & le Roux, 2016). The country is particularly at risk to loss of life, livelihoods and economic activity due to its high dependency on natural resources, high social vulnerability, low adaptive capacity and frequent exposure to intense weather-related hazards, making it arguably the SADC country most vulnerable to weather-related disasters (Van Niekerk & le Roux, 2017). The socio-economic effects from a more pronounced climate are expected to be substantial. Funding shortages are so acute that only routine road infrastructure maintenance is now carried out and there are no capital works.

### 3 Risk and Vulnerability Assessment of Roads at District Level in Mozambique

Risk and vulnerability assessments were undertaken to facilitate identification of districts where roads are most vulnerable to a changing climate in terms of the impact on rural accessibility. In Section 3.1, a geospatial, semi-quantitative method for assessing climate risk and vulnerability will be briefly described. This assessment method consisting of five key phases is described in more details in (Le Roux et al., 2018). The first three phases consist of identifying the main regional climate threats with respect to rural roads, where the current and projected climate information would be obtained using models discussed in Chapter 2. The results of the Mozambican road network risk and vulnerability assessment at district level are presented from Section 3.3.

#### 3.1 Climate risk and vulnerability assessment framework for road infrastructure

A climate risk and vulnerability assessment method, as illustrated in Figure 14, was developed for road infrastructure. This assessment method delineates on a national level where (in terms of districts) roads are most vulnerable to a changing climate and provides key geographic information to support decision makers in identifying high-risk districts in terms of climate impacts on road infrastructure (Le Roux *et al.*, 2018). High-risk areas can be identified and interpreted as areas that should be prioritised for road construction, adaptation or maintenance in the light of changing climatic conditions.

The method provides information that can be used to support the development of a climate adaptation strategy for rural access roads and guide investment decisions in Mozambique. This is done using existing data on the road network, vulnerable populations and climate change in combination with what is known about best road design principles in order to determine where roads could potentially be most affected by changes in climate and socio-economic patterns. The last two phases as illustrated in Figure 14 consist of exporting results into the national Road Asset Management Systems (RAMS) to be used to determine where in-depth local level road risk and vulnerability assessments would be most beneficial as well as for extracting summaries needed in identifying adaptation options. In some cases, this process may be iterative.

It is important to consider *criticality* when assessing vulnerability of road infrastructure. Currently there are four general methods, and the most common for regional and rural road networks are the serviceability- and the accessibility-based methods. In the current framework, the accessibility-based method was implemented (Step 3.2 in Figure 14) and the results are discussed in Section 3.5.

Other important aspects to consider in the assessment of vulnerability of roads are design and maintenance quality. Degraded sections of roads and drainage structures increase the vulnerability of a road network to climate related failures, even if the climate events are not “extreme” in terms of what the road or structure ought to have been designed to withstand. Road infrastructure must not only be designed and constructed adequately, but it must be maintained properly (regularly and using appropriate materials and engineering procedures) to last beyond its design life and to be resilient against climate and other environmental stresses (Paige-Green et al., 2018).

The current district-level risk and vulnerability assessment method indirectly accounts for deficiencies in design and maintenance quality by considering a qualitative indicator of road condition, where the categories are: good, fair, impassable, poor, very poor and in rehabilitation. The current risk and vulnerability assessment method can be modified to directly incorporate an indicator on design quality and maintenance once there are improvements in the collection and collation of road condition data, including data on maintenance frequency and quality through

regular road surveys by road engineers using resilience field assessment forms similar to the one described in the *Engineering Adaptation Guidelines* by Paige-Green et al., (2018).

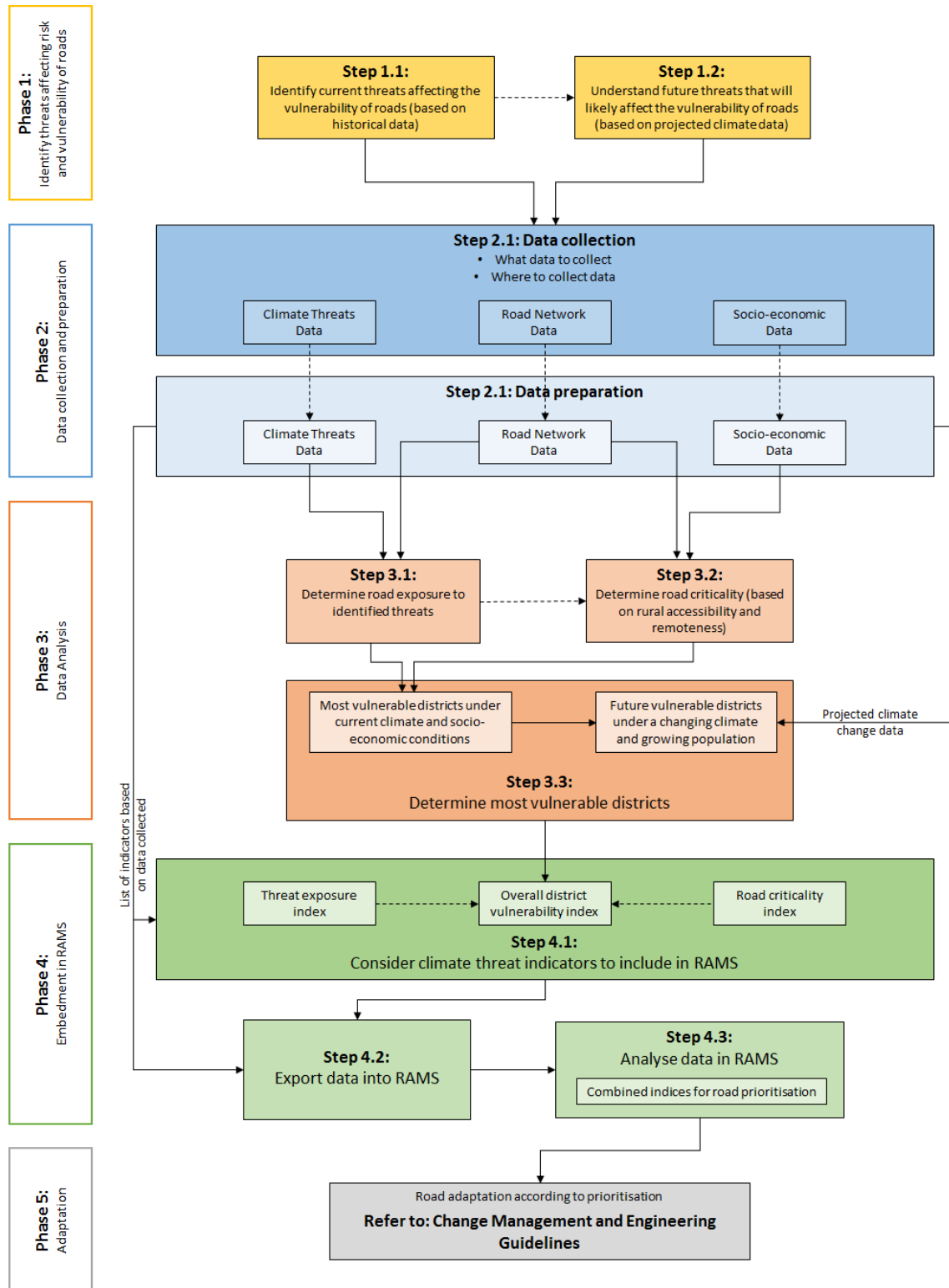


Figure 14: Framework for the rural access road risk and vulnerability assessment

Source: Le Roux et al. (2018)



### 3.2 Sources of information and data

To formulate a national climate threat picture, documents, data and statistics from country level assessments indicating the type, frequency and intensity of historical climate induced disasters should be sourced. In order of priority, the following are suggested resources for obtaining this information:

- Firstly, it is assumed that national data on historical climate threats are maintained and archived by the relevant national meteorological department and/or disaster management office. As the starting point, data should be sourced from these national authorities.
- Secondly, technical reports by the Intergovernmental Panel on Climate Change (IPCC) and The Nature Conservancy (TNC) can be consulted for background information.
- Lastly, knowledge sharing workshops should be conducted with active role-players such as the national meteorological department and disaster management office.

The investigation into historical climate data archives, country level assessment reports and knowledge sharing workshops inform the process of identifying the climate threats most affecting the vulnerability of roads. From this enquiry, the driving forces of vulnerability should be identified, and flagged for further analysis in this assessment process.

Table 2 outlines the possible data required to perform a district-level risk and vulnerability analysis, together with suggested national authorities in Mozambique responsible for maintaining specific custodian data. In the absence of such data, open source data repositories, where data can be sourced freely, are listed. It is recommended to source and use national scale GIS datasets from national departmental authorities as a first priority. Road data was obtained from the Mozambican roads authority (Administração Nacional de Estradas, ANE) and used in this analysis. In the absence of such data, open source data repositories might be used as a second choice. As a starting point, country specific custodian data might be sourced from the following places:

- National departmental authorities (e.g. the National Disaster Management Institute (Instituto Nacional de Gestão de Calamidades, INGC) , the Mozambique National Meteorology Institute (INAM), the roads authority (Administração Nacional de Estradas, ANE));
- Road asset management systems (coordinated and maintained by ANE);
- Country wide SDI (if implemented);
- Country specific assessment reports;
- Previous studies; and
- Commercial data vendors.

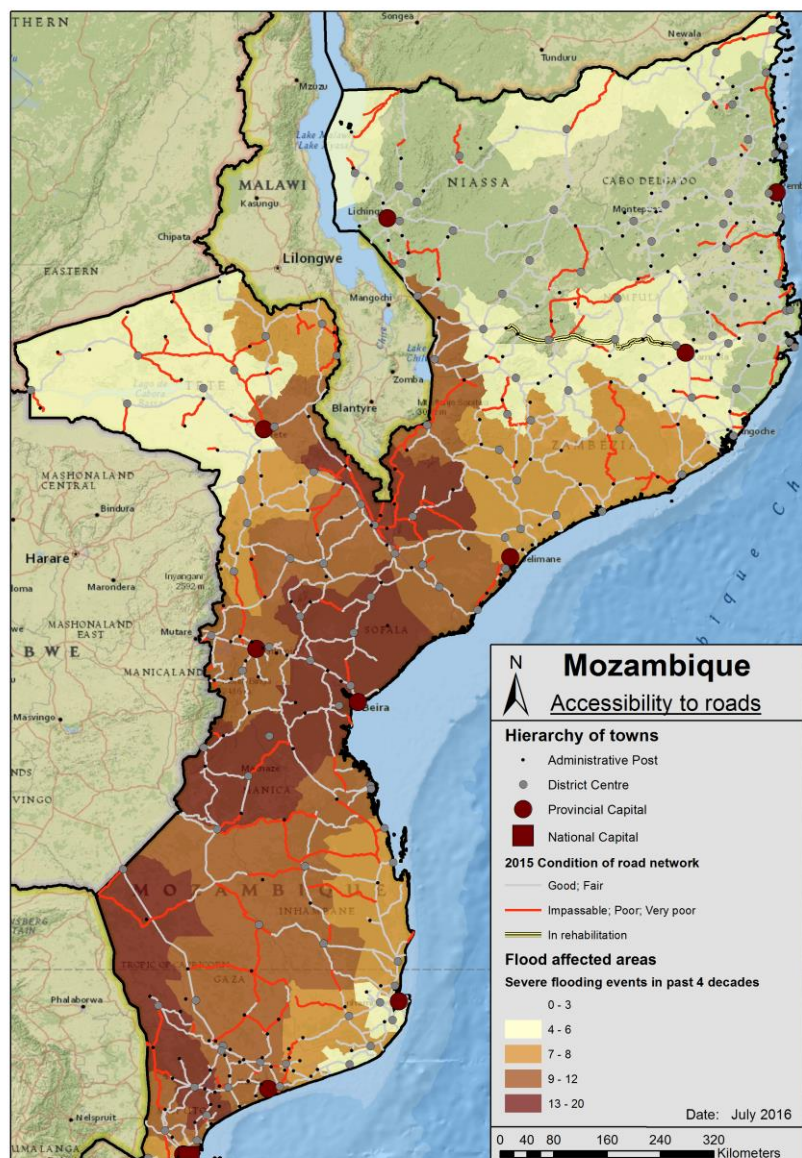
**Table 2: Suggested data required to perform a district-level risk and vulnerability analysis and possible Sources**

Methodology	Data Type	Possible national authorities (country specific)	Open source data repositories / Additional Sources
Road network	National road network	<ul style="list-style-type: none"> <li>– Administração Nacional de Estradas (ANE) – classified roads</li> <li>– National road asset management system</li> <li>– Districts – unclassified district roads</li> </ul>	<ul style="list-style-type: none"> <li>– Diva-GIS</li> </ul>
Climate Threat	Historical climate data (National Scale)	<ul style="list-style-type: none"> <li>– Instituto Nacional de Gestão de Calamidades (INGC)</li> <li>– Mozambique National Meteorology Institute</li> <li>– National directorate of Water Resources (DNRH)</li> </ul>	<ul style="list-style-type: none"> <li>– Em-Dat</li> <li>– ERA-Interim</li> <li>– CRUTEMP4v</li> </ul>
	Specific hazard data for main identified climate threats (e.g. Flood history) (District Scale)	<ul style="list-style-type: none"> <li>– Instituto Nacional de Gestão de Calamidades (INGC)</li> <li>– Mozambique National Meteorology Institute</li> <li>– National environmental department</li> </ul>	<ul style="list-style-type: none"> <li>– Dartmouth Flood Observatory</li> </ul>
	Projected climate change data (Resolution as fine as possible e.g. 8km resolution in the horizontal in Mozambique case study)	<ul style="list-style-type: none"> <li>– Mozambique National Meteorology Institute</li> </ul>	<ul style="list-style-type: none"> <li>– ACCESS1-0</li> <li>– CNRM-CM5</li> </ul>
Socio-Economic	Population data	<ul style="list-style-type: none"> <li>– National statistical office</li> <li>– National Institute of Statistics</li> </ul>	<ul style="list-style-type: none"> <li>– Worldpop</li> </ul>
	Settlements, towns and main cities	<ul style="list-style-type: none"> <li>– Surveyor general office</li> </ul>	<ul style="list-style-type: none"> <li>– Diva-GIS</li> </ul>
	Population projections	<ul style="list-style-type: none"> <li>– National statistical office</li> <li>– National Institute of Statistics</li> </ul>	<ul style="list-style-type: none"> <li>– UN ESA</li> </ul>
Analysis Supporting Data	District boundaries	<ul style="list-style-type: none"> <li>– Surveyor general office</li> <li>– Demarcation board</li> </ul>	<ul style="list-style-type: none"> <li>– Diva-GIS</li> </ul>
	Satellite images	<ul style="list-style-type: none"> <li>– National space agency</li> </ul>	<ul style="list-style-type: none"> <li>– Landsat (USGS EROS)</li> <li>– ESRI</li> </ul>

Many open source data repositories were consulted to provide information on the prevailing and historical socio-economic and environmental conditions, as well as the climate hazards. These included boundary data from Diva GIS (2017), basemap images from Esri online map portal (Esri, 2018), population data from WorldPop (2017), flood records from the Dartmouth Flood Observatory (2017) and historically recorded natural disasters from the EM-DAT database (CRED, 2018). These data sets were supplemented with country-specific information and reports about the national road network. Road data, including attributes on road condition and routine maintenance, should be captured and updated annually in the national Road Asset Management System (RAMS). In most African countries this is however not the case, and data is not adequately captured for the whole country and data that are captured are often out of date. Where possible, road condition data were included in the analysis. Once data were obtained, general data preparation was done to ensure that the data were ready for analysis. This included verification of the accuracy (in terms of its fitness for purpose) of data items and transformation into workable spatial data format.

### 3.3 Road asset exposure to identified threats

Almost 9 million Mozambicans (CRED, 2016) have been affected by flooding in the past 4 decades. Figure 15 illustrates the number of flood events per district. It can be observed that the areas most affected by flooding in the past have been southern and central Mozambique. Severe and frequent flooding causes widespread destruction to livelihoods and infrastructure. Data from 2017 road condition surveys suggest that approximately 38% of classified roads are considered to be in a poor, very poor or impassable condition (ANE, 2017). A substantial portion of the road network is located in frequently flooded areas (areas that have experienced more than 3 devastating floods in the past 4 decades) – as illustrated in figure 15. DRFI (2012) states that flooding impacts as many as a 100 km of roads with an estimated direct loss of \$ 700 000 every year.



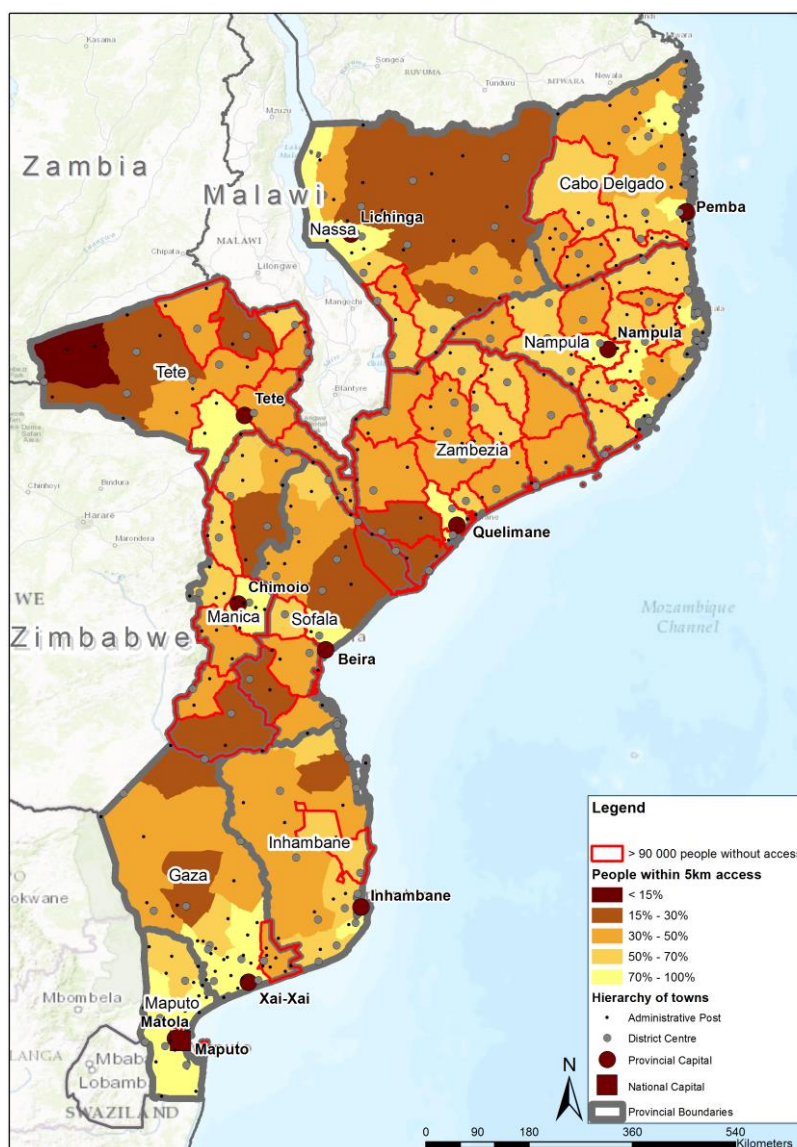
**Figure 15: Mozambique's current situation: Flood prone areas (climate threat)**

**Source:** CSIR, National Roads Administration (ANE) Mozambique, Dartmouth Flood Observatory

### 3.4 Road asset criticality

The map in Figure 16 depicts the Rural Access Index (RAI) calculated for Mozambique. This index considers people within 5 km of an access road and discounts for urban population through using a series of distance bands based on the gravitational influence of the various towns. However, it must

be noted that the standard rural access index has a distance threshold of 2 km. The map also shows the districts with less than 50% access as well as more than 100 000 people without adequate access. Zumbo District in the western area of the Tete Province is the most isolated district (in terms of percentage people without access) with less than 15% of its population having access to a road network, leaving more than 63 000 people without adequate access. Thirty-two districts (many of which are in the Zambezia and Nampula Province) have more than 100 000 people and less than 50% adequate access to a road network.



**Figure 16: Mozambique current situation: Rural accessibility and isolation (2015) (Asset Criticality)**

**Source:** CSIR and National Roads Administration (ANE) Mozambique

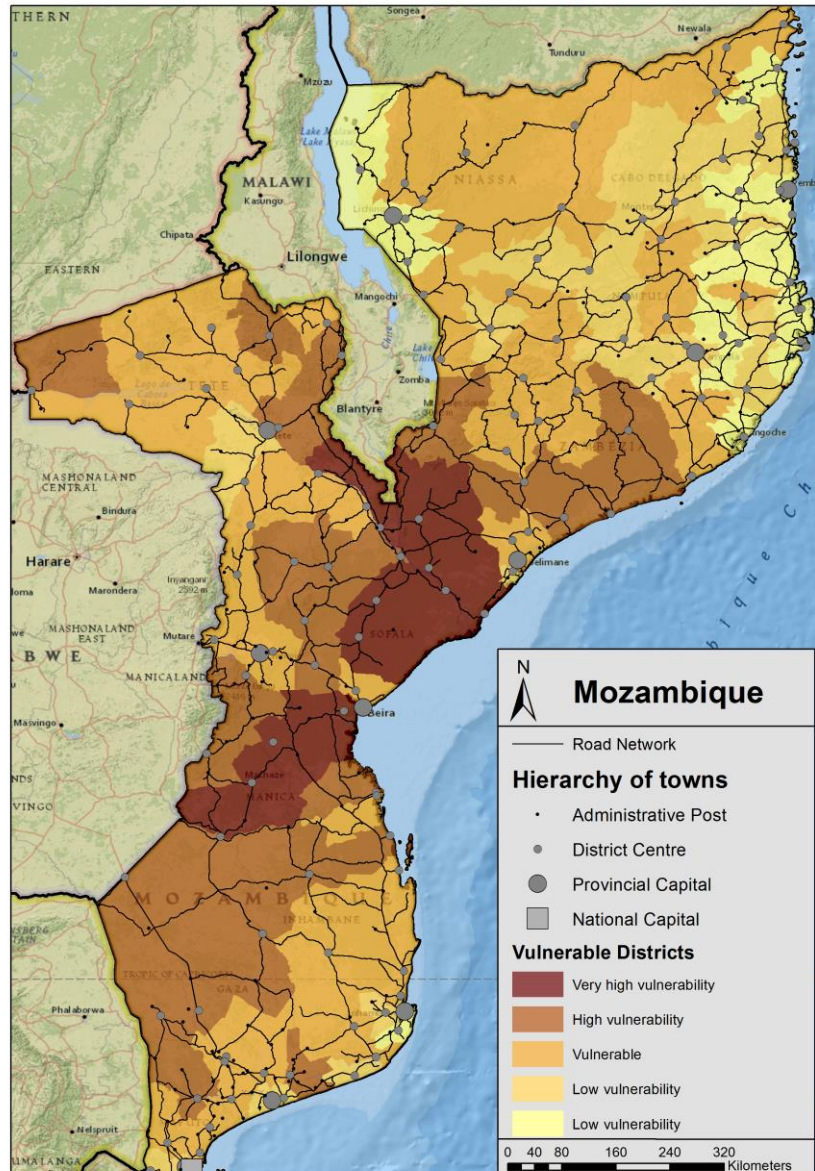
### 3.5 Highly vulnerable districts to climate impacts on road infrastructure

#### 3.5.1 Current vulnerable districts under current climate and socio-economic conditions

Areas in darker shades in Figure 17 depict districts that are exposed to frequent and severe flooding (asset exposure) as well as districts where asset criticality is key due to high isolation. The index was normalised to give preference to districts where larger amounts of people are without adequate access to a road network. The most vulnerable districts are located in the central, eastern and southern areas of Mozambique, and particular vulnerable areas in terms of climate impacts on



roads are located in the Districts of Buzi, Cheringoma, Chibabava, Chinde, Machaze, Marromeu, Mopeia, Morrumbala, Muanza and Mutarara. Almost 70% of districts in Mozambique are classified as vulnerable due to their high exposure to frequent and severe flooding as well as their low rural accessibility and high isolation rates.



**Figure 17: Mozambique current situation: Most vulnerable Districts (asset exposure and asset criticality)**

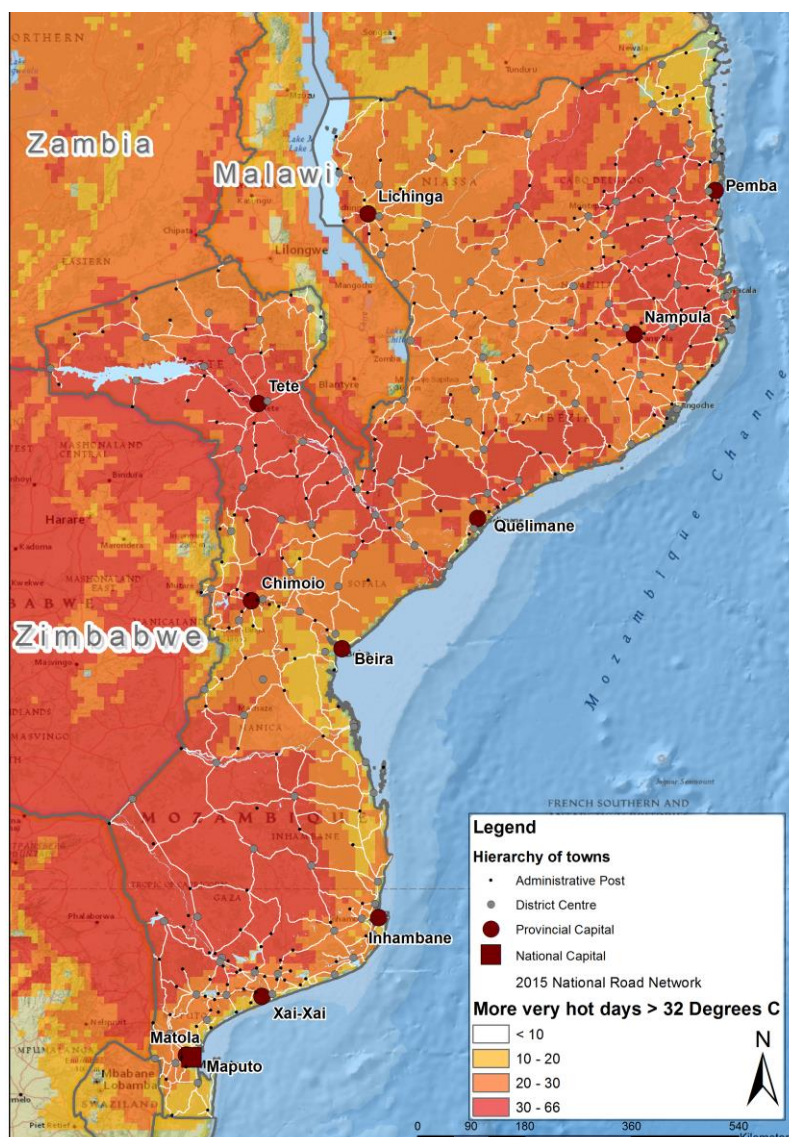
**Source:** CSIR, National Roads Administration (ANE)

### 3.5.2 Future vulnerable districts under a changing climate and growing population

The ACCESS model downscaling was used due to its predicted pronounced increases in very hot days over most of Mozambique. The map in Figure 18 shows that the road network is highly likely to be exposed to more days exceeding the threshold temperature of 32°C. The projections are for the period 2021 to 2050 relative to 1961 to 1990 under low mitigation scenario. The climate projections from CCAM indicate that the frequency of occurrence of days where maximum temperatures exceed 32°C will increase throughout Mozambique. The largest increases are projected for the Limpopo river basin in the south. These expected changes in the number of days with extremely high



temperatures need to be taken into account for softening of bitumen, expansion of concrete and loss of soil moisture that has secondary effects, including increased susceptibility to erosion.



**Figure 18: Future situation: Exposure of Road Network to increases in very hot days**

**Source:** CSIR, National Roads Administration (ANE) Mozambique, CCAM downscaled climatology from ACCESS1-0 and CNRM-CM5

The CNRM-CM5 downscaling was used to map the annual number of extreme rainfall days (number of events per grid point per year) over Mozambique, together with the high and very high vulnerable districts (section 5.1), as an example of the risks that extreme rainfall events may plausibly pose to Mozambique (see Figure 19). The annual number of extreme rainfall days, where an extreme rainfall event refers to more than 20 mm of rainfall in 24 hours occurring on the average over an area of 64 km<sup>2</sup>, is projected to increase along the northern Mozambique coastal belt starting from Beira, as well as in areas surrounding Lake Malawi. The already vulnerable communities (in terms of current accessibility and flood exposure) along the central coastal belt north of Beira and surrounding Quelimane may be affected most by such increases in extreme rainfall events. An increase in extreme rainfall events may be associated with increases in the likelihood of flooding. While the coastal areas are highlighted in the map, it should be noted that vulnerable communities in the central inland areas can potentially be exposed to increases in riverine flooding as extreme events are plausible to increase in international shared river basins such as the Zambesi River.

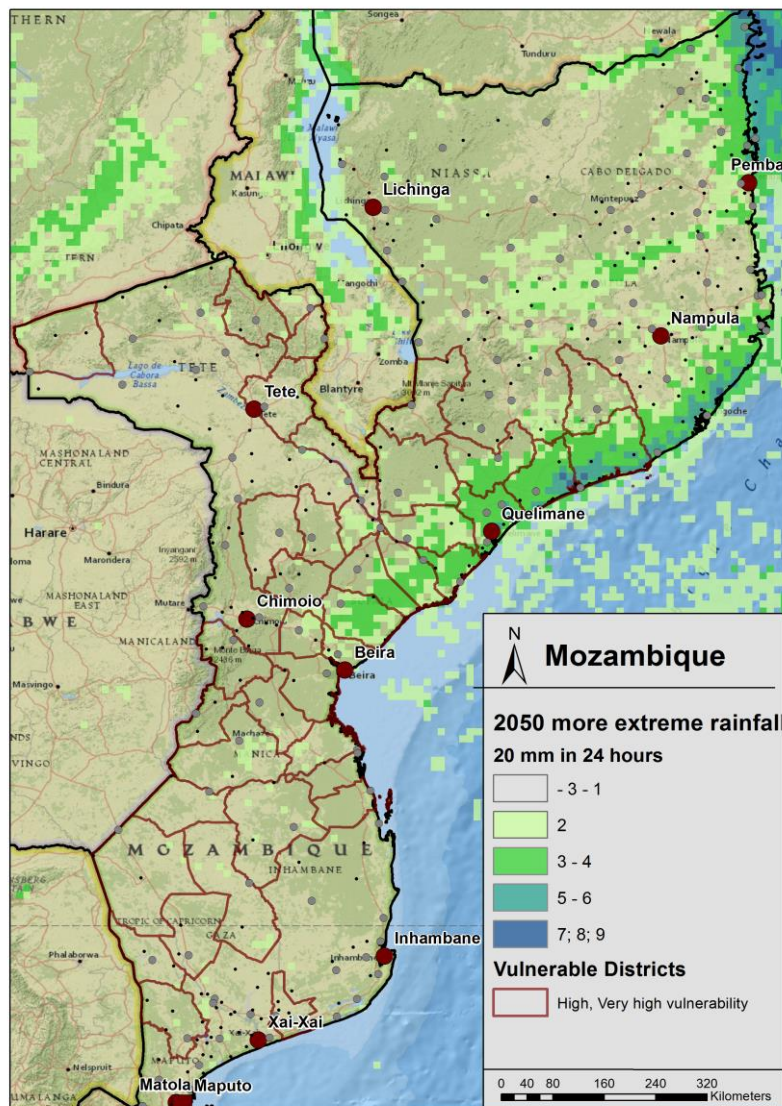


Figure 19: Exposure of Road Network and Vulnerable Communities to increases in extreme rainfall events

Source: CNRM-CM5 downscalings (CSIR), Road network data (ANE)

## 4 The Mozambican Climate Change Policy Environment

### 4.1 Overview of the climate change policy environment

Mozambique has established a practical, though ambitious policy programme. Its strategies are well documented and its Adaptation programme is underway. However, links to transport and road infrastructure are weak and poorly coordinated. Broad Government Policy addresses, *inter alia*, economic and social infrastructure development; and sustainable and transparent management of natural and environmental resources.

Mozambique's First National Communication to the UN Framework Convention for Climate Change (UNFCCC) was submitted in 2006. As a Least Developed Country (LDC) in the UNFCCC, Mozambique published a National Adaptation Programme of Action (NAPA) in 2007, identifying the most vulnerable areas to climate change, and proposing immediate actions to promote adaptation to these urgent issues. The NAPA identifies four high level priority actions for Mozambique:

- Strengthening of an early warning system;
- Strengthening capacities of agricultural producers to cope with climate change;
- Reduction of climate change impacts in coastal zones; and
- Management of water resources under climate change.

In 2012, the Government published its National Climate Change and Mitigation Strategy 2013-2025 (NCCAMS, 2012). This strategy widened the Government's approach to climate change in proposing actions that combine measures of adaptation and mitigation with the development of a low-carbon economy. The strategy provides a policy framework for climate priorities identified at sector, provincial and district levels. In September 2015, Mozambique submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC, 2016.

The Government's medium-term strategy is articulated in its five-year development plan (PQG, April 2015). Principle priorities cover national unity, peace, and sovereignty; human and social capital development; and improved employment, productivity and competitiveness.

### 4.2 Vulnerability and adaptation policies

Mozambique is particularly vulnerable to extreme weather events due to its location in the zone of inter-tropical convergence and downstream of shared watersheds; its long shoreline and the existence of extensive lowlands below sea level (NCCAMS, 2012). The country's vulnerability is also increased by its low adaptive capacity, poverty, limited investment in modern technology, and weaknesses in its infrastructure and social services, especially those related to health and sanitation. The effects of climate change can be seen in changes in temperature and precipitation patterns, sea-level rises and the increase in the frequency and intensity of extreme climatic events, such as droughts, floods and tropical cyclones, which affect different regions of the country every year. These events result in the loss of human lives, crops, livestock and wildlife; the destruction of social and economic infrastructure; increased dependency on international support; food price increases; harm to human health and the environment; and the destruction of ecosystems.

The effects of extreme weather events represent a major barrier to the Mozambican Government (the Government) and its partners' efforts to fight poverty and achieve its MDGs. The Government has made great strides to establish policies and plans that aim at mitigating the effects of extreme climate events. Mozambique's Vulnerability and Adaptation Policies are embedded within its National Climate Change Adaptation and Mitigation Strategy (NCCAMS, 2012).

Despite significant developments, Mozambique is considered the fifth most vulnerable country in the world, according to the Climate Change Vulnerability Index, due to two key factors, namely its risk exposure and low socio-economic development:

- **Risk exposure, characterised by:**
  - Mozambique is exposed in the east, with 2 700 km of coastline along the Indian Ocean, which is an active region for tropical cyclones;
  - Thirty nine percent of its population live in coastal areas below 100 m elevation;
  - The country lies downstream from nine shared river basins; and
  - A sharp drop in altitude from the interior to the coast, which leads to velocities of superficial runoff and river flow, causing flash floods in a short time when high levels of precipitation occur upstream.
- **Low socio-economic development, characterised by:**
  - High illiteracy rates (32% in men and 68% among women);
  - Large portion of population living in poverty (54.1% in 2003, down from 69.4% in 1997);
  - Weak socio-economic infrastructure networks, such as roads, dams and dykes and silos where crops can be kept and later consumed or sold; and
  - Poor access routes.

### 4.3 Role of climate change policies, strategies and programmes

Policy development has aimed to reduce vulnerability and improve the wellbeing of Mozambicans through the implementation of measures for adaptation and climate risk reduction, mitigation and low-carbon development with the active participation of all stakeholders in the social, environmental and economic sectors.

Due to poor coordination between sectors and limited capacity for mainstreaming, Climate Adaptation in planning and budgeting documents and the widespread recognition of Adaptation as an important issue among public, private and civil society actors have not resulted in effective adaptation and mitigation activities. Instead, independent actions have been sporadic and ineffective, despite the inclusion of mitigation and adaptation policies and strategies in the environmental sections of central- and district-level government.

### 4.4 Climate change activities in Mozambique

The National Climate Change Adaptation and Mitigation Strategy (NCCAMS, 2012) is the primary guidance and covers the period 2013-2025.

Its **Vision** is:

*A prosperous and Climate Change-resilient Mozambique, with a green economy in all social and economic sectors.*

Its **Mission** is:

*Reduce Climate Change (CC) vulnerability and improve the wellbeing of Mozambicans through the implementation of concrete measures for adaptation and climate risk reduction, mitigation and low-carbon development, aiming at sustainable development, with the active participation of all stakeholders in the social, environmental and economic sectors. It includes the strategic and priority guidelines for adoption and implementation.*

NCCAMS was prepared by the Inter Institutional Group on Climate Change (GIIMC), representing a number of sectoral ministries, the private sector and civil society, under the coordination of the Ministry of Land, Environment and Rural Development (MITADER).

Eight strategic areas for intervention, along with corresponding recommendations for strategic action, are identified:

1. Reducing climate risk;
2. Water resources;



3. Agriculture, fisheries and food security and nutrition (SAN);
4. Social protection;
5. Health;
6. Biodiversity;
7. Forests, and
8. Infrastructure.

Relevant strategic actions are:

- **Adaptation and climate risk reduction**
  - *Strengthen early warning systems;*
  - Increase capacity to prepare responses to climate risks; and
  - Increase capacity to manage water resources.
- **Cross-sectoral issues**
  - Align the current legal framework with the NCCAMS;
  - Align the current institutional framework with the NCCAMS;
  - Develop research on Climate Change (CC);
  - Strengthen institutions' systematic data collection on inputs to GHG inventories and National Communications; and
  - Develop the level of knowledge and capacity to act on CC.

To facilitate the implementation of this cross-sectoral strategy, including the participation of stakeholders from the community to the national level, it was agreed in 2014 that the coordination of implementation be done by the Climate Change Unit (CCU) created in the CONDES Secretariat and that this unit be responsible for the strategic orientation, cross-sectoral coordination and M&E. Further support comes from the World Bank's Climate Change Technical Assistance Project (CCTAP). It was also agreed that the coordination of finances will be undertaken by the National Environment Fund (FUNAB), and the necessary funds will arise from the state budget (OE) and Multilateral Environmental Agreements (MEA), bilateral accords and other resources mobilised by the private sector and civil society.

In January 2015, both the Ministry of Planning and Development and MICOA ceased to exist. The former was merged with the Ministry of Finance, while MICOA was merged into a Ministry of Land, Environment and Rural Development (MITADER).

NCCAMS (2012) presents opportunities to exploit synergies and complementarities with processes that promote the efficient use of existing resources for sustainable development, improving coordination between different sectors and actors. It prioritises interventions in adaptation and mitigation as well as in areas of support, such as:

- The systematisation of observations and collection of data relevant to research, in order to produce information that helps with decisions related to the implementation of appropriate measures; and
- Capacity building through training, education and awareness-raising at all levels, and in involvement with international processes, including submitting information to the UNFCCC in response to multiple requests. The early integration of climate risks in planning instruments leads to the prevention of damage and reduces future costs, and its inclusion in business plans can represent a competitive advantage in the market.

#### 4.5 Policies related to transport mobility and road infrastructure

According to the Medium-Term Fiscal Framework (CFMP), most of the investments made in Mozambique will be for the construction and maintenance of infrastructure – roads, bridges, viaducts, conduits, water supply, water treatment or drainage facilities, dykes and electricity networks, among others. Therefore, considerations of how to make these resilient to the impacts of



climate are vital to ensure that investments are not jeopardised and to avoid setbacks in national development efforts.

The Road Sector has prepared a Core Strategy to guide management of roads and bridges infrastructure during the implementation of Plano Quinquenal do Governo 2015-19 (PQG) and for medium-term planning through PQG 2020-24. The Government's over-arching objective is to promote the economic and social development of the country by enhancing productivity and competitiveness. The Road Sector Strategy (2015) supports the Government's objectives by facilitating good road connectivity to all major economically productive zones and by reducing travel times and vehicle operating costs through good maintenance of the road network. RSS-3 sets out its intention to improve rural mobility by prioritising investments in road and bridge infrastructure that link productive regions to markets.

#### 4.5.1 Road Sector Strategy

The Road Sector's Strategy is supported by three pillars that guide road sector management, planning and resource allocation:

- **Asset Preservation through Proper Maintenance:** the sustainability of the existing road sector infrastructure must not be compromised;
- **Inter-urban Connectivity through a Strong National Core Network:** the network of main arterial and connecting roads linking provincial capitals, ports and border crossings must provide a good level of service and be upgraded and expanded according to a coherent long-run vision; and
- **Rural Mobility by ensuring Access on Rural Roads:** the vast network of rural roads must be managed and adequately financed so that rural populations have uninterrupted access to markets and services through appropriate upgrade, maintenance and targeted interventions.

The medium-term vision for the National Core Network includes currently unpaved secondary roads and additional road sections that are a high priority for upgrade in the medium-term. The network vision also includes upgrade of the Regional Roads network whose management will be the responsibility of the provinces and districts. It also include some unpaved sections of secondary roads that are not yet included in the current National Core Network. The Road Sector's management objectives for Provincial and District Roads are:

1. Devolve management of these networks to the provinces and districts;
2. Establish realistic medium-term goals to be undertaken by the respective authorities;
3. Ensure all-year access for roads connecting district capitals and economic poles;
4. Address rupture points that cause poor access, prioritised by economic impact;
5. Maintain relatively high-traffic, maintainable roads in good and fair condition;
6. Use sustainable low-volume traffic designs in the upgrade of roads wherever applicable;
7. Help provinces manage their networks using roads and maintenance management systems; and
8. Allocate funding using systematic and transparent analysis of needs and prioritisation.

Bridges and other related structures are essential components to the road network and are included as part of the network vision. The Road Sector has established a Bridge Program that details the requirements for bridges on the National Core Network, contains inventories of the existing bridge infrastructure, and identifies works that need to be undertaken to ensure full all-year network connectivity.

#### 4.6 Embedment of climate adaptation in national engineering manuals and guidelines

Mozambique has experienced a long phase of reconstruction following the peace accord of 1994 which ended the civil war. Mozambique now faces the challenge of establishing a base for sustained, inclusive and broad-based socio-economic development. This includes the development of public infrastructure, including roads.

Poor road infrastructure has been a constraint to economic growth. Poor roads hamper access to social services, employment opportunities and agriculturally productive parts of the country. Poor road conditions have led to high transport costs and therefore higher opportunity costs for businesses and lack of competitiveness of the local economy.

The road network in Mozambique provides the dominant mode of freight and passenger transport and thus plays a vital role in the economy of the country. The network comprises a huge national asset that requires adherence to appropriate standards and specifications for design, construction and maintenance in order to provide a high level of service. As the length of the road network is increasing, appropriate choice of methods to preserve this investment becomes increasingly important, as addressed in the following Manuals/Specifications endorsed by the roads sector of Mozambique in recent years:

- Low-Volume Road Design Manual
- Work Standards for Road Works
- Geometric Design Manual
- Site Investigation Manual
- Pavement Design Manual
- Rehabilitation Design Manual
- Hydrology and Drainage Design Manual
- Standard Specifications for Road and Bridge Works
- Specifications for Bridge Loads
- Standard Details for Roads and Bridges
- Guidelines for Performance Specifications

In supporting the preparation of the Manuals and Standard Specifications, a number of thematic peer review panels were established that involved local experts from the public and private sector, who provided guidance and review for the project team. Their views and recommendations have been incorporated in the Standard Specifications.

The new Standard Specifications, and their supporting Manuals, have taken into consideration the balance between the risk of road failures and the high cost of maintaining high standards of construction, particularly considering *the extreme climate events* experienced in Mozambique in recent years and the shortage of good road building materials in many areas.

Of note is that the Hydrology and Drainage Design Manual devotes a full section of the manual on climate resilience, and more specifically on the development of climate resilient infrastructure.

#### 4.7 Other related policies

Government policy requires that climate knowledge will be managed by the Centre for the Management of Climate Change (CGCMC), created in the Academy of Sciences of Mozambique, within the Ministry of Science and Technology (MCT), having Thematic Groups managed by their corresponding public entities, which constitute a Network. The CGCMC will be a repository for studies, and will have a role in coordinating and disseminating research, and providing training to meet needs identified by all relevant stakeholders. The Network will coordinate a sub-network of research institutions, higher-education organisations and other entities that systematically collect climate and sectoral-activity data.

#### 4.7.1 Sector Working Group

A *Sector Working Group: Climate Change & Environment* (UK, Ireland, Germany, Netherlands, Norway, Finland, Sweden, Denmark, France, EU, USAID, Japan WB, AFDB, UNDP, UN-HABITAT, IFAD, WWF) programme aims at increasing resilience to high levels of short-term weather variability and longer-term climate change by strengthening planning and disaster-risk management capacity. The integrated program will coordinate with Government on cross-sectoral priorities to focus on:

- Strengthening institutional and policy responses to address climate change and disaster risk reduction;
- Improving water resources management and planning,;
- Investing in climate-resilient measures at local level, such as climate-smart agriculture and natural resources management practices for rangelands, forests and fisheries resources;
- Remote mechanisms for the planting of trees, and establishing forests for local use;
- Improving the management and protection of coastal zones; and
- Integrating climate risk assessments into planning and infrastructure development.

## 5 Actions for Implementation

Subsequent to the research work undertaken previously, the aim of the AfCAP programme is to move forward and to address issues of embedment and implementation. A further objective is, through embedment, to enhance the capacity of Mozambique to address climate resilience. It must be noted that Mozambique has already developed several policies to address climate resilience across various sectors. The main objective of the AfCAP work deals with the transport sector (specifically rural roads and related infrastructure), and as such the primary focus is on embedment within the roads sector. It is however important to note that there is a strong linkage with the broader national climate change environment. This dual focus on embedment is presented in the diagram in Figure 20.

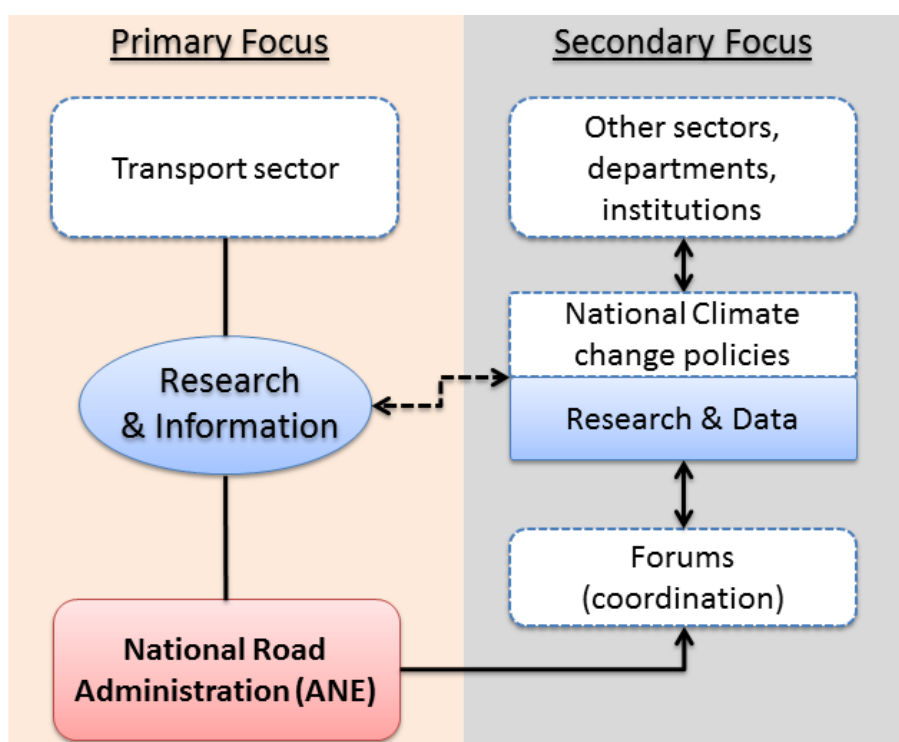


Figure 20: Dual focus of embedment.

The roads sector does not stand separate from other sectors and there needs to be a strong relationship between all sectors when dealing with the challenges of climate change and the required adaptation. A number of structures have been established as indicated previously to address climate change challenges in Mozambique. These structures have been utilised as best possible to incorporate the challenges addressed in the roads sector. In the following section, policies/strategies, collaboration, data and capacity issues are reflected upon. This is followed by agreed actions.

### 5.1 Policies and strategies

Although there are existing policies and strategies in the transport sector, these do not adequately address the issues of climate change adaptation. On a practical level, the incorporation of climate risk is already a requirement on projects funded by agencies such as the Work Bank, albeit at a broad scale. A gap exists in the government roads sector dealing with climate change. Roads adaptation needs to be incorporated in the policies within the roads sector and then reflected in the sector strategy documents. Where issues of climate change adaptation link to other sectors, these

also need to be reflected in such sector policies and strategies. As a starting point a policy statement setting out the scope and purpose of *Climate Adaptation for Roads* and associated assets should be drafted. A Climate Adaptation Strategy then needs to be drafted (including consultation) for the roads sector. An output of this strategy would be to augment national design standards to incorporate climate adaptation.

Within an institution such as the ANE there needs to be a responsible department and person that can lead implementation across the institution. Such a department can also lead cross-sectoral cooperation.

## 5.2 Collaboration within the wider Climate Change environment

A number of other sectors are already active in dealing with climate change adaptation. Several networks have been established to deal with information sharing, and coordination of research and data. It would be beneficial for ANE to join this network, especially to share or access the required climate change data. It is suggested ANE joins the following Climate Adaptation network:

- National Climate Adaptation Committee;
- Centre for the Management of the CC Knowledge (CGCMC); and
- Academy of Sciences of Mozambique, within the Ministry of Science and Technology (MCT).

In the longer term, collaboration with other institutions or groupings could be beneficial in order to elevate the road sector's climate challenges and add it to the agendas of such institutions. It is suggested that the ANE makes contact with the following organisations with a view to collaboration:

- MITADER in order to contribute to existing Adaptation Fora;
- Climate Change Unit (CCU), if created in the CONDES Secretariat;
- National Environment Fund (FUNAB); and
- Sector Working Group: Climate Change & Environment.

Additionally, the importance of climate change adaptation in the road sector needs to be promoted beyond Mozambique, across the wider region. Other countries have similar challenges and establishing mechanisms or platforms of exchange can expand the knowledge base to address such challenges. International exchange should also be considered – learning and sharing with countries beyond Africa also dealing with similar challenges.

## 5.3 Data and capacity

Two important elements when dealing with Climate Change Adaptation are data and capacity enhancement. The risk when capturing and analysing climate data is doing so in an uncoordinated manner where the shared benefit of such efforts is not achieved.

The National Climate Change Adaptation and Mitigation Strategy (2012) presents opportunities to exploit synergies and complementarities with processes that promote the efficient use of existing resources for sustainable development, improving coordination between different sectors and role-players. It prioritises interventions in adaptation and mitigation as well as in areas of support, such as the systematisation of observations and collection of data relevant to research, in order to produce information that helps with decisions related to the implementation of appropriate measures. It also places emphasis on capacity-building through training, education and raising of awareness at all levels, and on involvement with international processes, including submitting information to the UNFCCC.

The early integration of climate risks in planning instruments leads to the prevention of damage and reduces future costs.

Establishing the extent of climate risk also requires relevant and accurate data. The challenge for multiple producers of climate data can be that such data is not effectively coordinated and shared, resulting in wasted resources and poor implementation. Countries often require policies to ensure



effective data management and utilisation. Mozambique does not currently have such a spatial data policy. At a country level it would be beneficial to establish such a policy in order to achieve the following:

- Ensure sustainable data practices through the frequent updating of critical Sources;
- Establish a national spatial data infrastructure platform that promotes the sharing of critical national data between government agencies and departments (e.g National GSDI); and
- Enhance national databases that are aligned with sustainable development goals (SDG's) and the country's needs.

Because there is a strong reliance on spatial data to determine climate risk areas (and levels), it is important to build the capacity of departments/institutions dealing with GIS data collection and analysis. It is also important to develop the capability to sustainably undertake national risk and vulnerability assessments. The following are proposed:

- Climate threats vulnerability analysis and planning should be done and updated by the national disaster management department in conjunction with the data recorded by the **national meteorological department**;
- Road network coverage, criticality and accessibility analysis should be done and updated annually by the **national roads agency (ANE)**;
- Current climate trends and climate change projections should be recorded and analysed by the **national meteorological department**; and
- Socio-economic data and population trends to be captured by a national census conducted at regular intervals, overseen by the **national statistical service**.

Considering that multiple institutions/departments are dealing with climate risk data, the cross-disciplinary and inter-departmental coordination and collaboration is needed to effectively assess impacts, vulnerabilities, and adaptation options. Additionally, skills development and training in these departments are therefore required in terms of embedding the climate threats and vulnerability methodology into Mozambique's policy framework.

#### 5.4 Asset Management Systems – state of readiness

ANE uses the HIMS Asset Management System as its road asset management system. The system is a New Zealand system and is being operated and maintained for ANE by an Indian company, SATRA Infrastructure Management Services. The system includes the following sub-systems: Road Information System (RIS), Pavement Management System (PMS), Routine Maintenance Management System (RMMS), Bridge Management System (BMS), Accident Information System (AIS), and Traffic Information System (TIS). Of these sub-systems, it is only the RIS, PMS, BMS and TIS that are currently actively used. HIMS is also used to prepare files for analysis with HDM-4.

Visual assessment data for paved and unpaved roads are captured, stored and analysed in the HIMS. In addition, ANE uses ROMDAS to collect roughness (IRI and BI) and rutting information. FWD data is also collected.

HIMS can be adapted to include climate change data and to carry out analysis using such data. What would be required to initiate this is an instruction from ANE management. It is also important to ensure ANE has a CCA policy to embed climate change information within its systems. Currently there does not appear to be such a policy.

All the classified roads are included in the HIMS. There is also a network of unclassified roads at the community level, which are the responsibility of the district administrations, and urban roads which are the responsibility of municipalities. From anecdotal evidence, it appears as these last two categories of roads are currently not being managed by way of a formal RAMS. In terms of these lower order roads, Mozambique is not ready to incorporate climate impact issues in road asset management systems.

## 5.5 Research and systematic observation

One of the challenges with determining the real impacts of climate change, is the scale of information. Although large scale information might be sufficient when used at a national scale, some planning and implementation requires much finer grained information. Data also needs to be periodically captured in order to measure changing trends. When not addressed, these challenges create impediments to determining appropriate responses in both the short and, in particular, the long term. Proposals to address these challenges are as follows:

- Distributing responsibilities to the ad-hoc reporting group, and disseminating their reports (according to the National System);
- Expanding and maintaining the CC network, and setting standards for meteorological, hydrological, hydrometric, and agrometeorological data;
- Creating an integrated information-management system;
- Strengthening the mechanisms for standardising equipment and databases;
- Strengthening institutions that perform systematic data observation, gathering and processing in order to feed GHG Inventories and National Communications; and
- Putting arrangements in place with institutions outside Mozambique that generate climate related information, such as regional climate models, to periodically source information (as and when required) from them, or alternatively develop such capabilities within Mozambique.

## 5.6 Financing road and bridge infrastructure

The main objective of *Road Sector financial management* is to ensure sustainability through adequate financing of maintenance and to promote economic growth and social development through efficient application and management of financing for investments (Road Sector Strategy, 2015).

One of the biggest challenges that the sector faces is that the five main sources of funds (DP grants and credits, commercial borrowing, and PPPs) are not fungible and therefore there are serious limitations on the Road Sector's ability to allocate resources according to the principles described in the Strategy. Further, the Road Sector's ability to independently generate additional revenues sustainably is limited. One of the most important functions of financial management is to communicate clearly to the financial partners and stakeholders – Government and DPs – the need for balance and sustainability in resource flows. To ensure that funding sources are best allocated, the Road Sector will:

- Strengthen the long-term forecasting of public sources of roads financing
- Ensure that available budgets are allocated to maintenance;
- Encourage the appropriate prioritisation of DP grants and credits, including toward paved road periodic maintenance and to investments in rural roads;
- Limit commercial borrowing to where revenue streams for debt servicing are identified;
- Avoid investing in new infrastructures without ensuring sufficient funds for maintenance;
- Identify and negotiate concession agreements for financially viable infrastructure.

The projected availability of resources for the Road Sector based on historical revenues and those projected for the most recent Medium-Term Expenditure Framework indicate significant shortfalls in financing the projected uses for maintenance and rural road investments.

## 5.7 Agreed actions

The abovementioned items reflects broadly on a range of items that needs to be addressed at a country level (intra-government). To achieve the AfCAP climate adaptation objectives more emphasis should be placed on the roads sector. As the lead institution, ANE could then also be the institution that links with the other departments and forums to collaborate regarding climate

adaptation research. During April 2018, a series of mini-workshops, technical sessions and engagements were held in Maputo. A number of items were addressed and subsequent actions agreed upon. These agreed actions are as follows:

AfCAP Documents:

During these engagements, the importance of the AfCAP documents produced as part of this study, namely of the Climate Adaptation Handbook and three associated Guidelines, was empathized. Through its participation in the AfCAP project, ANE has contributed to engineering and non-engineering issues related to climate change adaptation in the roads sector. These contributions also need to be reflected in the AfCAP documents. ANE therefore agreed to prepare comments on the Climate Adaptation Handbook and three associated Guidelines and to contribute this during a work session. This would then complete ANE's contribution to the AfCAP documents.

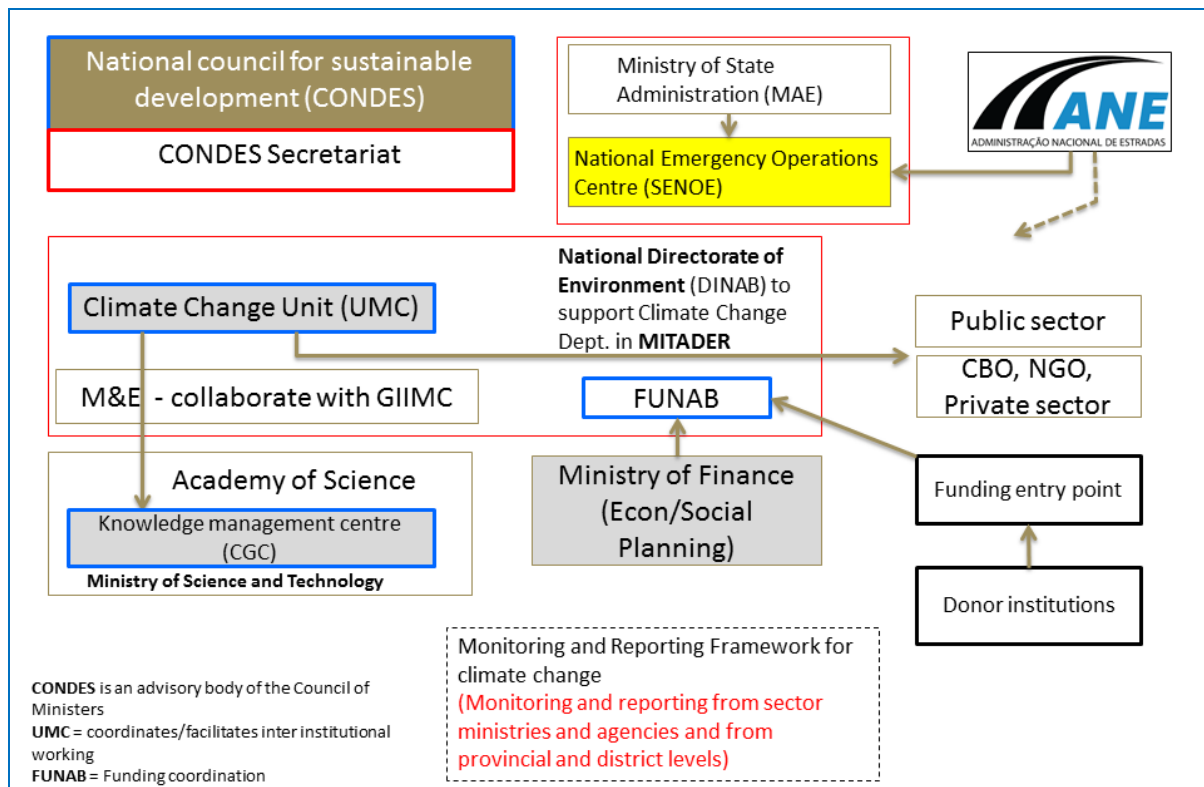
ANE Road Asset Management System and climate assessments:

The HIMS RAMS implemented at the ANE currently does not include climate related information. It only contains the standard inventory and condition data for the road network and structures such as bridges and culverts. It has however been indicated that it would be possible to add climate information as additional tables in the HIMS database. The AfCAP team emphasised that it is a key activity to link climate information to the HIMS. The spatial information currently available (at district level) could form the first round of information embedment. As the district level climate information is available and can be linked to the road network using a GIS. ANE has GIS capability and uses the same road link information in both the GIS and HIMS. It is possible to assign the climate relevant information (risk) to the GIS road links and to transfer this information to the HIMS system. ANE is further desirous to utilise the GIS information produced as part of the vulnerability assessments. The spatial information dataset and related documentation will therefore be transferred to the ANE GIS. Future sessions were arranged to provide the file-set as well as to work through the spatial content items and documentation. The subsequent linking is a query and assignment function. Once done, the prepared road link table can be provided (by the ANE GIS section) to the HIMS team where it can then be linked to the relevant tables in the HIMS database. This process will need to be repeated whenever the climate risk related GIS information is updated or improved, in order to keep the GIS information in sync with the HIMS database.

Contributing information to the wider climate adaptation environment:

A secondary focus of the project is to share the spatial information undertaken during the climate vulnerability and risk assessments, with other departments or institutions working with climate change data. Although a number of departments or institutions are listed in Table 2 and Figure 21, it was decided that the most appropriate process would be to utilise an established mechanism through which ANE has access to a range of government departments, institutions and development partners.

Mr Luis Fernandes (Director of ANE Emergency Services Department) indicated that ANE is already a member of the National Emergency Operations Centre (CENOE), which operates under the National Institute of Disaster Management (Mozambique) (INGC – see diagram in Figure 21). Through this centre, ANE is able to access a number of government ministries. Some of the development partners are also represented at SENOE. It is therefore regarded by ANE as a good forum where new data items could be introduced or shared. To initiate this action it was proposed that a request be made to SENOE for an opportunity to make a presentation on the geospatial climate related data that is available. This process should be driven by ANE to create awareness that the origin of the data is ANE. ANE indicated that they could arrange such a meeting at a future date (to be determined).



**Figure 21: Key government structures regarding Climate Change Adaptation/ Information**

#### ANE Policy:

Policy issues need to be addressed to enable embedment of climate change information in ANE activities and systems. It was therefore proposed that a strategy be developed, dealing with climate change resilience in ANE. A further recommendation was that a key person in ANE should be tasked or appointed as champion to deal with climate change adaptation (CCA) across all departments in ANE. Such an individual could also represent ANE at other institutions and forums dealing with CCA. CSIR indicated that they could assist with drafting a Climate Change Policy with ANE.

#### Engagements and coordination with other stakeholders:

The Nordic Development Fund project being undertaken by the Finnish Overseas Consultancy, includes *developing capacity for a climate resilient road sector* (including change management and climate adaptation), which overlaps with the ReCAP project. The project commenced in March 2018 and it was therefore opportune for ReCAP to engage and coordinate activities, especially where similarities exist. It also holds the potential to provide additional sites for the demonstration of climate resilience adaptations, considering that the NDF project focusses on the Nacala corridor (phase 3).

During discussions between the AfCAP and FinnOC teams, it was proposed that AfCAP and the Finnish Overseas Consultants (FinnOC) collaborate more closely to ensure that duplication of effort/activities are avoided. FinnOC was also asked to provide comments on the four documents developed by AfCAP. These comments are forthcoming.

#### General recommendations:

During engagements with ANE and some development partners, it became clear that construction or maintenance projects will require the inclusion of climate resilient designs. It was proposed that such projects could also serve as 'demonstration or learning' projects that could capacitate local technicians and engineers. Thus, more demonstration sites could be created as part of projects

across the country to enable local technicians and engineers to develop capacity to deal with climate change adaptation in design and construction.



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