Africa Community Access Partnership

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

Management of Vulnerability and Adaptation to Climate Change: Ethiopia

Council for Scientific and Industrial Research (CSIR), Paige-Green Consulting (Pty) Ltd and St Helens Consulting Ltd

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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 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 Ethiopia, 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) at the ERA and its operations.

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.

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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 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 *impacts* 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 reorganizing 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.
System Sensitivity	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).
Vulnerability	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.
Vulnerability Assessment	Process which attempts to identify the root causes for a system's vulnerability to hazards (e.g. to climate variability and change).

Acronyms, Units and Currencies

$	United States Dollar
°C	Degrees Celsius
yr	Year
ACCESS	Australian Community Climate and Earth System Simulator
AfDB	African Development Bank
ADB	Asian Development Bank
AfCAP	Africa Community Access Partnership
AsCAP	Asia Community Access Partnership
BELG	Short rainy season, the Belg, between March and April
CRED	Centre for Research on the Epidemiology of Disasters
CSIR	Council for Scientific and Industrial Research, South Africa
CRGE	Climate Resilient Green Economy
DFID	Department for International Development, UK
DMC	Developing Member Country
EM-DAT	Emergency Events Database
ERA	Ethiopian Roads Agency
GCM	Global Climate Model
GDP	Gross Domestic Product
GFDL	Geophysical Fluid Dynamics Laboratory Coupled Model
GIS	Geographic Information System
GTP	Growth and transformation Plan
GoE	Government of Ethiopia
MCA	Multi-Criteria Analysis
MDA	Ministries, Departments, Agencies/Authorities
MDG	Millennium Development Goal
MPI	Max-Planck Institute
NGO	Non-Governmental Organisation
NPV	Net Present Value
PMS	Pavement Management System
RAI	Rural Access Index
RAMS	Road Asset Management System
ReCAP	Research for Community Access Partnership
RCM	Regional Climate Model
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 Handbook has been developed to provide a methodology for carrying out a climate adaptation assessment for rural access to assist socio-economic development (Head et al, Verhaeghe, Paige-Green, Le Roux, Makhanya, & Arnold, 2018). It is supported by three separate Guideline documents covering the following aspects:

- Change Management[1];
- Climate Threats and Vulnerability Assessment[2]; and
- Engineering Adaptation[3].

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 Ethiopia, 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) at the ERA and its operations.

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

[2] 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.

[3] 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.

1 Introduction

1.1 Climate variability and change within the context of rural accessibility

Africa has experienced dramatic changes to the continents' 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 a 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 (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, 2018).

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 below (Figure 1).

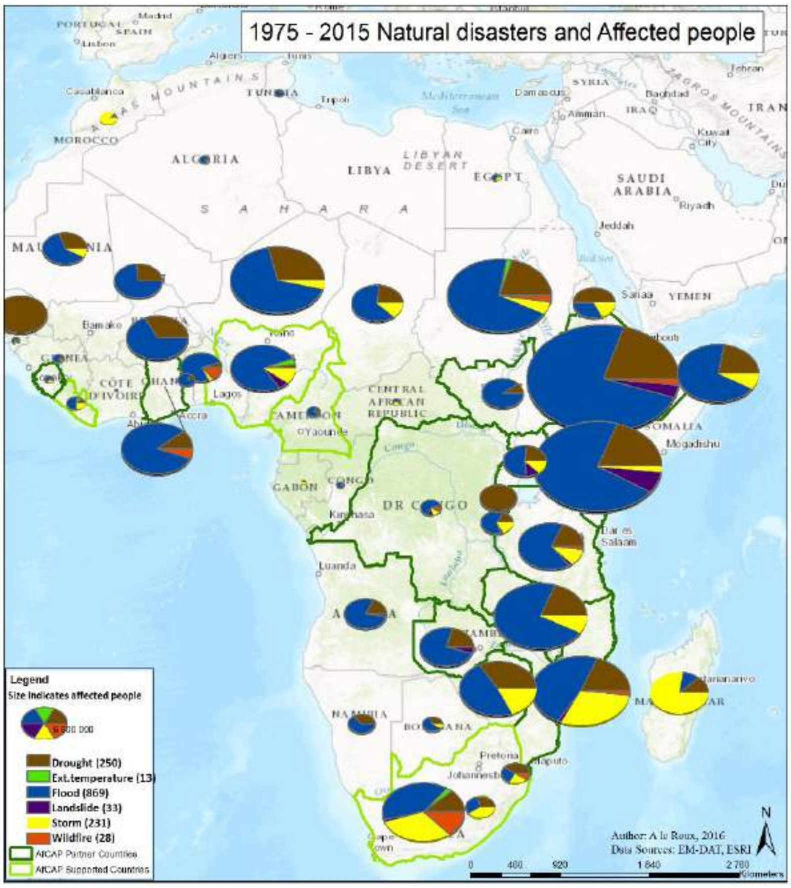


Figure 1: Recorded weather-related disasters and affected populations.

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 & Arndt, 2012). 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 (United Nations, 2015).

1.2 Climate effects in Ethiopia

Ethiopia has been identified as one of the most vulnerable countries to climate variability and change, and is frequently faced with climate-related hazards, commonly drought and floods. The variability of rainfall and increasing temperatures are a cause for frequent drought and famine, with disastrous impacts on the livelihoods of the local population. At the national level, the World Bank (2010a) suggests that climate change may reduce Ethiopia's GDP compared to the 2009 baseline scenario by up to 10% by 2045.

The Ethiopia National Meteorological Agency (National Meteorology Agency, 2007) report on climate change adaptation describes how average annual temperatures have increased by about 0.37 °C/decade between 1951 and 2006, while rainfall has been more or less constant. Analysis of climate records between 1950 and 1998 from 42 meteorological stations (Tesfaye, 2009) shows a declining trend in rainfall for the northern and southern parts of the country and an increasing trend in the central part. The high variability in rainfall is illustrated by annual rainfalls +/- 25% around the mean and in Tigray, for example, rainfall of up to 50% above the annual average have been recorded. Ethiopia has 11 major transboundary river basins including the Blue Nile, and when considering climate change, this presents challenges not only for Ethiopia but also for neighbouring countries.

The National Adaptation Programme of Action of Ethiopia (National Meteorology Agency, 2007) states that current climate variability is already imposing a significant challenge to the country by affecting food security, water and energy supply, poverty reduction and sustainable development efforts, as well as causing natural resource degradation and increases in the extent and magnitude of natural disasters. For example, the impacts of past droughts such as that of the 1972/73, 1984 and 2002/03 have had long lasting impacts. Floods in 2006 also caused substantial human life and property loss in many parts of the country.

Major floods that have caused loss of life and property have occurred in different parts of the country in the years 1988, 1993, 1994, 1995, 1996 and 2006. For example, in the main rainy season (June-September) of 2006, floods caused the following disasters (National Meteorology Agency, 2007):

- More than 250 people died, about 250 people were unaccounted for and more than 10 000 people became homeless due to the Diredawa flood;
- More than 364 people died, and more than 6 000 people were displaced due to flooding of about 14 villages in South Omo;
- More than 16,000 people were displaced in West Shewa; and
- Similar situations have also occurred over Afar, Western Tigray, Gambella Zuria and the low-lying areas of Lake Tana.

1.3 Socio-economic overview

Ethiopia's topography, dependence on rain-fed agriculture, current environmental status, expansive land degradation and demography, along with its developmental history and weak infrastructure, significantly increase the country's vulnerability to natural hazards (World Bank, 2004; GFDRR, 2015). The recurrent high exposure to intense droughts, floods, landslides and wild fires have devastated parts of the country and pose the greatest threat to local populations (World Bank, 2004; GFDRR, 2011). Climate-related threats are the major driver of hunger and food insecurity in the country, with the majority of poor communities being vulnerable to their impacts. The increasing effects of climate change in tandem with human-induced factors contribute to the expansion of drought and desertification (GFDRR, 2015). In addition to the widespread poverty and population pressures, a number of socio-economic factors exacerbate the development challenges in Ethiopia. Foremost among these challenges are the insufficiently developed water resources, sparse availability of social facilities (health services, schools etc.), inadequate road infrastructure (particularly in drought-prone areas), and weak institutions (GFDRR, 2011). Rapid population growth and the expansion of farming and pastoralism under a drier, warmer climate regime could dramatically increase the number of at-risk people in Ethiopia during the next 20 years (Funk et al., 2012).

Ethiopia is the second-most populous country in Sub-Saharan Africa with a population of over 100 million, and a population growth rate of 2.5% (World Bank, 2017a). Eighty-five percent of Ethiopia's population is concentrated in the northern and central highlands (Figure 2). Like other regions in sub-Saharan Africa, the population structure of Ethiopia is very young and the country has the largest youth population in the region. Children and young people (0 to 24 years) make up 65% of the total population, and with an average annual growth rate of 2.5%, the population is projected to double in less than three decades (IFAD, 2017). Given that Ethiopia is a land-locked country dependent on agricultural, agro-pastoral, and pastoral livelihoods, population expansion at this rate will place increasing stress on the courtiers natural resources.

The country's vision is to reach a middle-income status by 2025. Over the last two decades, the Ethiopian GoE has put in place a number of policies, strategies and laws that are designed to support sustainable development and the country is set to move towards a greener economy. Over the past decade Ethiopia has seen both rapid economic and population growth, making it one of the highest performing economies in sub-Saharan Africa (IFAD, 2017), but despite economic progress and its vast resources of land, water and labour, Ethiopia remains one of the most food-insecure countries in the world, faced with extreme poverty, wide spread inequality and resource underutilisation stunting development growth (Brown et al., 2017). The country is amongst the poorest countries in Africa (World Bank, 2004), with a human development index (HDI) of 0.442 (UNDP, 2015) and is ranked 174th out of 188 assessed countries in terms of its human development measures.

As one of the least urbanized countries globally, Ethiopia's current population is almost exclusively rural (81%), with only a small minority of people living in urban areas (Figure 3). Most rural people live in the highlands and middle-highlands, which comprise only one-third of the land area, and this population tends to be concentrated primarily in Oromia and northern SNNPR regions (Funk et al., 2012).

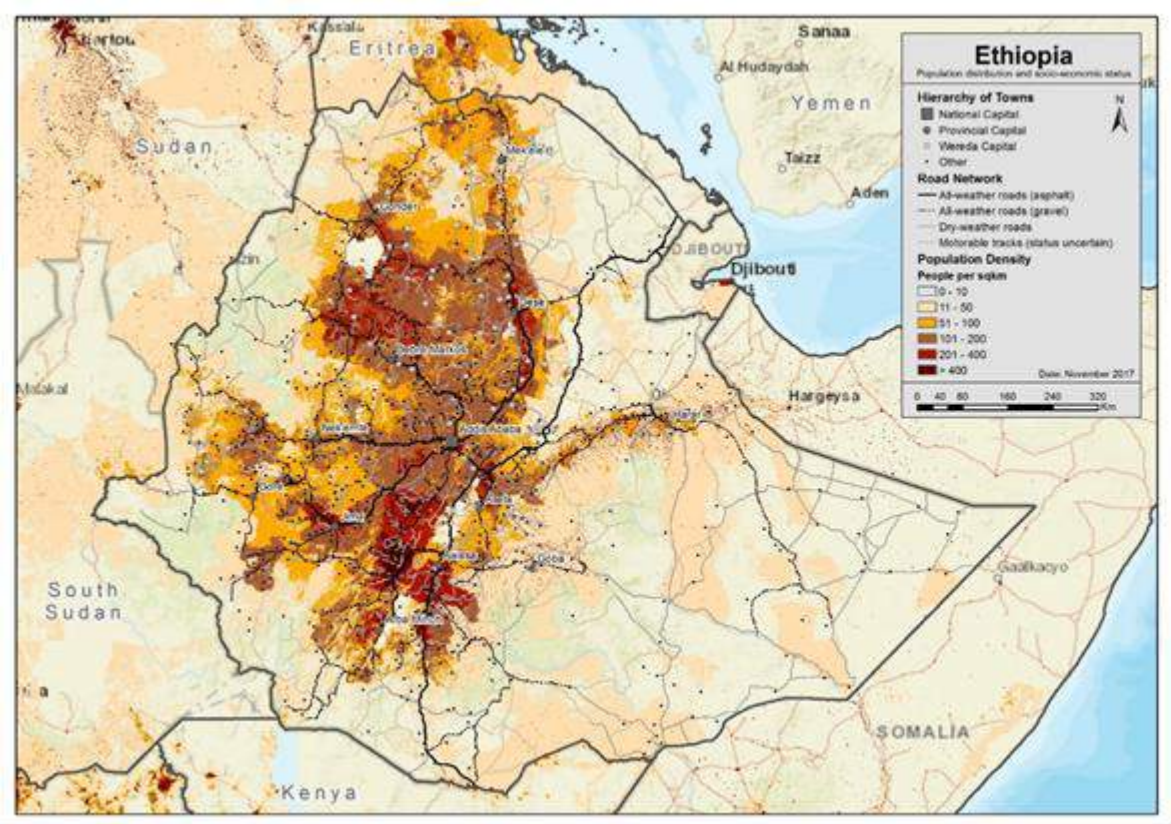


Figure 2: Population distribution

Source: CSIR analysis using WorldPop (2017), Diva-GIS (2017) and ESRI (2018) data

Although the country is projected to experience substantial urbanisation in the coming three decades (thereby starting to reduce the ratio of inequality), the rural population is still projected to out-proportion the urban growth rate by 2050 (UN ESA, 2014). The country is projected to become 38% urban by 2050 (up only 19% from 2015), and the rural population is expected to grow to 117 million people, thereby adding 37 million additional people in rural areas by 2050.

It is estimated that around 80 million of Ethiopia's almost 100 million people are dependent on small-scale subsistence agriculture for their livelihood. These rural communities produce 90% to 95% of Ethiopia's agricultural output through low-input, low-yield, rain-fed farming (World Bank, 2004).Agriculture constitutes nearly half of the county's annual GDP (CSA, 2015). The projected rapid population increase will therefore place great strain on the country's already vulnerable natural resources, potentially accelerating already high levels of soil erosion, land degradation, deforestation, biodiversity loss, air and water pollution and desertification, and rendering the vast majority of the population highly vulnerable to climate induced threats including drought, environmental degradation and flooding (GFDRR, 2011). Millions more rural people will also be at risk to weather-related hazards including recurrent droughts and floods which pose the greatest threat to local populations, placing more strain on the insufficiently developed water resources, sparse availability of social facilities and inadequate road infrastructure (GFDRR, 2011).

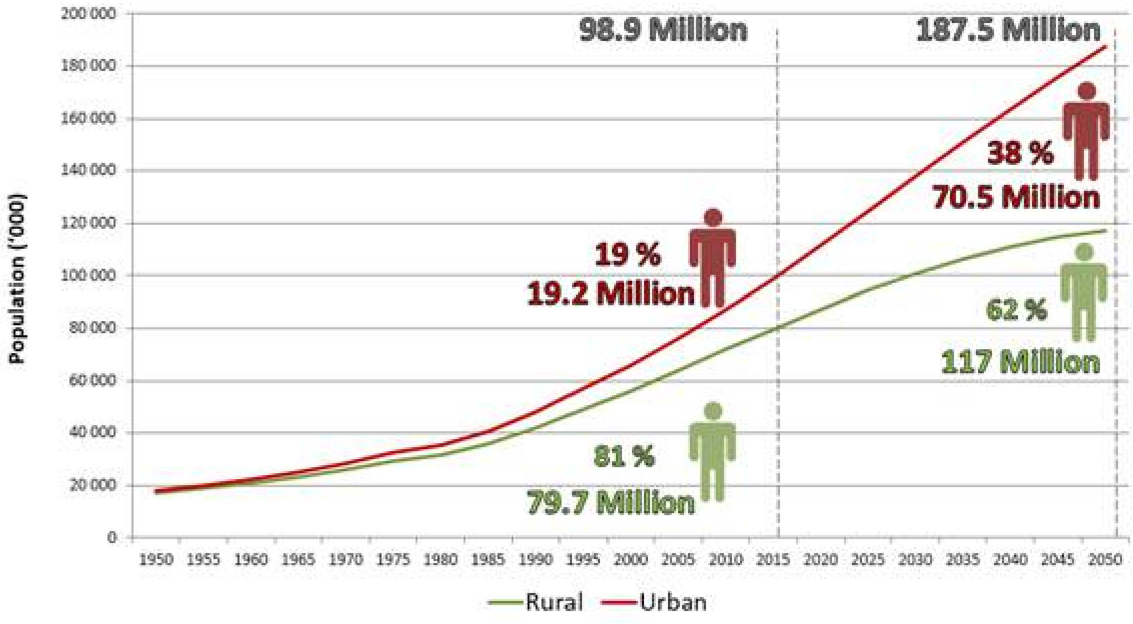


Figure 3: Projected changes in urban and rural population distribution (2015 – 2050)

Source: CSIR analysis using UN ESA (2014) custom data

1.4 Road network overview

Ethiopia has four levels of roads. These are federal roads; regional roads; municipal roads; and community roads. ERA is responsible for the federal and regional roads, while municipal road authorities are responsible for the municipal roads. The woreda administrations are responsible for community roads through the Woreda Road Desk. The length of the Ethiopian classified road network in 2016 is summarised in Table 1.

Table 1: Length of Ethiopian Classified Road Network (2016)

Road Type	Paved	Gravel	Total
Federal	14 632	13 400	**28 032**
Rural		31 620	**31 620**
Woreda		48 057	**48 057**
Municipal	1 693	3 664	**5 357**
Total:	**16 325**	**96 741**	**113 066**

Source: ERA, 2016

The World Bank (World Bank, 2010a) considers that the biggest problems affecting current roads in Ethiopia are the overloading of vehicles and poor maintenance of roads, including a lack of repair. By contrast, they consider that the success of new roads will depend on taking into account the choice of alignment, design and construction, the climate and topography in which the road is situated, the need for axle load restrictions, and the need for proper maintenance.

In addition to providing access to the rural and urban areas of the country, road transport plays a critical role in reducing transportation costs and supporting economic growth in the Ethiopian economy, being a landlocked country with largely non-navigable rivers and a limited railway system

(Shiferaw *et al*., 2012). The most notable characteristic of the Ethiopian road network is that most all-weather roads radiate outwards from Addis Ababa (the capital), to major towns. Direct links between regions are rare, often discouraging interregional trade and 60% of the rural population remains without access to an all-weather road (World Bank, 2016).

The reliance of the economy on Ethiopia's small road network of mostly dry-weather roads makes commerce highly vulnerable to climate threats. In this way large parts of the country are faced with inadequate road infrastructure (particularly in drought-prone areas) (GFDRR, 2011), and ERA (2016) reports that 28% of Ethiopia's current classified road network is considered to be largely deteriorated or in a poor condition. Rural roads are the most largely under-serviced category in the network, with as much as 45% of the rural road network considered to be in a poor condition (ERA, 2016). Rural roads play a vital role in connecting isolated rural communities with economic centres, markets and basic social services, and it has been acknowledged that the limited road network coverage and poor condition of the existing road network in Ethiopia has been a major obstacle to economic recovery and economic growth, especially in times of climate related crisis (ERA, 2016).

The classified road network in Ethiopia has expanded from 26 550 km in 1997 to 113 066 km in 2016 (ERA, 2016). However, the 2016 road density of 1.23 km per 1 000 people or 103.8 km per 1 000 km^2 land area, is still one of the lowest in Africa, (World Bank, 2016) and well below the African average of 204 km of road per 1 000 km^2 of land area (Foster & Briceno-Garmendia, 2009). Figure 4 depicts an overview of the classified road network density (km of roads per zone/total area of zone), while Table 2 summarises the progress made against selected indicators during the Road Sector Development Program (RSDP), overseen by ERA between 1997 and 2016 (ERA, 2016).

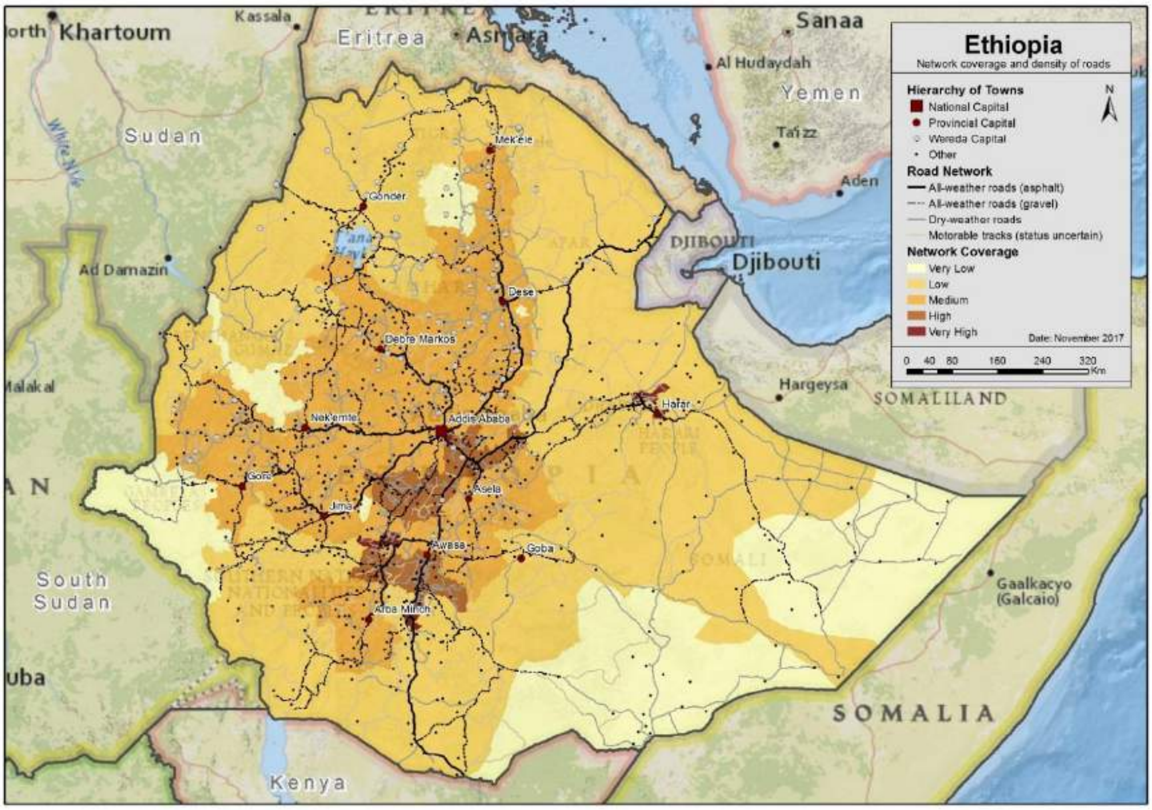


Figure 4: Overview of Ethiopian road network density (km per area) (2016)

Data source: CSIR analysis using WorldPop (2017) & DIVA-GIS (2017) data

Table 2: Change in Selected Indicators of the Ethiopian Classified Road Network (1997 to 2016)

Indicators	1997 (RSDP Start)	2016 (First Year of RSDP V)
Proportion of Asphalt roads in Good Condition	17%	**73%**
Proportion of Gravel roads in Good Condition	25%	**59%**
Proportion of Rural roads in Good Condition	21%	**55%**
Proportion of Woreda roads in Good Condition	-	**83%**
Proportion of Total Road network in Good Condition	22%	**72%**
Road Density 1/1 000 sq.km	24.1 km	**102.8km**
Road Density 1/1 000 population	0.46 km	**1.23 km**
Proportion of area more than 5 km from all-weather road	79%	**35.8%**
Average distance to all weather road	21 km	**4.9 km**
Road Network length (in km) including URRAP and Municipality Roads	**26 550**	**113 066**

Source: ERA, 2016

1.4.1 5th Road Sector Development Plan (2016 - 2020)

The objectives of the Road Sector Development Program Support Project are to contribute to Ethiopia's economic development by improving trunk and regional rural road access and utilization to meet the agricultural and other economic development needs; building up the institutional capacity in both the public and private sectors for sustainable road development and maintenance; and providing economic opportunity for the rural poor both through increased employment in rural road works and development of appropriate affordable means of transport and services.

Under the four previous Road Sector Development Plans, the road network expanded from 48 812 km in 2009 to 113 066 km in 2016. Under the Universal Rural Road Access Programme, 48 057 km of all-weather woreda[4] roads were constructed. As a result, the proportion of kebeles connected by all-weather roads increased from 40% in 1997 to 76% in 2016 (ERA, 2016).

In the fifth Road Sector Development Plan for the period 2016 to 2020, the GoE plans to double the road network from 113 066 km in 2016 to 215 000 km in 2020 and advance the paved road ratio from 14% in 2016 to 15% by 2020 (ERA, 2015).Relevant components of the plan include:

1. Rehabilitation/strengthening of paved trunk roads;
2. Upgrading trunk routes from gravel to asphalt paved standard;
3. Institutional strengthening and capacity building support for the Ethiopian Roads Authority;
4. Financing for the provision of technical assistance and capacity building for four Regional State Rural Roads Organizations; and
5. Environmental guidelines and sector environmental assessment (EA) capacity building.

[4] Woreda or districts are the third-level administrative divisions of Ethiopia. They are further subdivided into a number of wards (kebele) or neighbourhood associations, which are the smallest unit of local government in Ethiopia.

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.

This country report summarises relevant information from the AfCAP programme on rural access road climate adaptation, namely, the methodology and findings for Ethiopia. It includes an analysis of the current and projected climate situations and the impacts on rural road infrastructure, as well as a summary of the Ethiopian socio-economic and policy environment. Finally, Change Management options to reduce risk in order that agreed actions can be implemented are identified.

2 Ethiopia's Current Climate and Climate Change Impacts on Road Infrastructure

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 Ethiopian 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).

2.2 Downscaling approach of climate projection models

In order to project future climate scenarios for Ethiopia (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[5]), were selected for further downscaling to a very high resolution over three AfCAP countries, including Ethiopia (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).

[5] Representative Concentration Pathways (RCP)

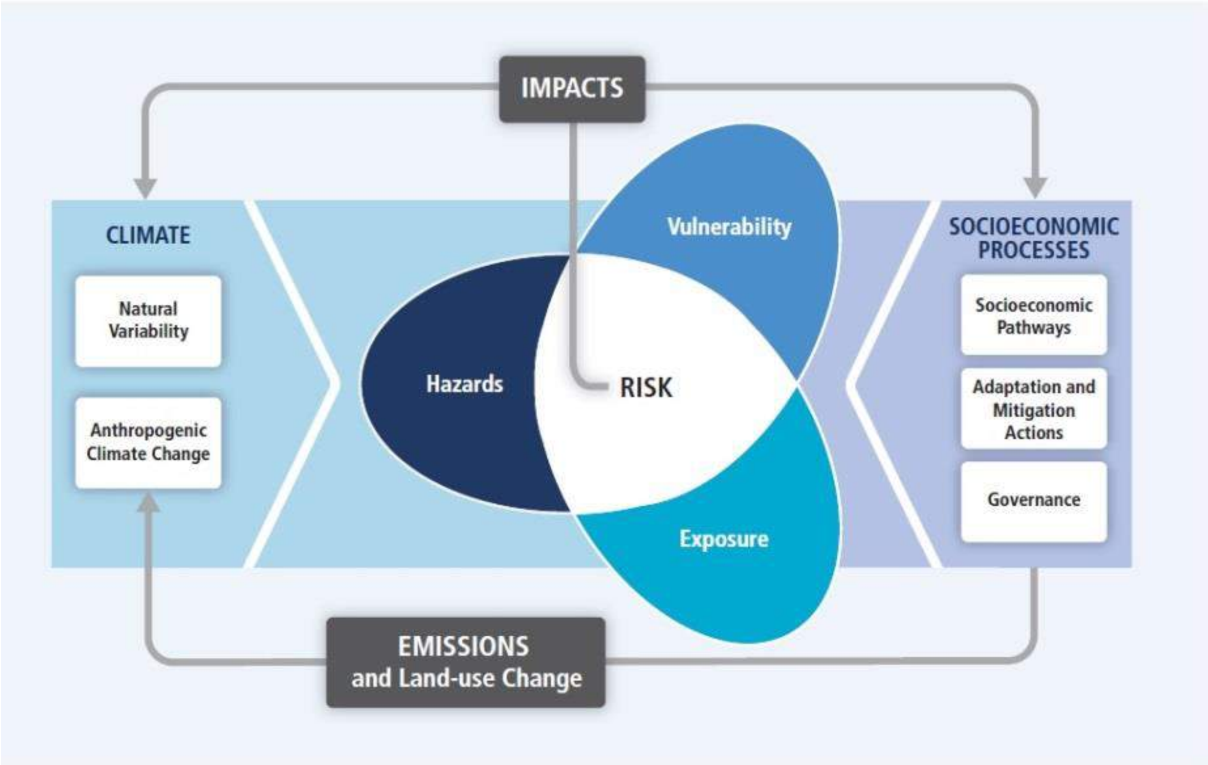


Figure 5: A conceptual framework for climate-related risk as an interaction between climate-related hazards, exposure and vulnerability of human and natural systems.

Source: Niang *et al*. (2014)

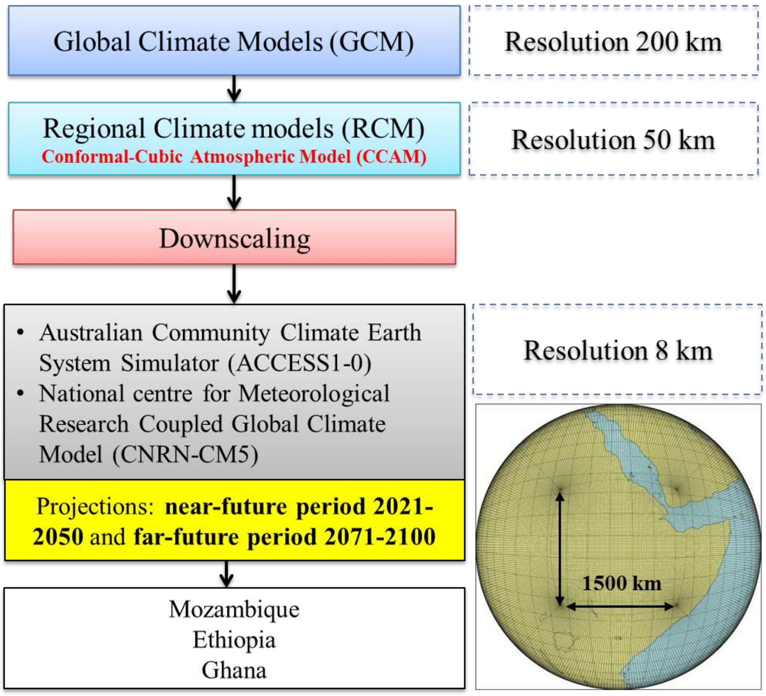


Figure 6: Climate model downscaling

The stretched conformal-cubic grid used to obtain the 8 km resolution model projections of future climate change over Ethiopia is displayed in Figure 6 (every second grid-point is shown). Centred over Addis Ababa, the high-resolution grid panel of the model domain stretches about 1 500 km from the south to the north, and 1 500 km from the west to the east, covering Ethiopia at an 8 km resolution. For the periods 1971-2000, 2021-2050 and 2071-2100, four climate variables were included for analysing projected changes in climate (1971-2000 base climate relative to 2050/2100 projections, see Figure 7), 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.

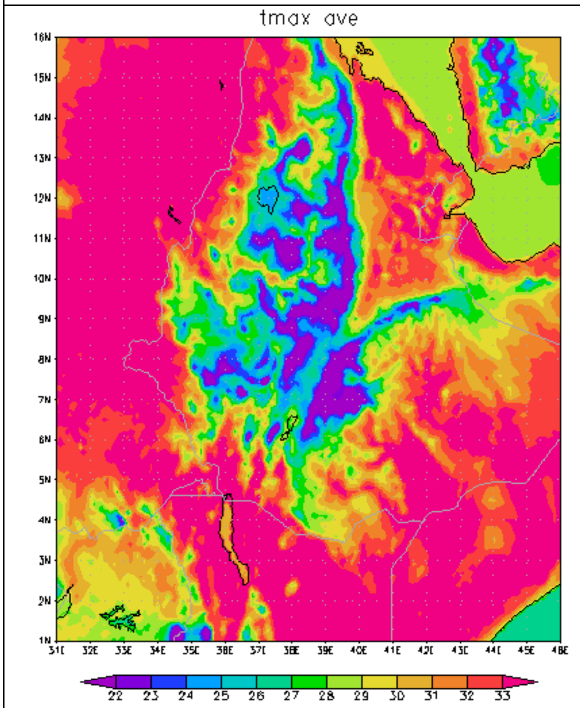
2.3 Current climate variability and observed trends

From the modelled present day climate for Ethiopia (Figure 7), it is observed that annual average maximum temperatures in the low twenties (°C) are simulated to occur over the Ethiopian highlands, with significantly higher annual average maximum temperatures occurring over eastern Ethiopia and also to the west of the highlands - in correspondence with observations. More than 100very hot days are simulated to occur annually in the southeast, the coastal belt in the northeast and to the west of the Highlands, but less than 10 of these days are simulated to occur annually over the highlands.

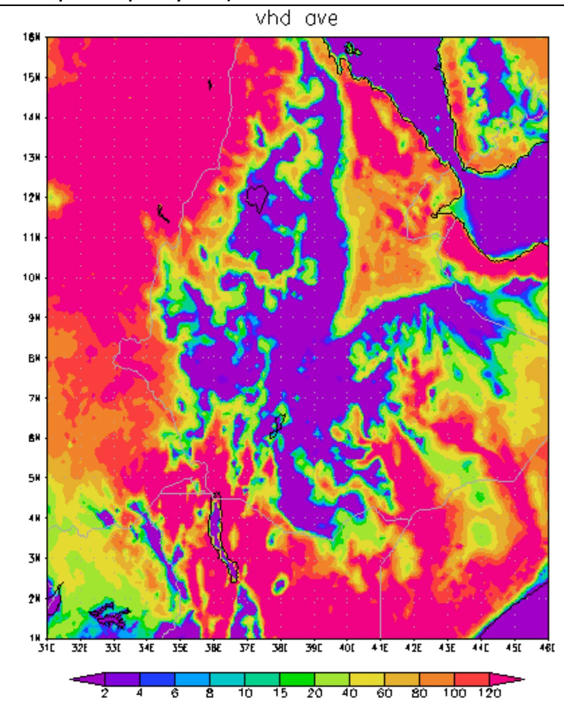
High average annual rainfall totals of more than 1 000 mm per year are simulated to occur over the highlands region, with significantly lower totals and in fact semi-arid conditions are simulated for the eastern part of the country. As such, the model simulations realistically represent the significant east-west rainfall gradient observed over Ethiopia. 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 locations in the highlands region.Temperatures have been increasing across the East African region over the last five decades (Funk *et al*., 2011; Funk *et al*., 2012; Anyah & Qiu, 2012), with increases in extreme events also being observed (Vincent *et al*., 2011). Recently, the rate of temperature increase over Ethiopia over the last five decades has been reported to be about 2.5°C/century in the northeast, 2°C/century in the southwest and somewhat less in the remainder of the country (Engelbrecht *et al*., 2015).

There is some evidence of observed rainfall decreases over East Africa, including Ethiopia, but in general these changes are not statistically significant (Niang *et al*., 2014). However, there is also evidence of the frequency of occurrence of both floods and droughts increasing over East Africa over the last three to five decades (Williams & Funk, 2011). Whether these changes can be attributed to enhanced anthropogenic forcing, as opposed to natural multi-decadal variability, remains unclear (Lyon & DeWitt, 2012; Lyon *et al*., 2013).

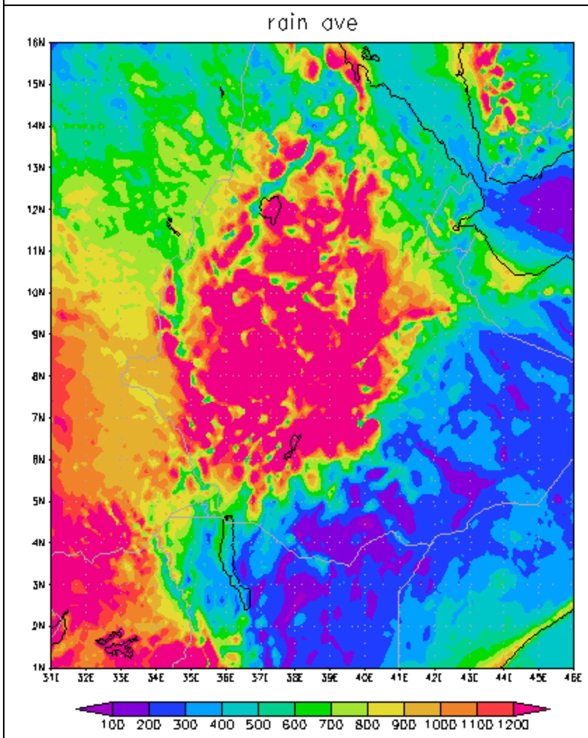
a) Annual average maximum temperature (°C)



b) Very hot days (number of events per grid point per year)



c) Annual rainfall totals (mm)



d) Extreme rainfall days (number of events per grid point per year)

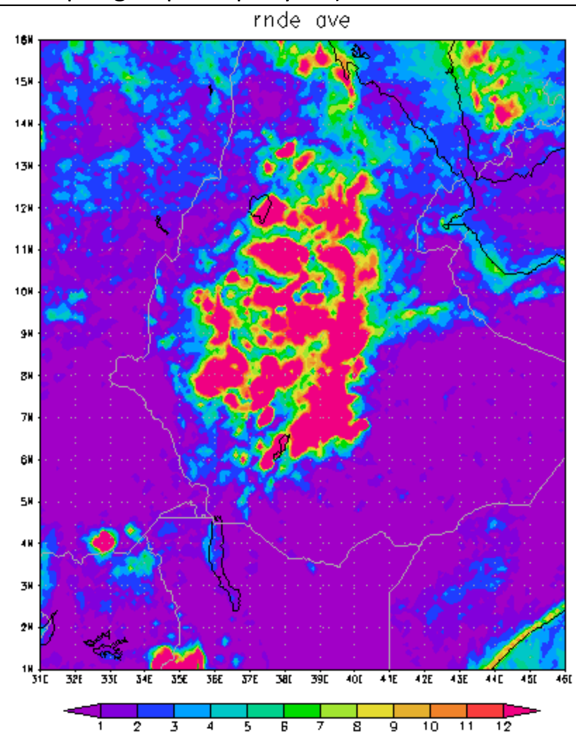
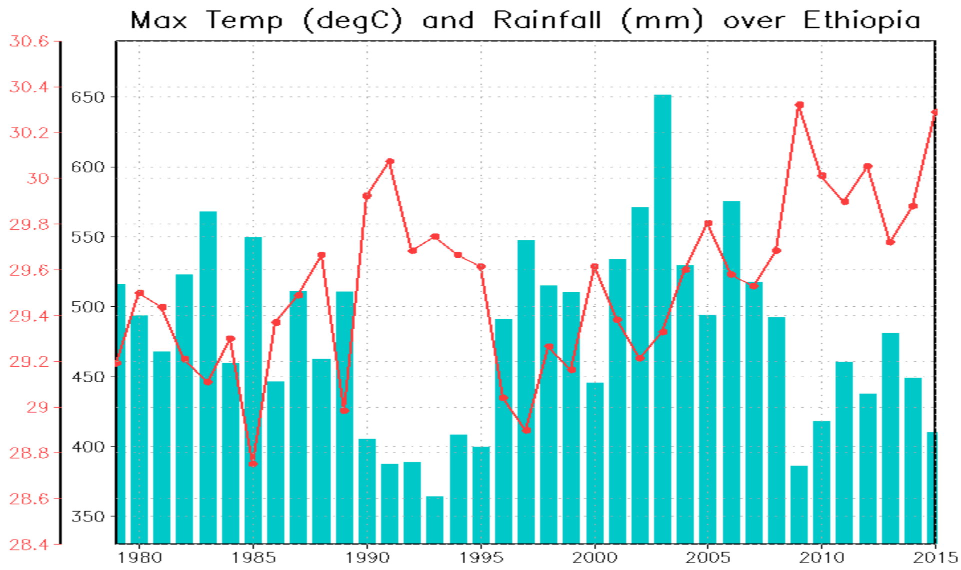


Figure 7: Present-day climatology (1971-2000) over Ethiopia

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

The variability in maximum temperature and rainfall over Ethiopia as represented in ERA interim data is displayed in Figure 8, for the period 1979-2015. Consistent with the temperature trend analysis of Engelbrecht *et al*. (2015), based on station data incorporated into the CRUTEMP4v data set of the Climatic Research Unit (CRU), and the rainfall-trend analysis of Niang *et al*. (2014), the analysis is indicative of statistically significant increases in maximum temperature but insignificant trends in rainfall. The rainfall time-series for Ethiopia shows pronounced decadal to multi-decadal variability, rather than systematic change in the mean (Figure 8). With the seasonal movements of the ITCZ, the onset and duration of the rainy seasons (as well as rainfall intensity and annual quantity) vary considerably inter-annually, with fluctuations regularly resulting in devastating droughts in various parts of the country.



Data set	Period	Temperature trend (°C/century)	Rainfall trend (mm/century)
CRUTEMP4v	1961-2010	1.4	Not available
ERA interim	1979-2015	1.7	Not significant

Figure 8: Ethiopia's temperature and rainfall variability and trends (1979-2015)
Data source: ERA-interim and CRUTEMP4v

2.4 Projected climate change

General temperature increases are projected for Ethiopia under low mitigation, across all seasons, and occurring in association with increases in heat-wave days and higher rates of evaporation (Conway & Schipper, 2011; Niang *et al*., 2014). The CMIP5 and CMIP3 (Coupled Model Inter-comparison Project Phase 3) are indicative of a generally wetter climate over the larger East African region towards the end of the 21st century (Moise & Hudson, 2008; Niang *et al*., 2014). These rainfall increases are projected to occur in association with the more frequent occurrence of seasonally associated heavy rainfall, and a few seasons associated with severe drought. The number of days associated with extreme rainfall is correspondingly projected to increase under climate change (Seneviratne *et al*., 2012; Vizy & Cook, 2012).

Over Ethiopia, most GCM projections are indicative of generally wetter conditions, consistent with the changes projected for the larger East African region (Niang *et al*., 2014). However, the projected changes are generally small in amplitude. Comparatively few RCM studies have been performed for Ethiopia, but from such studies there are indications of a shortening of the spring rainfall period over the eastern parts of the country (Cook & Vizy, 2013).

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

Figure 9 shows the projected changes in annual average maximum temperatures (°C, Figure 9- top) and the annual number of very hot days (number of events per grid point per year, Figure 9 - bottom) over Ethiopia, for the ACCESS1-0 (left) and CNRM-CM5 (right) downscalings.

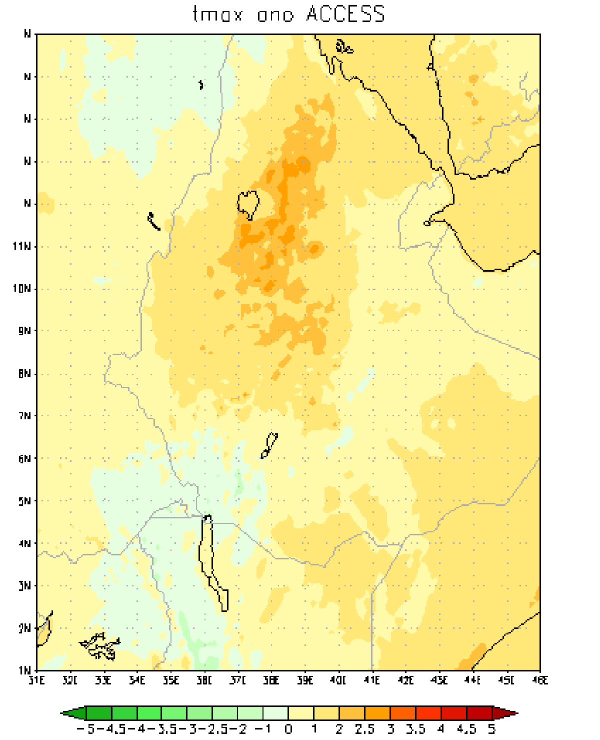
The projections are for the period 2021-2050 relative to 1971-2000 under low mitigation scenario (RCP 8.5). For the mid-future period of 2021-2050 the ACCESS1-0 and CNRM-CM5 downscalings are consistently indicating projected temperature increases of 1 to 2°C in the south-eastern parts of Ethiopia. However, over the highlands there are some discrepancies between the different downscalings, with increases projected to be less than 1°C by the CNRM-CM5 downscaling and more than 1°C, reaching values as high as 3°C over some areas, in the ACCESS1-0 downscaling. Over the south-eastern parts, large increases in the number of very hot days, reaching values of 100 days per year, are consistently projected by the downscalings. Figure 10 shows the projected changes in annual average rainfall totals in mm (Figure 10- top) and the annual number of extreme rainfall days (number of events per grid point per year; Figure 10- bottom) over Ethiopia, for the ACCESS1-0 (left) and CNRM-CM5 (right) downscalings. The projections are for the period 2021-2050 relative to 1971-2000 under low mitigation scenario (RCP 8.5). For the mid-future period of 2021-2050, both of the downscalings are indicative of pronounced rainfall decreases occurring over the highlands regions already by the mid-future, but with compensating and pronounced increases in rainfall projected over the eastern parts. Extreme rainfall event changes are projected to follow a similar pattern than the projections of rainfall totals. An increase of 4 of these events or more per year (an increase of 30% or more in the frequency of occurrence of such events) is projected in particular to the over the eastern highlands region, with smaller increases projected further to the east.

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

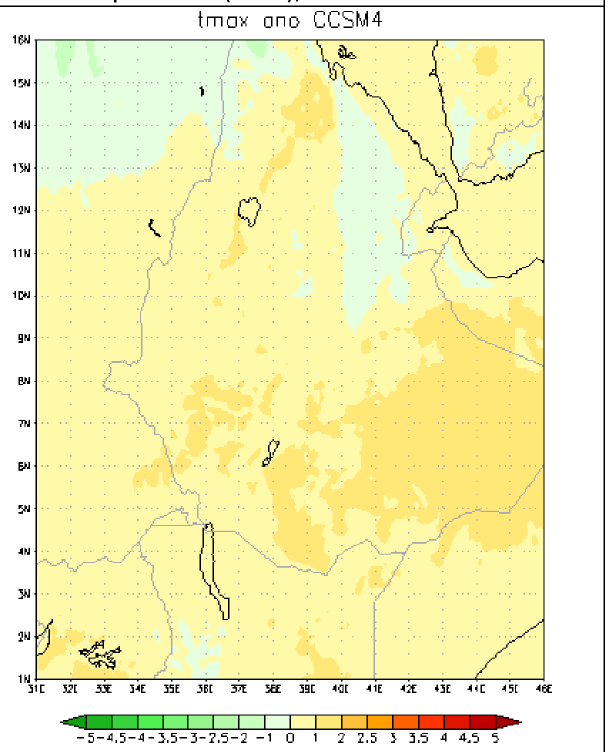
Figure 11 shows the projected changes in projected changes in annual average maximum temperatures (°C; Figure 11 - top) and the annual number of very hot days (number of events per year; Figure 11 - bottom) over Ethiopia, for the ACCESS1-0 (left) and CNRM-CM5 (right) downscalings. The projections are for the period 2071-2100 relative to 1971-2000 under low mitigation scenario (RCP 8.5). Drastic temperature increases, of more than 5°C are projected for the far-future (2071-2100) over the highlands region of Ethiopia in the ACCESS1-0 downscaling. However, in the CNRM-CM5 the projected increases for this region are only in the order of 3°C. Both downscalings are indicative of drastic increases in the number of very hot days in the southeast (increased of as many as 100 days per year). In the ACCESS1-0 downscaling, these drastic increases in the number of very hot days also extend westwards to and over the highlands.

Figure 12 shows the projected changes in annual average rainfall totals in mm (Figure 12 top) and the annual number of extreme rainfall days (number of events per grid point per year; Figure 12 bottom) over Ethiopia, for the ACCESS1-0 (left) and CNRM-CM5 (right) downscalings. The projections are for the period 2071-2100 relative to 1971-2000 under low mitigation scenario (RCP8.5). Both downscalings are indicative of pronounced rainfall decreases over the highlands and pronounced increases over the eastern parts, with extreme rainfall events exhibiting corresponding patterns of change over these regions.

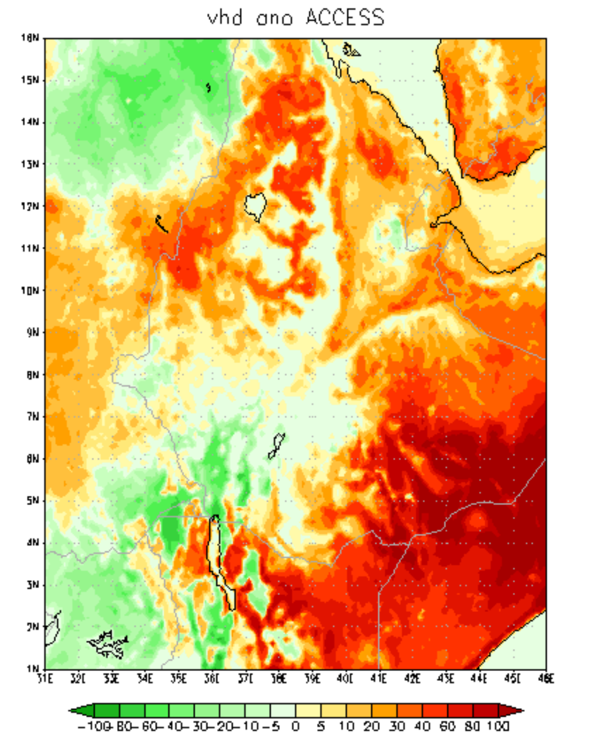
a) Changes in annual average maximum temperature (in °C); ACCESS model



b) Changes in annual average maximum temperature (in °C); CNRM-CM5 model



c) Very hot days; ACCESS model



d) Very hot days; CNRM-CM5 model

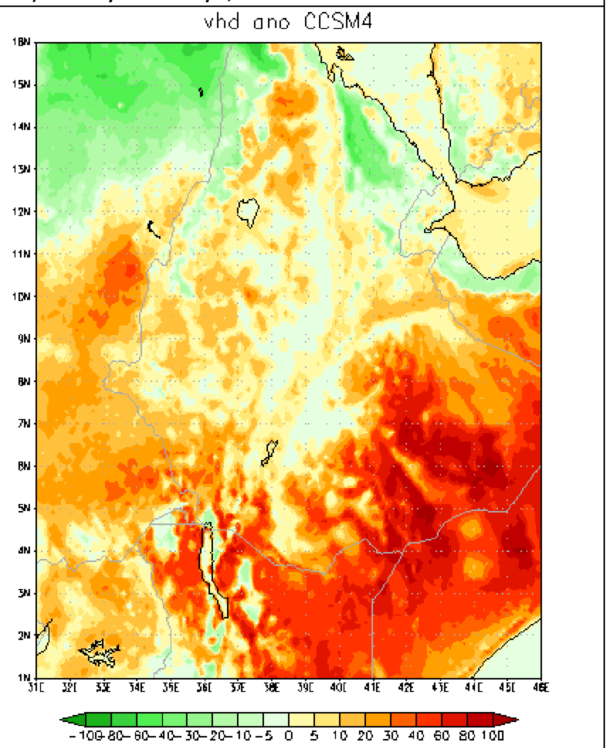
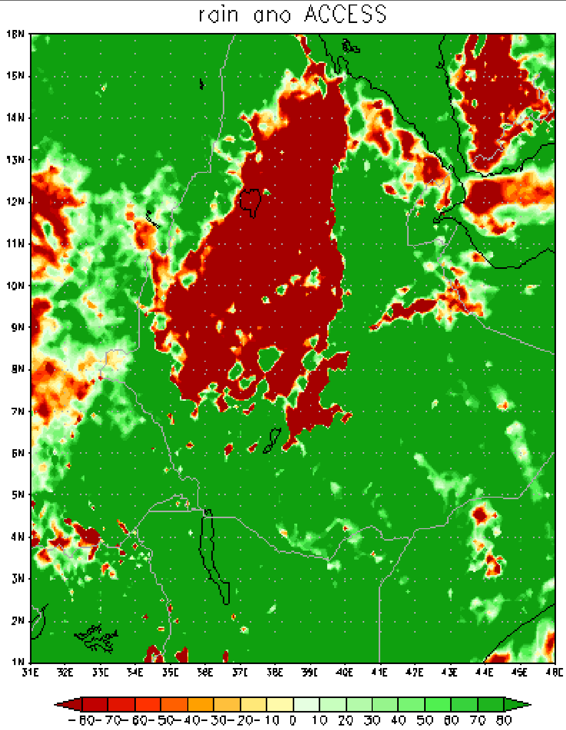


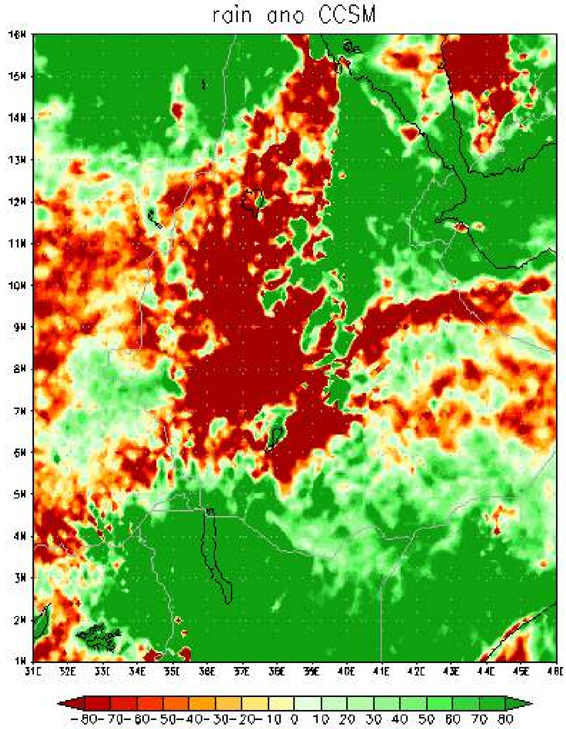
Figure 9: Projected changes in annual average maximum temperatures (top) and very hot days (bottom) (period of 2021-2050)

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

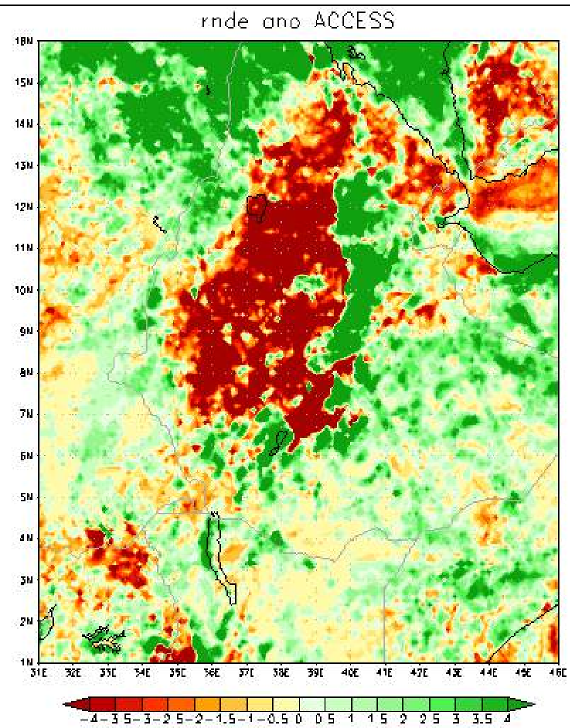
a) Changes in annual average maximum temperature (in °C); ACCESS model



b) Changes in annual average maximum temperature (in °C); CNRM-CM5 model



c) Changes in extreme rainfall events; ACCESS model



d) Changes in extreme rainfall events; CNRM-CM5 model

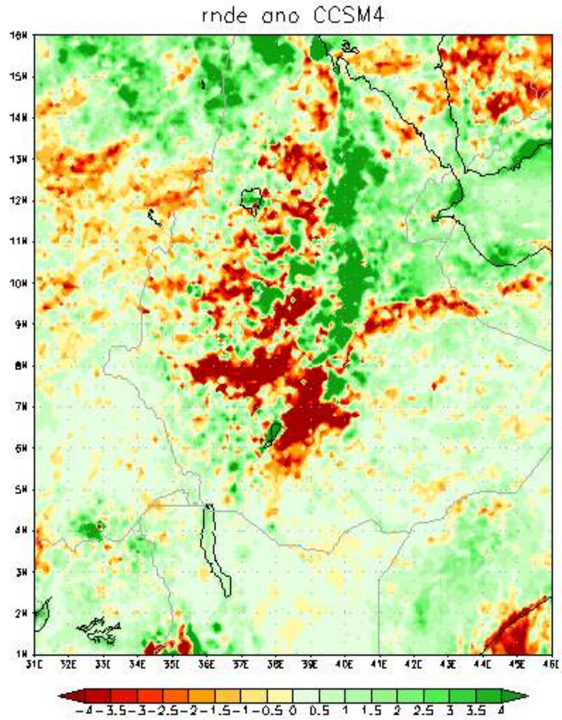
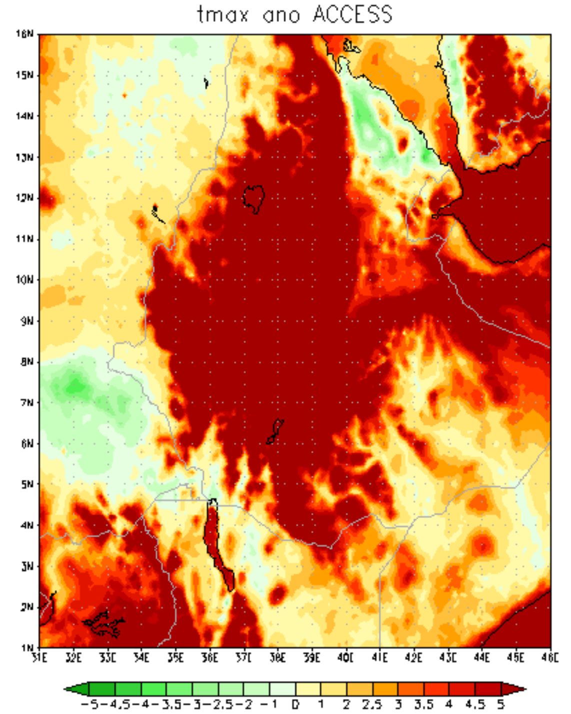


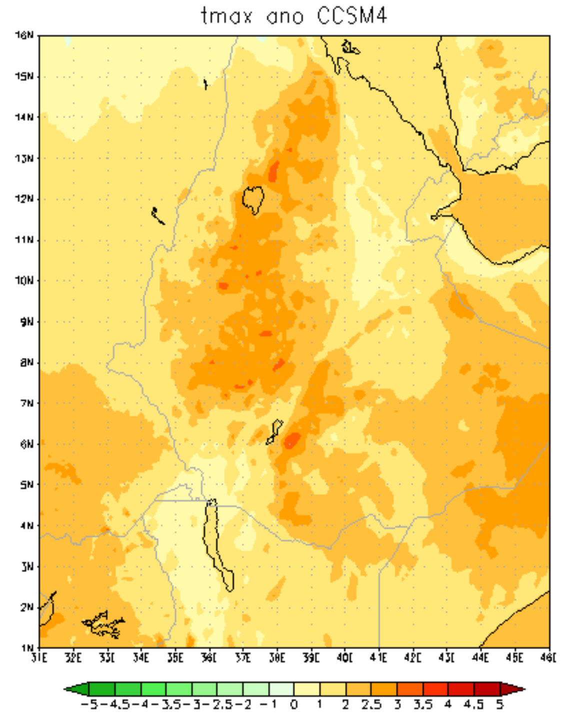
Figure 10: **Projected changes in average rainfall (top) and changes in extreme rainfall events (bottom) (period of 2021-2050)**

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

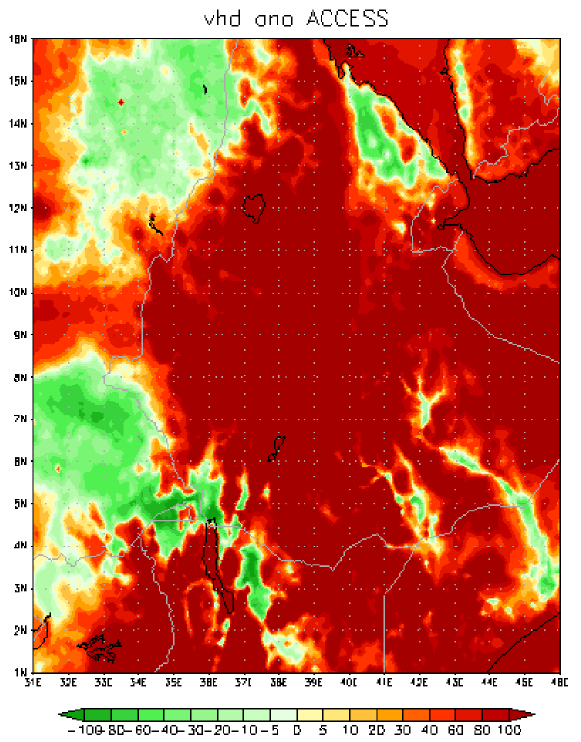
a) Changes in annual average maximum temperature (in °C); ACCESS model



b) Changes in annual average maximum temperature (in °C); CNRM-CM5 model



c) Changes in very hot days; ACCESS Model



d) Changes in very hot days; CNRM-CM5 model

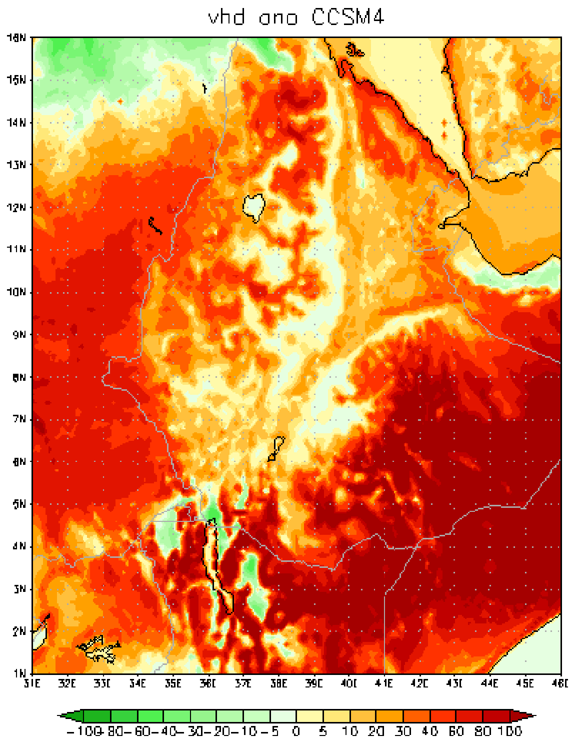
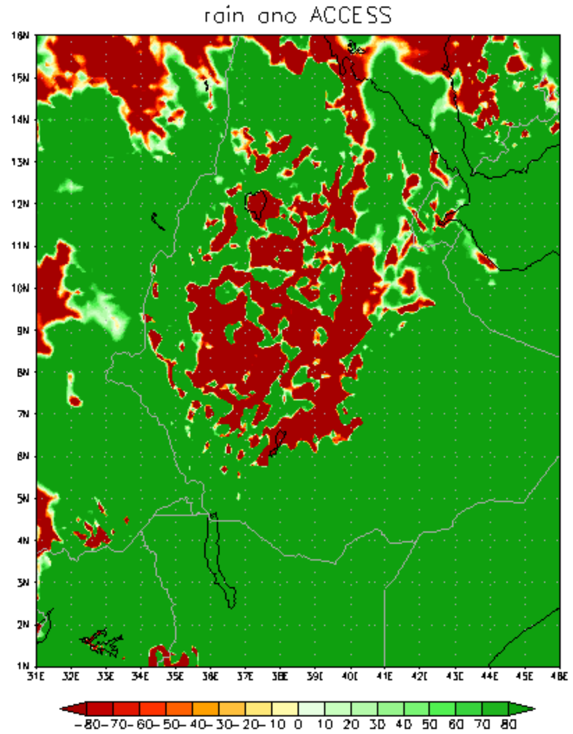


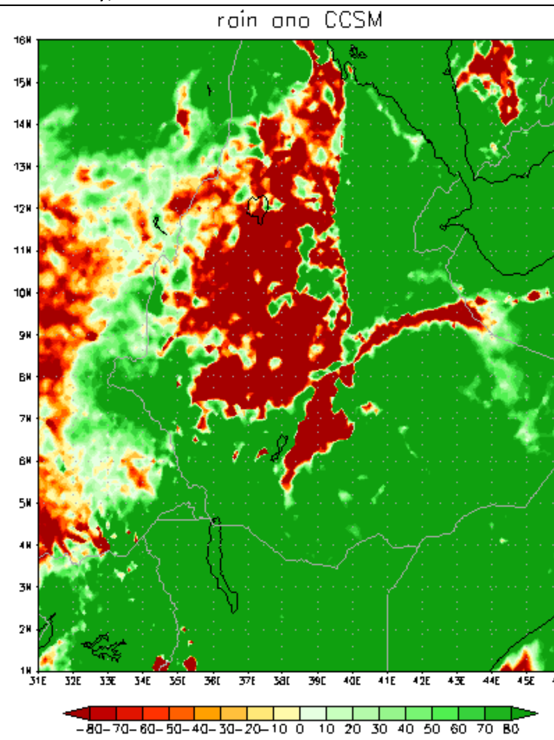
Figure 11: Projected changes in annual average maximum temperatures (top) and very hot days (bottom) (period of 2071-2100)

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

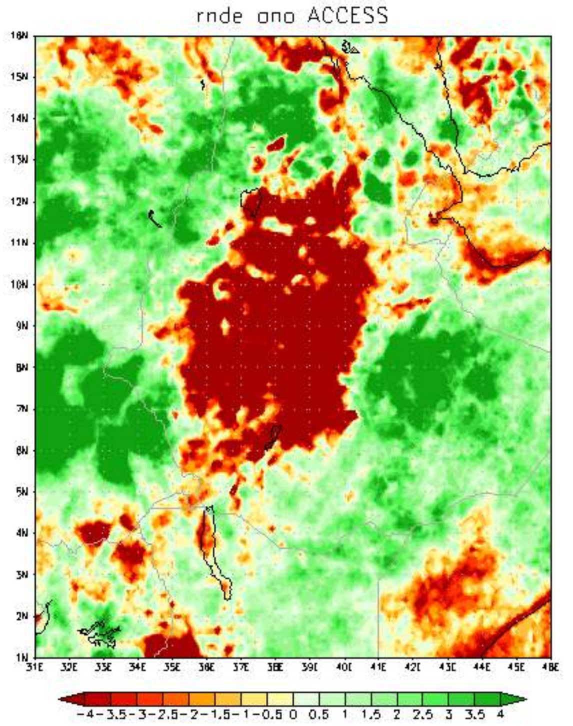
a) Changes in annual average rainfall (in mm); ACCESS model



b) Changes in annual average rainfall in (in mm); CNRM-CM5 model



c) Changes in extreme rainfall events; ACCESS Model



d) Changes in extreme rainfall events; CNRM-CM5 model

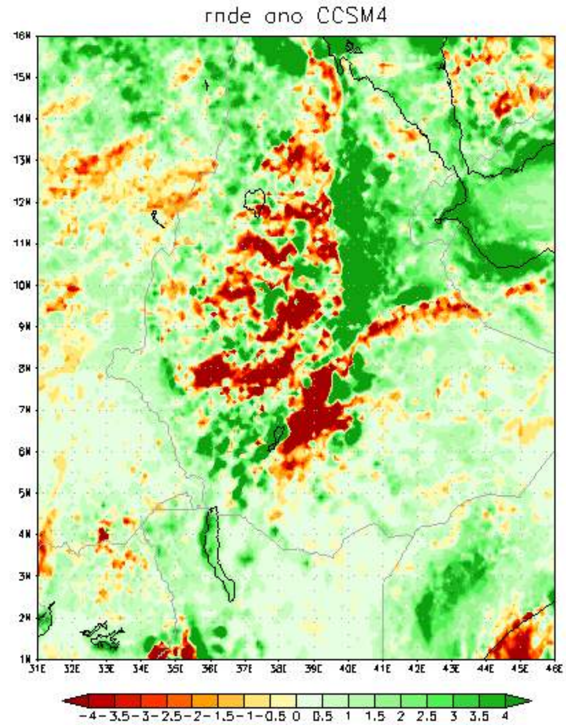


Figure 12: Projected changes in average rainfall (top) and changes in extreme rainfall events (bottom) (period of 2071-2100)

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

2.5 Impacts of current climate variability

Climate change is expected to have a significant impact on transportation, affecting the way transportation system is planned, designed, constructed, operated, and maintained. The risk of climate change to transport infrastructure has however not been quantified recently[6], as a detailed vulnerability assessment has not been undertaken for the sector, specifically the roads sector. The recent **Climate Resilient Transport Strategy (ECRTS)** undertook a *qualitative assessment* of vulnerability. As part of this qualitative assessment, the significance of the primary climate drivers, temperature and precipitation, and their related variables, was assessed in terms of impacts on infrastructure design, operations and construction (Ministry of Transport, 2018). In the following sections, the effects on the climate change vulnerability of existing and new road infrastructure, drawn from the recent **Climate Resilient Transport Strategy**, are described.

2.5.1 Impact on existing infrastructure (Ministry of Transport, 2018)

Roads are critical for the transport network of Ethiopia, as the bulk of transport and access is achieved through roads. Impact brought about by climate change can have significant impact on the economy and livelihoods of citizens. Earthworks and drainage are considered the areas where road assets are mostly affected. Considering different components of road infrastructure the following are relevant:

Road embankments are vulnerable to wash-away or landslides from either surface water runoff or from overflowing streams or rivers, as the high flows can scour and destabilize them... With regard to drainage elements, the increase in the intensity of extreme rainfall could place greater demands on their capacity at local level, intensifying the reservoir effect of some embankments or, combined with the concentration effect of many cross-drainage elements of roads, increase downstream erosion caused by water flows. A reduction in average precipitation, coupled with drier soils and less runoff will decrease soil moisture, resulting in a decline of slides in slopes adjacent to roads and highways. It also would mean less settling under pavements, with a decrease in cracking and undermining of road and pavement base courses.

More intense extreme rainfall and flash floods are the main risks for bridges and protective structures. The rise in rainfall intensity could lead to an increase in local episodes of erosion at piles, abutments and retaining walls, and have an impact on piers due to debris deposits. Increases in extreme heat also have significant impacts. Maintenance and construction costs for roads and bridges are likely to increase as temperatures increases. It is likely that higher temperatures will cause some pavement materials to degrade faster, requiring earlier replacement. Maintenance and replacement costs will likely grow as the number of days above 30ºC increases and as the projected maximum record temperatures increase.

2.5.2 Impact on new infrastructure (Ministry of Transport, 2018)

The impacts that will have the greatest effect on the design of new roads relate primarily to slopes with an expected increase in local damages. The main triggers will be the rise in intensity of short, extreme rainfall and more severe flash floods. These could affect the stability of slopes due to

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[6] In 2010 a World Bank study quantified climate change costs.

surface runoff and increased erosion. More severe flash floods may affect the stability of the slopes at bridge abutments and undermine their pile foundations, protection elements and drainage infrastructure.

- *Road surfaces:* The greater regularity of very hot days will lead to a greater need for maintenance of roads and asphalt pavements (although some paving materials may handle temperature extremes better than others) due to degradation in materials. Concrete road surfaces can also fail due to the expansion joints closing, which in certain cases can cause the slabs of concrete to lift up, and the road to be closed. The rise in maximum temperatures could lead to an increased risk of non-structural ruts and cracks due to the premature oxidation of the binder. A decline in the average annual precipitation could preclude the use of porous asphalt over a larger area of the country

- *Design temperature:* The designs of steel and concrete bridges in Ethiopia are based on a maximum design temperature of 35ºC to 50ºC. In some countries, the maximum design temperature for bridges and pavements is 46ºC to 53ºC. It would be prudent to review the design standards and ensure that the projected increase in temperatures is smaller than these values and to ensure that joints in steel and concrete bridge superstructures and concrete road surfaces can adequately accommodate thermal expansion resulting from these projected temperatures. Consideration should be given to designing for higher maximum temperatures in both replacement and new construction.

- *Bridges:* Bridge foundations across the road network are vulnerable to scouring from increased levels of rainfall and higher river flows that can lead to instability of the structure and in extreme cases, to failure and collapse. Those bridges on the road network not founded on piles are most vulnerable to scour. In addition, road bridges longer than 60 m are typically designed with expansion joints. If the maximum temperature exceeds the design temperature, these joints may fail as the expanding bridge decks could cause the joints to be compressed beyond their design parameters. This could cause further damage to the bridge, usually resulting in road closures. Severance of access for communities due to bridge failures can lead to major disruptions, even on local roads. The age of the majority of the bridges on the road network poses a unique opportunity for systematic improvements.

- *Road geometry:* In terms of the road geometry, a rise in the intensity of extreme precipitation may lead to an increasing number of locations where the drainage capacity of the road surface is insufficient, requiring a review of the design of the carriageway's drainage conditions, such as the transition of the super-elevation.

- *Drainage:* The rise in the intensity of extreme precipitation could lead to an increase in the number of locations where the drainage capacity of the road surface or bridge drainage systems is insufficient, resulting in aquaplaning problems or the accumulation of stones that fall onto the road from the hillsides and cut slopes. The intensity of the rainfall can also lead to high rates of runoff that overwhelms the road drainage system, resulting in ponding.

Table 3 provides a scoring on the vulnerability of the various road infrastructure components. Definitions of low, medium and high impact are based on the impact on infrastructure functionality and the likely geographic scale of the impact.

- *Low:* Do not anticipate any loss of function of the infrastructure/no disruption in functionality from expected impacts.
- *Medium:* An impact is expected but is only associated with a disruption of service for a short period on a local basis, OR, there will be an impact but there are certain uncertainties that require additional work to be done.
- *High*: There is a risk of significant impact at a national scale or severe functionality disruption/failure.

Table 3: Road vulnerability matrix (rainfall and temperature to 2030)

Infrastructure		Rainfall	Temperature
Pavements	**Technical risks**	**Low**	**Medium**
	Operational risks	**Low**	**Medium**
Structures	**Technical risks**	**High**	**Medium**
	Operational risks	**High**	**Medium**
Drainage	**Technical risks**	**High**	**Low**
	Operational risks	**High**	**Low**
Earthworks	**Technical risks**	**High**	**Medium**
	Operational risks	**High**	**Low**

Source: Modified from ECRTS by author (Ministry of Transport, 2018)

Assessment of road locations against areas of known exposure to wildfire, flooding and precipitation driven landslides show that the entire asset base is at medium–high risk. While road design standards have been reviewed recently, there is an urgent need to review them once again against known climate parameters and assess the potential impact on both existing roads and the design of new roads. In addition, given that 38% of the bridges are more than 30 years old and 26% are more than 60 years old and are getting towards the end of their design life, their urgent redesign with more stringent criteria is needed.

2.6 Cost of climate change on roads

The road network is impacted by climate change in two areas, namely standard maintenance and flood-induced maintenance. The former represents costs that are incurred due to precipitation and/or temperature changes that occur during the life span of the road. The latter represents changes in extreme events and the costs associated with repairing the roads affected. A contributing factor to the cost of climate change on the road network is the fact that only 14.4% of Ethiopia's road system is paved (ERA, 2016). Both the paved and the unpaved roads are vulnerable to an increase in rainfall and temperatures, resulting in washed-out roads or damaged road surfaces (Environmental Protection Authority, 2011).A number of studies has been done to estimate the cost of climate change on the Ethiopian road network.

The World Bank estimated that maintenance on paved roads, directly attributable to climate change, ranges from $ 15 million to $ 31 million per year, depending on the climate model used. These numbers are on the lower bound of what may be expected due to assumptions that (1) regular maintenance are done; (2) the effects do not include flooding damage; and (3) adaptation to paved roads is completed when roads are repaved. If any of these assumptions fails to materialize the costs are likely to be between $ 270 and $370 million annually (World Bank, 2010a).

The World Bank (2010b) also reported that the greatest adaptation costs for the road sector arise from adaptation to flooding. Combined, the average annual adaptation costs for both maintenance and flooding are in the range of $ 80 million to $ 90 million. However, the costs of proactive adaptation is about 20% of the costs that would be incurred if no adaptation is put in place and a reactive approach only is followed.

The EPA (2011) reported that recovery and maintenance costs may escalate with climate change, with estimates ranging from $ 10 million to $ 21 million, depending on the climate model used (EPA, 2011). In addition to the direct economic costs related to road damage, indirect costs are also incurred through disruption in the transportation system and its related sectors, such as agriculture and industry, ultimately affecting communities that become disconnected and face food insecurity and the disruption of basic services.

Robinson *et al*. (2013) estimated that the cost of maintenance on paved (sealed) roads directly attributable to climate change ranges from $ 5 million to $ 13 million per year depending on the chosen climate change model, and for unpaved (unsealed) roads the comparable figures are $ 2 million to $ 14 million. However, the costs arising from repairs due to more severe and frequent flood events range from $ 250 million to $ 340 million per annum.

2.7 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.

3 Risk and Vulnerability Assessment of Roads at District Level in Ethiopia

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 Ethiopian 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 13, as 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 Ethiopia. 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 13 consist of exporting results into the national 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 13) 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). Ethiopia is currently focusing on network expansion and is spending less than half of the $ 200 – 280 million (2.5-3.5% of the total existing asset value of the 150,000 km road network) estimated as a requirement for yearly maintenance by the Road Fund (World Bank, 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. For the Ethiopian case study, however, road condition data were not available at the time of undertaking the assessment. 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).

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[7] (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,

Table 4 outlines the possible data used to perform a district-level risk and vulnerability analysis, together with suggested national authorities in Ethiopia who should be responsible for capturing and maintaining specific custodian data. It is recommended that national scale GIS datasets sourced from national departmental authorities be used as a first priority. Data were obtained from some of the national authorities in Ethiopia, but the quality of the data varied and as such it could not be used in its current form for the district-level assessment. Therefore, open source data repositories were used as a second choice. Country specific custodian data from Ethiopia can be sourced from the following places:

- National departmental authorities (e.g. National Disaster Risk Management Commission (NDRMC), Ethiopia National Meteorological Agency);
- Road asset management systems (Ethiopian Roads Agency);
- Country wide SDI (if implemented);
- Country specific assessment reports, including by development partners such as The World Bank;
- Previous studies; and
- Commercial data vendors.

[7] https://www.nature.org

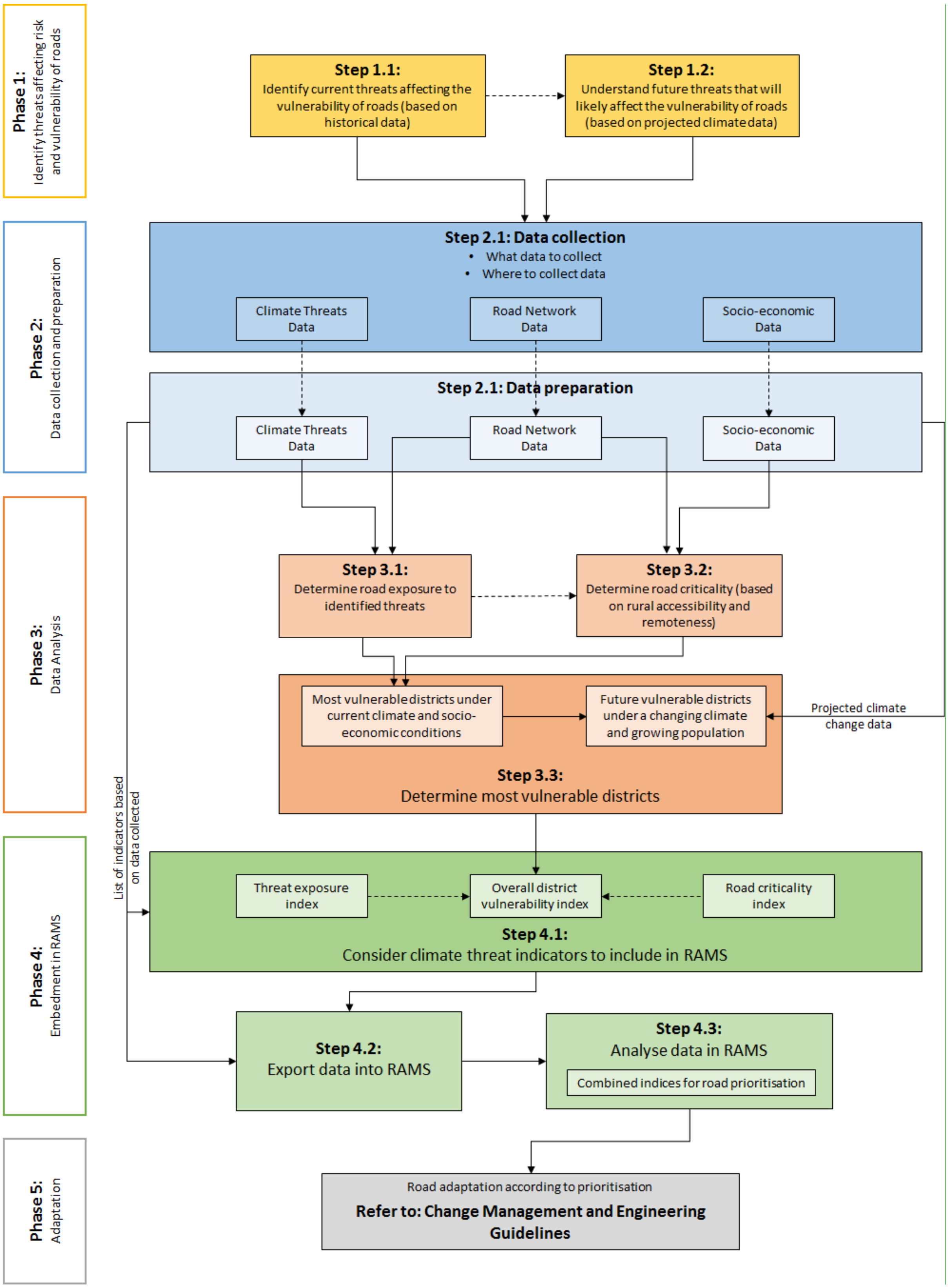

Figure 13: Framework for the rural access road risk and vulnerability assessment

Source: Le Roux *et al*. (2018)

Table 4: Suggested data required to perform a district-level risk and vulnerability analysis and possible data sources

Methodology	Data Type	Possible national authorities (country specific)	Open source data repositories / Additional data sources
Road network	National road network	– Ministry of Roads and Highways – National road asset management system	– Diva-GIS
Climate Threat	Historical climate data (National Scale)	– National Disaster Risk Management Commission (NDRMC) – Ethiopia National Meteorological Agency	– EM-DAT – ERA-Interim – CRUTEMP4v
	Specific hazard data for main identified climate threats (e.g. Flood history) (District Scale)	– National Disaster Risk Management Commission (NDRMC) – Ethiopia National Meteorological Agency – Environmental Protection Authority	– Dartmouth Flood Observatory
	Projected climate change data (Resolution as fine as possible e.g. 8km resolution)	– Ethiopia National Meteorological Agency	– ACCESS1-0 – CNRM-CM5
Socio-Economic	Population data	– National Statistical Office – Central Statistical Agency of Ethiopia	– WorldPop
	Settlements, towns and main cities	– Geological Survey of Ethiopia	– Diva-GIS
	Population projections	– National Statistical Office – Central Statistical Agency of Ethiopia	– UN ESA
Analysis Supporting Data	District boundaries	– Geological Survey of Ethiopia – Ethiopian Mapping Agency	– Diva-GIS
	Satellite images	– Ethiopian space agency – Ethiopian Mapping Agency	– Landsat (USGS EROS) – ESRI basemaps

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 Climate hazards

Flooding and droughts are the most frequent weather-related hazards, posing significant risks to rural communities, infrastructure and rural accessibility in Ethiopia (Table 5). Droughts have been particularly devastating with respect to the loss of lives and livelihoods. Thirteen drought disasters in the past four decades resulted in the death of over 300 000 people and affected almost 71 million people. Floods, in the form of flash floods in the highland areas and riverine floods in the lowlands, are the most frequent climate hazard that the country has to deal with, and the hazard most damaging to road infrastructure and rural accessibility. Fifty-six flooding disasters affected almost 3.1 million people, displaced nearly 200 000 and killed an estimated 2 500 people between 1977 and 2017. Flood disasters are occurring at increasing frequency and greater intensity across the country (Figure 14) due to increased vulnerabilities imposed by high rates of deforestation, land degradation, increasing climate variability, and settlement patterns (GFDRR, 2011).

There are several climate hazards that can be considered, but given the focus on rural access roads (typically gravel or earth roads), the climatology and the most frequent hazards in targeted countries, focus is narrowed to hazards caused by rainfall and temperature anomalies, namely floods and very hot days.

Table 5: Hazard frequency and impact in Ethiopia (1977–2017)

Source: Arnold et al. (2018), using EM-DAT (CRED, 2018) data

Hazard	Number of events (1977–2017)	Total deaths	Total affected
Drought	13	300 367	70 941 879
Riverine flood	32	1 105	1 809 978
Flash flood	8	863	929 358
Other flood	16	564	352 788
Wild fire	1	-	5
Landslide	3	39	194
Total	**73**	**302 938**	**74 034 202**

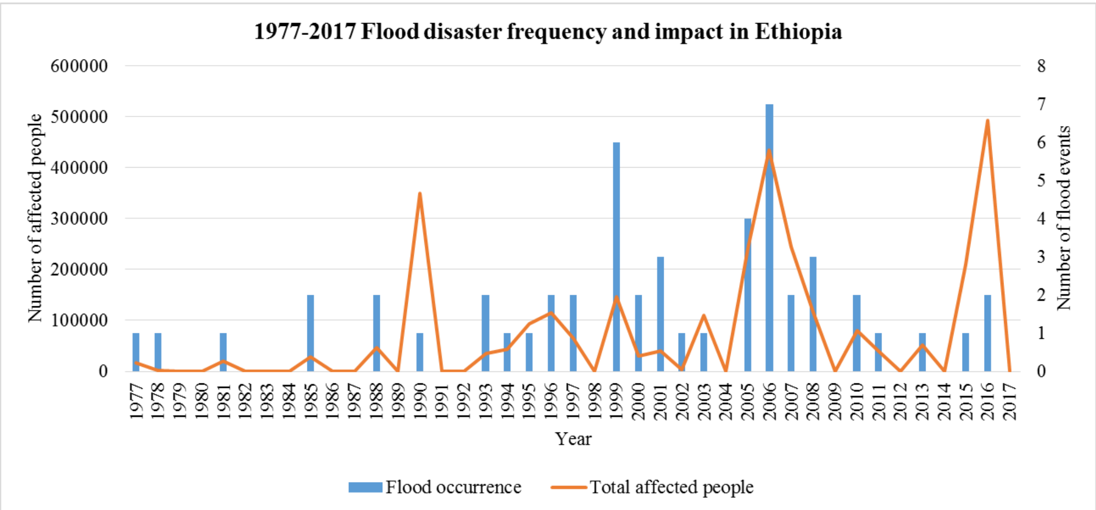

Figure 14: Flood disaster frequency and impact in Ethiopia between 1977 and 2017

Source: Arnold *et al*. (2018), using data from EM-DAT (CRED, 2018)

3.4 Flood exposure assessment

Flooding is the most frequent and damaging hazard from the perspective of rural road infrastructure. To quantify the frequency of a flood exposure index was developed and the output of the flood exposure index for Ethiopia is illustrated in Figure 15. Largescale floods occur mostly in the lowland areas, including the Awash River Basin which forms part of the Rift Valley, and the southern Somali lowlands (specifically in the Shabelle district, the namesake of the river that runs through the district and neighbouring Afder district bounded by the Genale River). Flash floods resulting from intense rainfall events over highland water catchment areas destroy settlements and infrastructure downstream. A number of internationally important watersheds originate from the flat-topped hills of the Ethiopian highlands, including the Awash River in the Rift Valley; the Shebelle River in the Somali region; the Omo River in the south; and the Blue Nile, which arises near Lake Tana in the highlands and later flows into Sudan and Egypt (Arnold *et al*., 2018).

The majority of the roads in these flood-prone areas are dry-weather roads (Figure 15) that cannot be used effectively during the rainy season due to poor conditions and inadequate river crossings, making communities that depend on these roads for access to marketplaces and services highly vulnerable to floods and heavy rainfall.

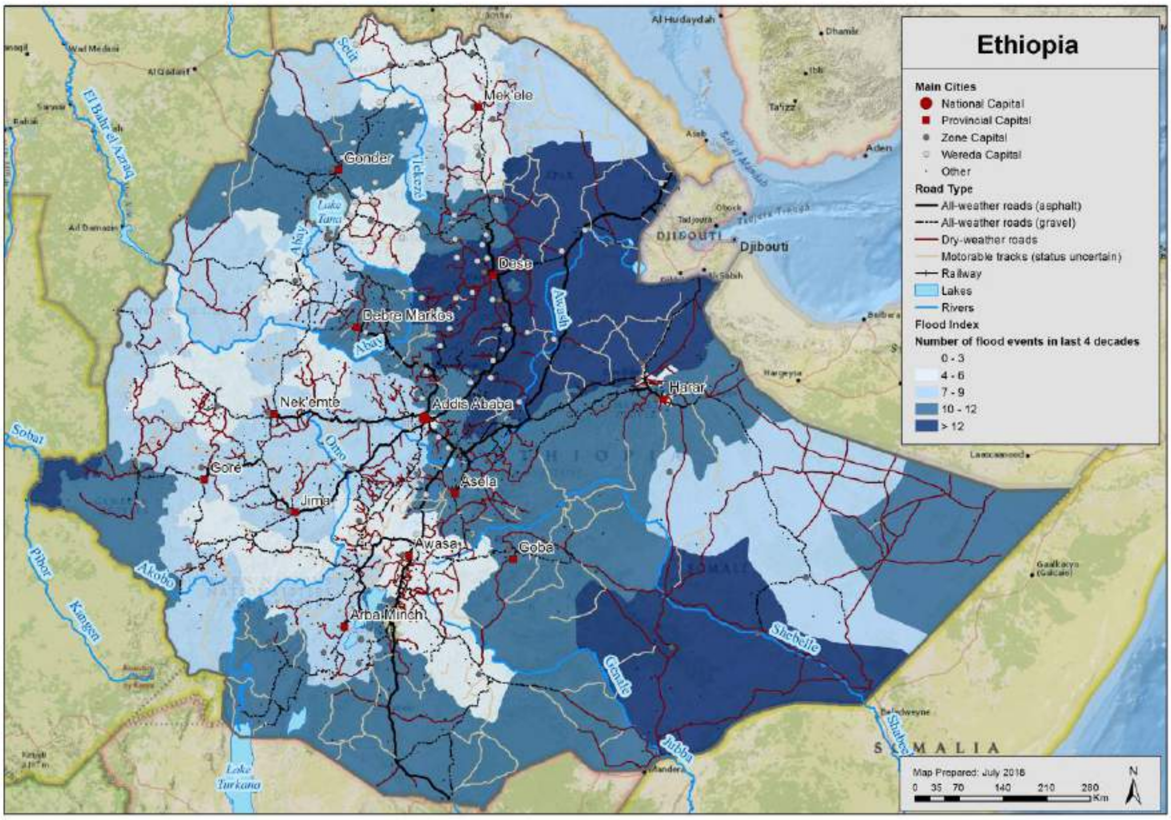

Figure 15: Ethiopia's most flood-affected areas over the past four decades and location of dry-weather roads in flood-prone areas

Source: Arnold *et al*. (2018), using flood data from Dartmouth Flood Observatory (2017)

3.5 Road asset criticality

The Rural Access Index (RAI) calculated for Ethiopia is depicted in Figure 16. The index considers people within 2 km of an all-weather access road. The most notable characteristic of the Ethiopian road network is that most all-weather roads radiate outwards from Addis Ababa (the capital) to major towns (Figure 15). Rural roads play a vital role in connecting isolated rural communities with economic centres, markets and basic social services, but the Ethiopian Roads Authority has acknowledged that the limited coverage of the existing road network, coupled with poor surface conditions in many instances, is a major obstacle to economic recovery and economic growth, especially in times of climate-related crisis. In this way, large parts of the country are faced with inadequate road access, where only eight of Ethiopia's 74 districts have an RAI of 50% or higher, and only three of these districts have an RAI of more than 70%. These districts are located on the central highlands of the country. The east of the country, especially districts in the Somali province that borders Somalia, have the poorest rural access nationally. Here more than half for the districts have an RAI of less than 15% (i.e. less than 15% of the population in these districts live within 2 km of an all-weather access road) (Arnold *et al*., 2018).

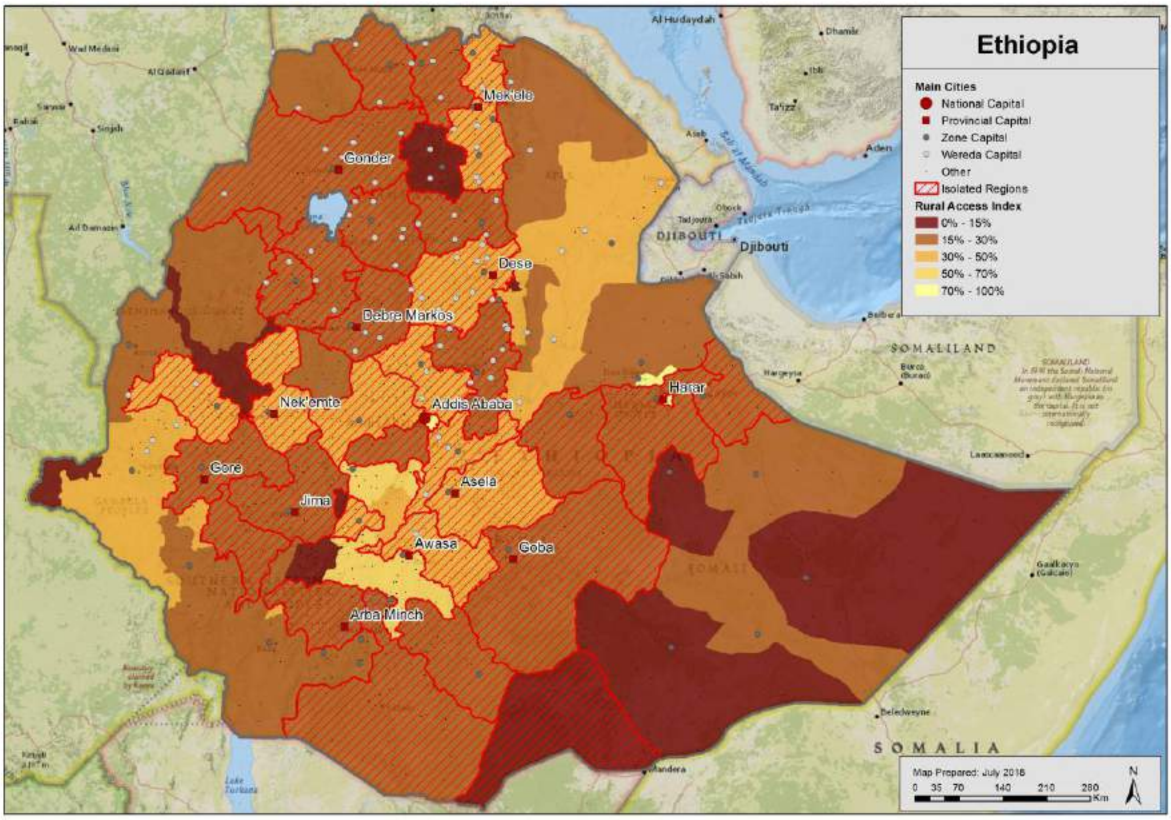

Figure 16: Rural Access Index and isolated regions calculated for Ethiopia
Source: Arnold *et al*. **(**2018**),** using population data from WorldPop (2017)

3.6 Highly vulnerable regions to climate impacts on road infrastructure

3.6.1 Most vulnerable districts under current climate and socio-economic condition

Almost 84% of districts in Ethiopia are classified as vulnerable (62 districts) to the impacts of climate due to their high exposure to frequent and severe flooding as well as their low rural accessibility and high isolation rates, with 46% being highly or very highly vulnerable (Figure 17). Areas depicted in red and orange in Figure 17 indicate high vulnerability given their exposure to frequent and severe flooding (flood exposure) as well as districts where road criticality is key due to high isolation. The index gives preference to districts where larger amounts of people are without adequate access to a road network. The most vulnerable districts are in the eastern half of the country, located in and along the ridge of the Awash River Basin, in particular in the North Shew district to the east of Addis Ababa. The majority of districts in the southern Somali lowlands of the Somali Province are also highly vulnerable in terms of climate impacts of road infrastructure, including the Liden and Afder districts that are classified as very highly vulnerable. The Nuer district in the far western corner of the country is also very highly vulnerable given its exceptionally low RAI and proximity to the Pibor River that forms the border with South Sudan (Arnold *et al*., 2018).

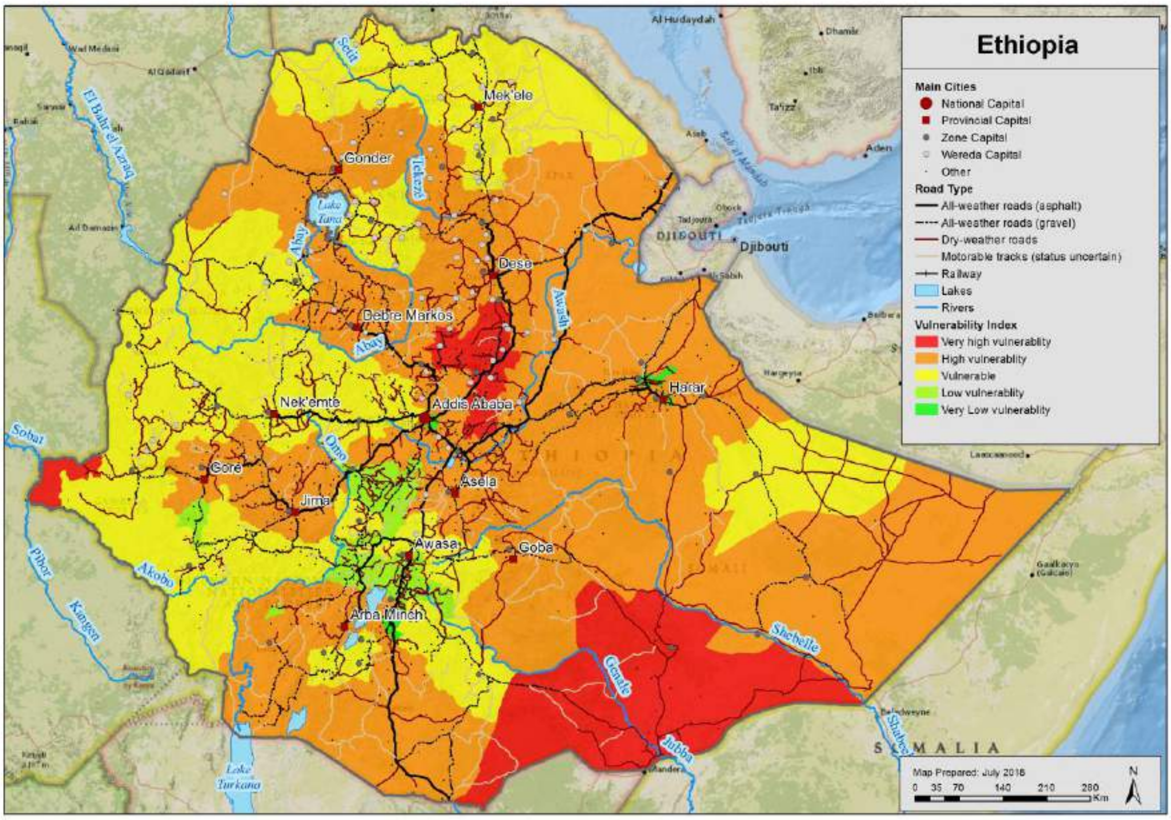

Figure 17: Ethiopia's most vulnerable districts in terms of flood exposure and road criticality

Source: Arnold *et al*. **(**2018**)**

3.6.2 Future vulnerable districts to the impacts of climate change and population growth

The CNRM-CM5 downscaling was used to map the annual number of extreme rainfall days (number of events per grid point per year) over Ethiopia, together with the highly and very highly vulnerable zones as an example of the risks that extreme rainfall events may plausibly pose to Ethiopia

(Figure 18). The annual number of extreme rainfall days, where an extreme rainfall event refers to more than 20 mm of rainfall in 24 hours is projected to substantially increase along the ridge of the Afar depression and the bounding Ethiopian plateau and escarpment. The already highly vulnerable communities around the Awash River Basin and Rift Valley may be affected most by such increases in extreme rainfall events (Arnold *et al.*, 2018). An increase in extreme rainfall events may be associated with increases in the likelihood of flash flooding.

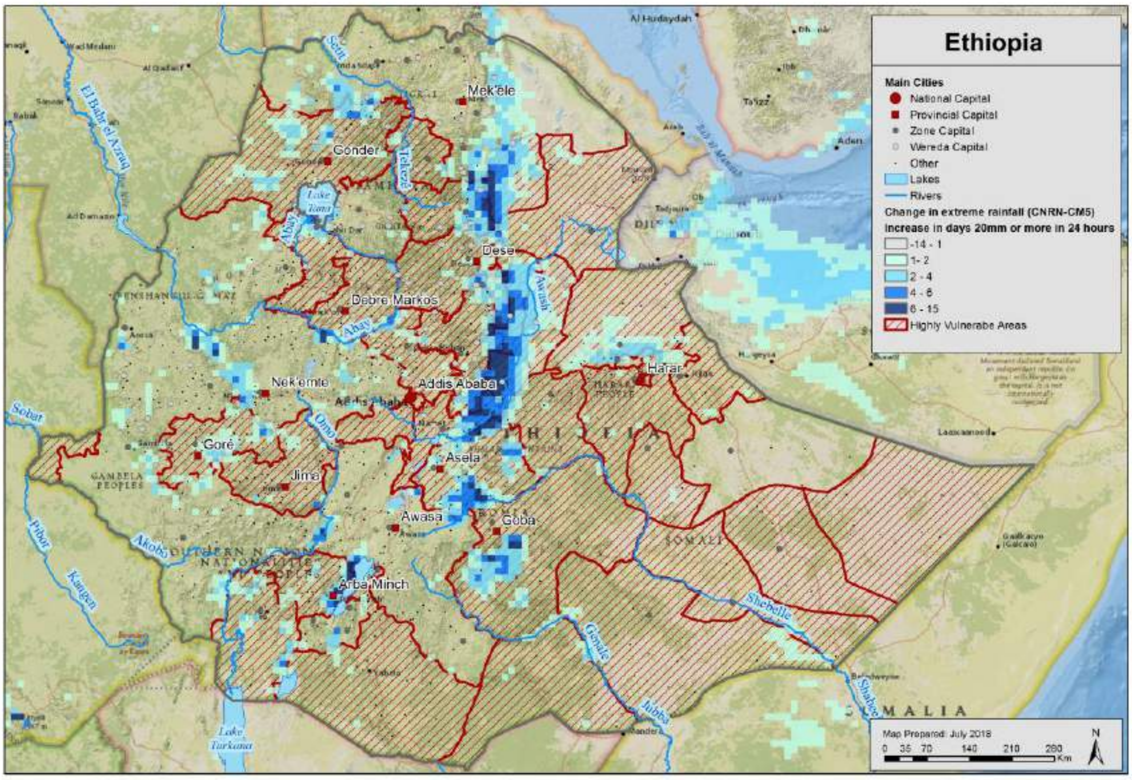

Figure 18: Exposure of Ethiopia's vulnerable communities to increases in extreme rainfall events
Source: Arnold *et al*. **(**2018**)**

The climate projections from the CNRM-CM5 downscaling indicate that the frequency of occurrence of days where the maximum temperature exceeds 35 °C will increase throughout the lowland areas of Ethiopia (Figure 19). The largest increases are projected for the lowlands bordering Somalia towards the southeast corner of the country where infrastructure is almost exclusively dry-weather road or gravel. Moderate increases will also be noticeable in the Afar Triangle. The projections are for the period 2021-2050 relative to 1971-2000 under a low mitigation (RCP8.5) scenario (Arnold *et al.*, 2018).

For unpaved roads, these expected changes in the number of extremely high temperature days need to be taken into account in terms of loss of soil moisture which has secondary effects, including increased susceptibility of the road environment to erosion. Possible problems and damage to road infrastructure include more rapid drying out of roads, increased susceptibility to cracking and roughness and quicker generation of loose material. For paved roads, the softening of bitumen, the increase in the loss of volatiles and concrete expansion are also critical considerations.

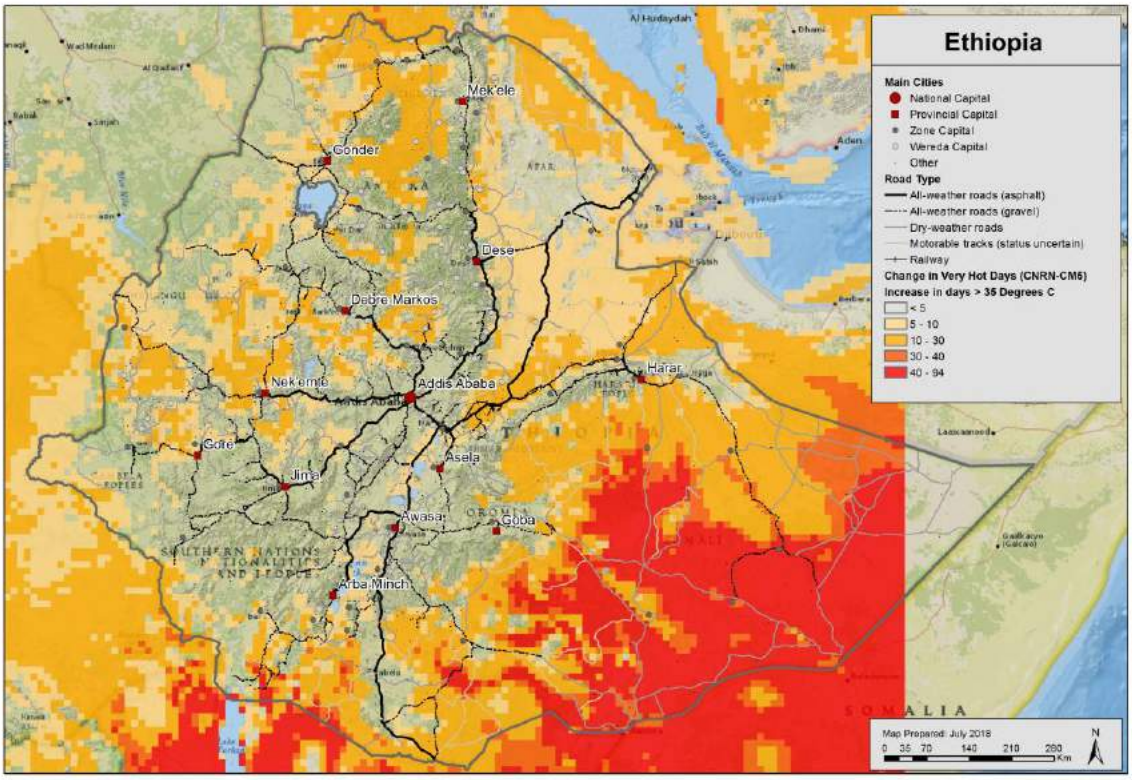

Figure 19: Exposure of Ethiopia's road network to increases in the number of very hot days (heatwaves)

Source: Arnold *et al*. (2018)

4 Change Management Options for Adaptation

4.1 Overview of the Policy Environment

Ethiopia has established a number of policies to deal with climate change, however there is a strong focus on mitigation (see Figure 20). The country is a signatory of the UN framework on climate change as well as other conventions dealing with climate change. Under these commitments the country has undertaken a number of actions. The National Meteorology Agency drafted and submitted a plan, the National Adaptation Programme of Action that describes the country's vulnerabilities and most urgent needs to adapt to climate change. This was updated and replaced by the Ethiopian Adaptation Programme of Action to Climate Change (EPACC) which aims to mainstream climate change throughout government sectors by ensuring climate change is embedded within government policies and plans through Sectoral Climate Programmes and Action Plans. EPACC is closely linked with the Climate Resilient Green Economy (CRGE) Strategy. The CRGE is a strategy to build a green economy and to avoid a development path that results in a sharp increase in GHG emissions and unsustainable use of natural resources. This Strategy still forms the core of the countries climate change drive. To achieve the CRGE goals, the plans and programmes of all ministries should be guides by the CRGE. To improve Ethiopia's economy and to achieve the CGRE, the Growth and Transformation Plan (GTP) states that physical infrastructure has to be improved. This includes the provision of rural access roads required by communities to access service- and market towns as well as social facilities. Supporting ministries with scientific data and informing plans, is the Ethiopian Panel on Climate Change (EPCC), an interdisciplinary body established in 2014 and administered by the Ethiopian Academy of Sciences and the Horn of Africa Regional Environment Centre and Network. The EPCC is tasked to produce periodic assessments of climate change issues in Ethiopia. It is a sub-project of the "Environment Service and Climate Change Analyses Program (ESACCCAP)" jointly run by the Ethiopian Academy of Sciences, the Climate Science Centre (CSC) and the Horn of Africa Regional Environment Centre and Network (HoA-REC&N) of Addis Ababa University, with financial support from the Department for International Development (DFID) UK, the Danish Government and the Norwegian Government through the Strategic Climate Institutions Programme (SCIP).

Other programmes that have been put in place to enhance the adaptive capacity and reduce the vulnerability of the country to climate variability and change include the *Sustainable Development and Poverty Reduction Program (2002–05*); the *Plan for Accelerated and Sustainable Development to End Poverty* (PASDEP, 2005-10); the *Environmental Policy of Ethiopia (1997)*, and the *Agriculture and Rural Development Policy and Strategy*. Improved economic growth has been noted as a result of these policies, strategies and programs.

The Ministry of Finance and Economic Development is currently implementing the third phase of its Growth and Transformation Plan (GTP III) which runs from 2019/20 which aims to continue improvements in physical infrastructure through public investment projects. Parallel to the GTP, in 2010 Ethiopia released the Environmental Management Programme of the Plan for Accelerated Sustainable Development to Eradicate Poverty: 2011–15 (Environmental Protection Authority, 2010a). Among its goals was enhancement of national, subnational, and sectoral capacity to mainstream actions that will build a carbon neutral and climate resilient economy. To achieve this goal, the plan seeks harmonization of all national policies, strategies, laws, programs, and governmental documents, to the extent possible, with efforts to address climate change adaptation and mitigation (Environmental Protection Authority, 2010b).

The majority of national and international programming efforts concentrate on the agricultural sector, including pastoralism, as well as disaster risk management and capacity building for government officials and civil society. However, there are gaps in adaptation action addressing vulnerabilities in specific sectors, notably transportation and roads. The policies relating to adaptation of roads and transportation is generally either superficial or absent. This is especially of concern when considering Ethiopia's drive towards constructing roads. Development Partners have recognised the need to create more resilience within the road network and in new or upgraded infrastructure and are currently very proactive in their adaptation policy and strategy. This however is mostly focussed on projects. There are also gaps between the environmental commitments made and the actual implementation to improve environmental outcomes,

Policy development has aimed to reduce vulnerability and improve the wellbeing of Ethiopians 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. Although policies exist, the challenge remains in their implementation, while weak capacity in environmental management and enforcement is a key challenge. Due to poor coordination between sectors and limited capacity for mainstreaming, including climate adaptation in planning and budgeting documents coupled with 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.

In the following section some of the policies, strategies and programs, which have been put in place with the aim to enhance the adaptive capacity and reduce the vulnerability of the country to climate variability and change, are discussed. Improved economic growth has been noted as a result of these policies, strategies and programs.

4.2 Ethiopian policies, strategies and programmes to deal with climate change

4.2.1 The Environmental Policy of Ethiopia, 1997

The Environmental Policy of Ethiopia was approved in 1997 and is the first key document that captured environmental sustainable development principles. Environmental Impact Assessment (EIA) policies are included in the cross-sectoral environmental policies. The EIA policies emphasis the early recognition of environmental issues in project planning, public participation, mitigation and environmental management, and capacity building at all levels of administration.

The policy also establishes the authority of the then Environmental Protection Agency (EPA) to harmonize Sectoral Development Plans and to implement an environmental management program for the country. It also imparts political and popular support to the sustainable use of natural, human-made and cultural resources at the federal, regional, zonal, Woreda and community levels.

Figure 20: Key policies, strategies and programmes to deal with Climate Change

4.2.2 The Climate Resilient Green Economy (CRGE) Strategy, 2011

The GoE issued the Climate-Resilient Green Economy (CRGE) strategy in 2011 to protect the country from the adverse effects of climate change and to build a green economy that will help to realize its ambition of reaching middle income status before 2025. Since 2011, the CRGE has been widened to include associated climate resilient sectoral strategies, guidelines and checklists. The CRGE Strategy presents a vision for a low-carbon, resilient economy. As the severity and frequency of droughts continue to increase, building resilient and expanding market access for farmers is critical to strengthen agricultural and rural livelihoods for the bottom 40% of the population. While risks arise from volatility in seasonal rainfall, recent gains in sustainable land management practices have helped to minimise the countries vulnerability to climate shocks. The future of managing these climate shocks will be rooted in national programs and line ministries as they build their capacity to respond to longer term needs as well as acute events (World Bank, 2017b).

The core of the CRGE Strategy is made up of a set of sectoral climate change strategies. These detail the specifics of Ethiopia's climate change response. These sectoral strategies will be based on a systematic assessment of the implications of actions on climate change – both on resilience and on green growth – for specific sectors. The drafting of Sectoral Climate Change Strategies (SCCSs) is led by the technical sub committees, with support from the relevant line ministry and the Environmental Protection Authority. Transport is one of those committees. Following the SCCSs, the drafting of Regional Climate Change Strategies (RCCSs) is to be led by the relevant regional government. The EPA will also be responsible for harmonising across regional and sectoral action plans to ensure that they are mutually compatible. In the short-term, the CRGE Unit will draw on the expertise and capacity of key development partners. In the medium-term it will build up both its own capacity and capacity within other government departments to deal with climate change issues.

CRGE have developed an iterative model for climate adaptation that comprises the following key steps:

- **Planning:** Strategic and operational planning, including stakeholder consultation, mainstreaming climate resilience, identifying actions (programmes, policies etc.), and costing.
- **Implementation:** Activities and actions to counter climate change. For this to happen, financing, capacity building, and technology transfer are required.
- **Revision:** Using monitoring and evaluation systems, progress will be tracked and reported on. Verification systems will also be needed to meet international obligations.
- **Assessment:** Progress will also need periodic assessment, review of enabling environment, roles and responsibilities. This work will need to be supported by piloting/demonstration along with research and analysis. It will include dialogue with all stakeholders and the public.

The Ministry of Finance and Economic Development is currently implementing the third phase of its Growth and Transformation Plan (GTP III) which will commence from 2019/20 with the aim to continue improvements in physical infrastructure through public investment projects. Parallel to the GTP, in 2010 Ethiopia released the Environmental Management Programme of the Plan for Accelerated Sustainable Development to Eradicate Poverty: 2011–15 (Environmental Protection Authority, 2010a). Among its goals was enhancement of national, subnational, and sectoral capacity to mainstream actions that will build a carbon neutral and climate resilient economy. To achieve this goal, the plan seeks as far as possible the harmonization of all national policies, strategies, laws, programs, and governmental documents, with efforts to address climate change adaptation and mitigation (Environmental Protection Authority, 2010b).

4.2.3 National Adaptation Program of Action (NAPA)

Through the National Adaptation Program of Action (NAPA) process, twenty priority project ideas were identified to address the immediate climate change adaptation need of the country. These projects broadly focus on the areas of human and institutional capacity building; improving natural resource management; enhancing irrigation, agriculture and water harvesting; strengthening early warning systems; and awareness raising – areas that are quite relevant in improving a dry-lands livelihood system.

4.2.4 Ethiopian National Adaptation Plan, 2017

The latest Ethiopian National Adaptation Plan (NAP-ETH document 2017[8]) falls under the existing broad Climate-Resilient Green Economy (CRGE) strategy and provides a dedicated plan for climate change adaptation, a critical step towards a climate-resilient economy. Different tools and documents have been developed to support the implementation of the CRGE strategy, however to date these have primarily focused on the aspects of the strategy that relate to reducing greenhouse

[8] Not available.

gas emissions, with some attention to adaptation co-benefits. With the finalization of the NAP-ETH, there is an opportunity to strengthen these tools to better incorporate adaptation options that will build climate resilience in vulnerable sectors.

The GoE indicated that the fifteen-year NAP-ETH will cost about $ 6 billion annually and is intended to address climate change. NAP-ETH is expected to bring about transformational change in the country's capacity to address the adverse consequence of climate change. NAP-ETH focuses on agriculture, forestry, health, transport, power, industry, water, and urban sectors that are identified as most vulnerable. Within these sectors, 18 adaptation options have been identified for implementation at all level and across different development sectors. The NAP-ETH initiative is part of an action of mainstreaming climate change mitigation and adaptation into its national development plans, in particular into its Growth and Transformation Plan (GTP).

4.2.5 Ethiopia's Programme of Adaptation to Climate Change (EPACC)

EPACC is a programme of action to build a climate resilient economy through adaptation at sectoral, regional and local community levels. EPACC updates and replaces Ethiopia's National Adaptation Programme of Action (NAPA). The Environmental Protection Authority (EPA) has been mandated to co-ordinate national response to climate change through EPACC and emissions abatement initiatives, including the Nationally Appropriate Mitigation Actions (NAMAs) (CRGE Vision 2011). EPACC will help to put in place the local building blocks of adaptation and will be reinforced by action at the federal, regional and local levels. Climate action plans identify opportunities for mainstreaming climate change into sectoral and regional development strategies.

4.2.6 Ethiopia's Climate Resilient Transport Sector Strategy – 2018-2032

This Climate Resilient Transport Sector Strategy sets a 15 year framework for the GoE to deliver an integrated, modern transport system with a strong focus on multi modal transportation links and a customer service. The vision of this Strategy is to ensure that Ethiopia's national development, poverty reduction and climate resilience goals are promoted by the transport sector. This multi-pronged focus matches the direction set by the GoE in its national level strategies and provides the Ethiopian transport sector with a unified vision, mission and implementation plan. Underpinning the vision are the key principles of safety, sustainability, integration and affordability, consistent with the GoE's vision outlined in the Climate Resilient Green Economy Strategy and existing sectoral strategies and plans.

Although there is a strong focus on mitigation (reducing GHG), some critical adaptation issues are raised. Some of the relevant items raised include:

- Strengthening Transport planning (Objective 1), this includes the need to look at asset management systems;
- Storm water Management (Objective 3), measures to address storm water are highlighted to reduce their potential impact on transport infrastructure;
- The need to reduce social disadvantage (Objective 4) by ensuring good access roads. Also affect the planning process – the need to consider the social impacts; and
- Adopting new design standards, operation and maintenance practices considering climate projection scenarios.

One of the aspects raised in the strategy is that the prospect of climate change will increase the need for maintenance and rehabilitation for all types of roads and bridges, in virtually all climate contexts. A first key area of focus for transport sector authorities is therefore to incorporate climate change in road asset management, with a particular focus on institutionalizing regular road maintenance (Ministry of Transport, 2018). In addition, the strategy also proposed the creation of an interagency coordination unit within the Ministry of Transport that will also assist to coordinate the climate resilient activities.

4.2.7 The National Policy and Strategy on Disaster Risk Management, 2013

In 2013, the National Policy and Strategy on Disaster Risk Management was released. This policy and strategy seeks to increase Ethiopia's capacity to withstand disaster-related impacts and hazards as well as to significantly reduce the damage caused by disasters by 2023. A framework is presented for the establishment of a transparent and decentralized disaster risk management system that focuses on multi-hazard and multi-sectoral approaches, taking a both proactive and reactive approach (FDRE, 2013b). Climate variability and change are recognized as a risk, and the document notes that disaster risk management should contribute to environmental protection and climate change adaptation–related activities. The strategy reflects the importance of disaster risk profile information to indicate the vulnerability at local levels. It therefore reiterates the need to capture and apply such information to support disaster risk management. As part of the overall operationalisation of the strategy, it proposed assigning lead institutions to implement disaster risk management activities ranging from monitoring to response. This also required the lead institutions to prepare and implement disaster risk management plans and programmes. The lead institution, with respect to transport service related hazards and associated disasters, is the Ministry of Transport. The policy also sees climate change as a cross-cutting issue and views climate change adaptation activities as critical to reduce disaster risks and vulnerabilities.

4.3 Embedment of climate adaptation in national engineering manuals and guidelines

The road network in Ethiopia 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 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 are becoming increasingly important.

In 2002, the Ethiopian Roads Authority (ERA) first brought out road design manuals and standard technical specifications to provide a standardised approach for the design, construction and maintenance of roads in the country. Due to technological development and change, these manuals and specifications required periodic updating.

In 2013, by funding provided by DFID through the Africa Community Access Programme, all technical manuals as well as standards specifications for road and bridge works were updated and reviewed in close consultation with the federal and regional roads authorities and the stakeholders in the road sector including the contracting and consulting industry, and through thematic peer review panels established for such purposes.

The complete series of documents, covering all roads and bridges in Ethiopia, are contained within the prevailing versions of the following:

1. Geometric Design Manual
2. Site Investigation Manual
3. Geotechnical Design Manual
4. Route Selection Manual
5. Pavement Design Manual Volume I Flexible Pavements
6. Pavement Design Manual Volume II Rigid Pavements
7. Pavement Rehabilitation and Asphalt Overlay Design Manual
8. Drainage Design Manual
9. Bridge Design Manual
10. Low Volume Roads Design Manual
11. Standard Environmental Procedures Manual
12. Standard Technical Specifications and Methods of Measurement for Roadworks
13. Standard Detailed Drawings
14. Standard Bidding Documents for Road Work Contracts

Several of the Manuals refer to climate, and on how to deal with climate effects to sustain the network. For instance, in the section describing the purpose and scope of the Drainage Design Manual it is stated that: "The drainage design of roads is aimed at the protection of the road through the prevention of damage due to water to achieve a chosen level of service, without major rehabilitation, at the end of a selected design period. The design procedures take into account factors such as rainfall intensity, catchment areas, land use/land cover, topography, *climate change*, and run-off".

In the Policy and Planning chapter of this Manual, it acknowledges that "although flooding cannot be wholly prevented, its impacts can be avoided and reduced through good planning and management. *Climate change* over the next few decades is likely to mean increased wetter and dryer seasons within the various regions of Ethiopia. These factors will lead to increased and new risks of flooding within the lifetime of planned schemes." It also states that "the Government attaches great importance to the management of flood risk in the planning process, taking account of *climate change*", and hence "planning should facilitate and promote sustainable route alignments while addressing the impacts of *climate change*".

Design storm frequencies have been updated in the Manual to reflect the low maintenance practices in Ethiopia, *climate change* and uncertainties with future land use change; it was recommended that a 20% flow allowance for *climate change* should be added to the indicated design flows.

4.4 Change Management

The aim of Change Management is to manage adaptation more effectively. This involves consulting widely, proactively identifying the means of foreseeing and dealing with climate adaptation in a proactive way, making practical decisions based on data, selecting preferred options and then implementing in a collaborative way. In order to strengthen management to be more effective, a sustained training and development programme might be necessary.

In order to develop and enhance knowledge and capacity, the following should be considered:

- Developing and integrating climate adaptation content in formal and informal education programmes;
- Increasing general public awareness, and disseminating information pertaining to climate change– including:
    - Building integrated planning and budgeting capacity to include elements related to adaptation; and
    - Building capacity to guide the design and development of projects and programmes to include access to international climate funds.

4.5 Recommended integrated approach to incorporate climate change in the policy environment

Relevant stakeholders including Ministries, Departments, Authorities, institutions and research organisations should be consulted in order to start to participate in their programmes and also to understand how their policies can become more inclusive. Further, specific engagement of local communities, non-government organisations, and small to large businesses operating in the sector will be important for conducting a vulnerability assessment and for engagement in selecting the most effective adaptation strategies.

Recommended options for collaboration and cooperation are:

- Establish or enhance cross-ministerial committees for managing adaptation to climate change, including for transport;
- Strengthen departments of disaster risk management and meteorology to improve information on which to make decisions;
- Introduce early warning and response systems for transport ministries to improve maintenance schedules and to respond quickly to post-disaster recovery needs;
- Promote low-risk adaptation strategies that will have development benefits regardless of the nature of climate changes that may take place. This is a useful approach where uncertainty is high regarding climate change and capital investments cannot be justified for large-scale infrastructural changes; and
- Incorporate climate change adaptation into environmental impact assessments and strategic environmental assessment guidelines. This can take place specifically in the transport sector or, preferably, as part of the national standards. Road and transport ministries can test tools and adaptation approaches by applying strategic environmental assessments with climate change to their sector policies and plans.

Adjustments can also be made to environmental management plans by selecting more drought- and heat-tolerant indigenous species during post-construction rehabilitation works or during maintenance works.

It is recommended that an integrated implementation approach is adopted. For example, design and implement ecosystem-based adaptation strategies focusing on environmental or green planning for project roads to improve flood and drought management. Climate change resilient trees can be planted along embankments of all project roads with selected grass and biomaterials. Water harvesting (including storm water) is recommended where dry season water shortages are found.

Research and development priorities are:

- Create a 'Climate Adaptation Network' of multi-sectoral research teams;
- Design the National System to monitor and gather data on the effects of Climate, including the effects of adaptation measures and GHG activity data, emissions and other parameters;
- Use the results of studies for the design of public policies for improving people's well-being;
- Create systems for generating and sharing knowledge among and between the government, academia, the private sector and civil society;
- Adapt and enhance (academic and other) research institutions to deal with the environment in the context of adaptation; and
- Promote regional and international exchange.

At the national level, knowledge sharing on climate change related issues is facilitated by the Consortium for Climate Change Ethiopia, which was officially registered in June 2015 and was formerly called the Ethiopian Civil Society Network on Climate Change.

5 Actions for Implementation

Subsequent to the research work undertaken in the preceding period, 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 Ethiopia to address climate resilience. It must be noted that Ethiopia 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 roads- and related infrastructure), and as such the primary focus, as indicated in the diagram in Figure 21, is for embedment within the roads sector. It is however important to note that there is a strong linkage with the broader national climate change environment.

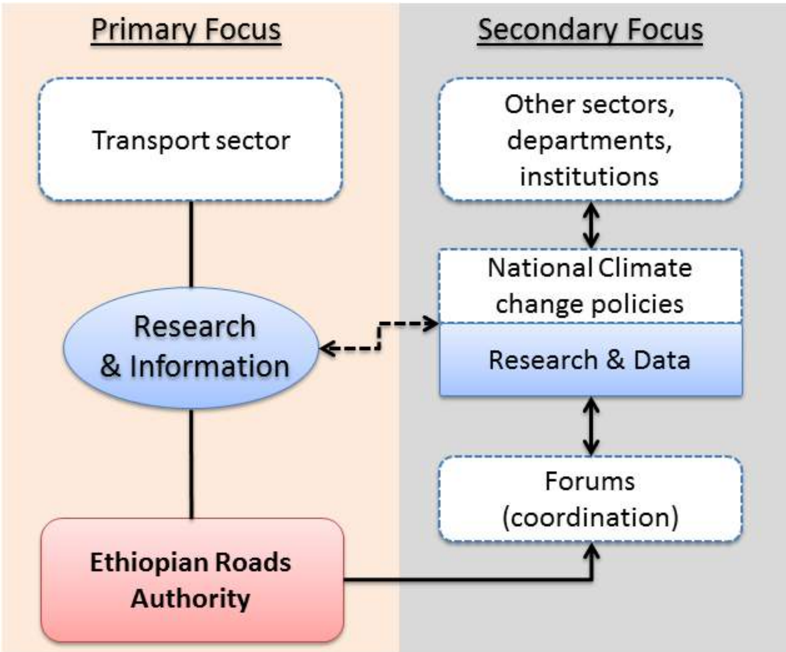

Figure 21: The dual focus of embedment

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 has been established as indicated previously to address climate change challenges in Ethiopia. These structures have to be utilised as best as possible to incorporate the challenges addressed in the roads sector. The following sections reflect on policies/strategies, collaboration, data and capacity issues.

Inclusion of climate adaptation in relevant planning and budgeting documents and the widespread recognition of adaptation as an important issue among public, private and civil society actors, has hitherto not resulted in effective adaptation and mitigation activities. Instead, independent actions have been sporadic and ineffective, despite the inclusion of mitigation and adaptation in policies and strategies of central and district-level government. The following actions are set out for discussion and agreement.

5.1 Policies and strategies

Since Ethiopia has committed to address Climate change issues, there have been various policies and strategies in transport sector. Initial strategies and plans did not adequately address the issues of climate change adaptation. The most recent strategy, namely the Climate Resilient Transport Strategy, has increased the scope and focus of climate change measures in the transport sector. This Strategy is envisioned as an overarching framework to guide the development of a series of subsequent and more detailed transport plans, policy decisions, reforms and funding decisions. This Strategy is not a detailed step-by-step plan for all transport initiatives. Rather, each agency, in line with their mandated responsibilities, will develop the appropriate detailed plans and strategies. This strategy makes reference to the following:

- Strengthening transport planning (objective 1) including asset management;
- Requires the review and update of design standards;
- It recognises the threat of flooding and importance to deal with storm water management to avoid damage to roads (objective 3);
- Acknowledges that social disadvantage be reduced through better access (objective 4);
- Seeks opportunities to reduce climate change vulnerability through both adaptive and reactive strategies; and
- Sees the importance to build an information base on vulnerabilities.

The main challenge is the practical implementation of policies and strategies. Projects undertaken funded by agencies such as the World Bank are already requiring the incorporation of climate risk, albeit at broad scale. In the roads sector in Ethiopia, a gap still exists in dealing with climate change. Roads adaptation needs to be incorporated in the policies within the roads sector and then reflect 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. Although the Climate Resilient Transport Strategy provides the overall intent, it is still dependant on Agencies such as ERA to implement ii. It is also important for ERA to incorporate climate change in its planning, operations and research. A starting point could be for ERA to have its own policy statement setting out the scope and purpose of climate adaptation for roads and associated assets. An output of such a strategy could also be to augment national design standards to incorporate climate adaptation.

Within an institution such as ERA, there needs to be a responsible department and person to lead implementation across the institution. Such a department can also lead cross-sectoral cooperation. Within the Ministry of Transport a new Inter-agency Coordination Directorate is proposed under the ECRTSS.

5.2 Collaboration within the wider Climate Change Environment stakeholders

A number of other sectors are already active in dealing with climate change adaptation. Several networks have been established to deal with information sharing, coordinating research and data. It would be beneficial to join such networks, especially to share or access the required climate change data. It is suggested that the following climate adaptation networks be joined or engaged with:

- The Climate Change Coordination section established by the Ministry of Environment, Forestry and Climate Change (responsible for CRGE);
- The Ethiopian Panel on Climate Change (EPCC);

- National Climate Adaptation Committee;
- The Environmental Protection Authority (EPA) Programme of Adaptation to Climate Change (EPACC), including the Nationally Appropriate Mitigation Actions (NAMAs) to develop Sector Development Plans for harmonisation;
- The CRGE ministerial committee technical working groups; and
- The EPA Transport Climate Change Sub-Committee.

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 ERA makes contact with the following entities with a view to collaborate:

- Ethiopia National Meteorological Agency (NMA);
- National Disaster Risk Management Commission (NDRMC) – it has an Early warning and Response Directorate; and
- The Ministry of Water Resources National Meteorological Agency: Climate Change National Adaptation Programme of Action (NAPA).

Additionally, the importance of climate change adaptation in the road sector needs to be promoted beyond Ethiopia, into 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 is 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 **Climate Resilient Green Economy** initiative did not reflect on data or the capacity to deal with climate change data directly. At the start of the CRGE, the lack of high quality recent data was acknowledged. It was also acknowledged that various institutions deal with climate data e.g. IHoAREC&N, the Academy of Sciences, NMA, and National Disaster Risk Management. This also means that the capacity to undertake climate science is distributed among several institutions. The implication is that no single institution is undertaking a coordination role. The implication for ERA is that it has to engage and deal with several institutions. The Ministry of Environment, Forestry and climate change might play a coordinating role – this is however unclear and needs to be confirmed.

The later **Climate Resilient Transport Sector Strategy** does however place emphasis on developing an information base on climate vulnerabilities. It is seen as critical in order to adopt concrete measures on the ground. It is also important to understand current and future vulnerability which also requires research. From this base and the research conducted, several outcomes can emerge, such as the development of guidance; identification of adaptation measures; review of standards; monitoring and contingency planning; and the scheduling of adaptation to coincide with asset renewal.

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. Ethiopia 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 thought the frequent updating of critical data 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 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 such as was provided through the AfCAP project. The following actions 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 **ERA**;
- Current climate trends and climate change projections should be recorded and analysed by the **national meteorological department**; and
- Socio-economic data and population trends should be captured by way of 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 Ethiopia's policy framework.

5.4 Asset Management Systems – state of readiness

ERA has an established Road Asset Management department, headed by a Deputy Director General. The RAM department includes four directorates. One of these is the Pavement and Bridge Directorate, which includes, inter alia, a PMS team and a BMS team. The RAM department also includes 10 Road Network Branch Directorates in different parts of the country which directly administer roads under their respective jurisdiction.

ERA has a Pavement Management System (PMS) and a Bridge Management System (BMS), but these systems only include the federal roads, which is ERA's responsibility. Regional, municipal and community roads are not included. The PMS and BMS are not integrated and do not currently make provision for climate related information. There is further no link between the PMS/BMS and the Planning and ICT Department's GIS road data set. An exchange of data between the systems can only be done through an MS Excel table.

The ERA is currently engaged in a project titled "The Development of a Modern Road Asset Management System". The project has been launched and is funded by the AfDB. The objectives of the project are to:

- Review the policies, system and structure of RAM;
- Prepare Road Asset Management Policy;
- Improve existing systems;
- Develop new required systems; and
- Integrate all the systems.

This project will also include the addition of GIS capability within the Road Asset Management Department.

The project for the development of a new RAMS for ERA presents an ideal opportunity to incorporate climate change issues in the RAMS. This could require some adjustments to the scope of work of the project. This would however only address the federal road network, while the regional and community roads are not managed by way of a RAMS. In terms of these lower order roads, Ethiopia 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 it 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 these challenges are not addressed, it creates impediments to determining appropriate responses in both the short and, in particular, the long term. The strengthening of these entities requires the following actions:

- Expanding and maintaining the climate change network, and setting standards for meteorological, hydrological, hydrometric, and agrometeorological data, as this would be of value to the transport sector when undertaking detailed local risk analysis;
- Creating an integrated information-management system (although this relates to the national situation. it is also applicable to ERA to ensure that data and analysis is captured in relevant systems where it is accessible to various users);
- Strengthening the mechanisms for standardizing equipment and databases;
- Strengthening institutions that perform systematic data observation, gathering and processing in order to feed GHG inventories and national communications. Where infrastructure data capturing is outsourced, there must be compliance to capture and provide it in standardised formats; and
- Where information is generated externally (example, regional climate models) then arrangements need to be made with such institutions in order to periodically source information (as and when required). Alternatively, such capability needs to be developed within the country or institution itself.

5.6 Agreed Actions

The abovementioned items reflect broadly on a range of issues that needs to be addressed at a country level (across government). It is however critical to achieve the AfCAP objectives that a particular emphasis be placed on the **roads sector** and by implication also on the institution responsible for the management of the country's road network (ERA). As the lead institution, ERA can then also be the institution that links with the other departments and forums to collaborate regarding climate adaptation research. During June 2018, a series of mini-workshops, technical sessions and engagements were held in Addis Ababa. A number of items were addressed and the actions as described in the following sections were agreed to.

5.6.1 AfCAP documents:

During the engagements, the importance of the AfCAP documents consisting of the Climate Adaptation Handbook and the associated three guidelines was emphasized. Printed and electronic versions of the handbook and the three guidelines were provided to ERA staff at the 2-day workshop. A request was made for users of these documents to give input and comments that could be used to finalise the documents before they are shared with other AfCAP member countries. Such inputs or comments were requested by mid-July 2018.

5.6.2 AfCAP Spatial information:

During the engagements, a session was held with the Mr Mohammed Abduraheman (Eng. Operations Department Deputy Director General). Given his interest, he requested a set of the information. The geospatial map package was successfully installed and tested on his computer. He was also taken through the contents and the accompanying documentation. The same set of information was also provided to ERA's GIS persons, Mr Hawi Adupmo and Mr Yosef Tamiro.

5.6.3 ERA Road Asset Management system and climate assessments:

The Road Asset Management Department currently operates several asset management systems, including a Pavement Management System and a Bridge Management System. These two systems do not currently include climate risk related information. ERA's asset management system is currently being improved with the assistance of AfDB funding, which provides the opportunity to deal with enhancement and the addition of information and functionality relating to climate change. An added limitation to dealing with asset management is that current strategies do not reflect climate change adaptation.

The AfCAP team emphasized that a key activity for ERA would be to link climate information to systems such as the pavement and bridge management systems. The spatial information currently available at district level could form the first round of information embedment. There is however also a further important need to include climate risk information at the local/road link level.

Currently ERA does not have a climate change adaptation (CCA) policy. In order to fully operationalise CCA in ERA, such a policy would firstly have to be adopted. Mr Alemayehu Ayele indicted that the starting point would be to incorporate a CCA strategy in the Asset Management Strategy Project currently being completed (expected completion date is the end of June 2018). He indicated that he would task the consultants currently dealing with the Asset Management Strategy Project to include CCA components in the strategy.

5.6.4 Contributing information to the wider climate adaptation environment

Climate change spatial data that has been generated from the AfCAP work in phase 1 (and expanded in phase 2), has been supplied to ERA (See Item 2) and is available for use by ERA (and other departments). A decision is however required as to the best place to house the data in ERA and the mechanism that could be used by ERA to make this climate change data available to other ministries and state agencies.

Regarding the hosting of the geospatial information at ERA, it was concluded that it would be best placed within the **Planning Department**. This is due to the fact that this department also need to look at environmental and social issues and would benefit from a range of (spatial) data categories (not limited to roads). According to Mr. Alemayehu Ayele it would then also be easier to access this information across the various departments within ERA. The current constraint is that ERA's GIS capacity is limited and it would need to be expanded[9]. This could also be addressed by partnering or linking with other institutions such as the Water and Land Resource Centre (Addis Ababa University) that have good GIS capability and that can also assist with training if required. As indicated in section 5.2, there are several institutions that ERA can establish connections with. These institutions are already active in climate change issues and are also capacitated to deal with geospatial information. They include:

- National Meteorology Agency;
- Ethiopian Mapping Agency; and
- The Water and Land resource Centre (Addis Ababa University).

The sharing of the geospatial information supplied by AfCAP with the wider climate change community could start with these institutions through possible collaboration.

5.6.5 Climate change responsible person

Currently there is no one person in ERA that carries the responsibility to deal with Climate Change. ERA will need to consider tasking someone to take up the responsibility (possibly someone in the planning department). Such a person would need to then deal with the issue across all departments of ERA and thus also play a coordinating role.

5.6.6 Incorporation of climate change adaptation in the new asset management strategy:

Policy issues also need to be addressed to enable embedment of climate change information in ERA activities and systems. As stated earlier, the starting point would be to include this in the new Asset Management Strategy for ERA currently being completed.

[9] Future phases of AfCAP project to expand capacity development can also be considered to assist with GIS analysis capacity development.

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