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: Ghana

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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 Ghana on the Management of Vulnerability and Adaptation to Climate Change using the principles and recommendations set out in the AFCAP Climate Adaptation Handbook and the relevant associated Guidelines.

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 or human-induced or 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.
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
AfDB	African Development Bank
ADB	Asian Development Bank
AfCAP	Africa Community Access Partnership
AsCAP	Asia Community Access Partnership
CRED	Centre for Research on the Epidemiology of Disasters
CSIR	Council for Scientific and Industrial Research
DFID	Department for International Development, UK
DFR	Department of Feeder Roads
DMC	Developing Member Country
EM-DAT	Emergency Events Database
GDP	Gross Domestic Product
GIS	Geographic Information System
GMet	Ghana Meteorological Services Agency
MCA	Multi-Criteria Analysis
MDA	Ministries, Departments, Agencies/Authorities
MDG	Millennium Development Goal
MESTI	Ministry of Environment, Science, Technology and Innovation
MoFEP	Ministry of Finance and Economic Planning
MRH	Ministry of Roads and Highways
NADMO	National Disaster Management Organization
NDPC	National Development Planning Commission
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
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, Verhaeghe, Paige-Green, Le Roux, Makhanya, & Arnold, 2018). It is supported by three separate Guideline documents covering the following:

- 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 Ghana, dealing with the issues of adaptation, incorporation of climate risk information into systems, and actions to put in place a policy that specifically deals with incorporating Climate Change Adaptation (CCA) into the Roads Agency of Ghana 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).

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 Ghana

Ghana is in a part of West Africa exposed to flooding, landslides and drought. Floods are particularly prevalent in the northern Savannah belt, with associated risks of landslides. Extreme rainfall events have increased over the 1986-1995 period, including a high number of 24-hour maximum rainfall events—a trend that has continued in the last decade. The recurrence of both floods and drought is becoming a common phenomenon, often associated with high temperatures and intense heat. Already affected by coastal erosion, especially along the eastern coastline, the coastal regions of Ghana are likely to be affected by further sea level rise and storm surges by the end of this century (UNDP, 2016).

Climate extremes amplify food security threats and can severely affect economic development. Insufficient rainfall during the major cropping season caused by the last major severe drought in 1982-1983, affected more than 12 million people. More recently, the 2007 catastrophic floods in northern Ghana occurred immediately after a period of drought and damaged the initial maize harvest. Current development dynamics and demographic changes in Ghana put more people at risk from disasters as a result of increasing rural poverty, rapid urbanization, growth of informal settlements, poor urban governance, and declining ecosystem and land conditions. With more than

60% of Ghana's 20 million people depending directly on agriculture, localized disasters are likely to have even greater accumulated impacts on rural livelihoods over time as a consequence of climate change. These impacts are likely to be more obvious in the north, where soil erosion is more pronounced and poverty among crop farmers is high. Overall, the impacts of climate risks are likely to magnify the uneven social and spatial distribution of risk in Ghana, and possibly amplify poverty in the north.

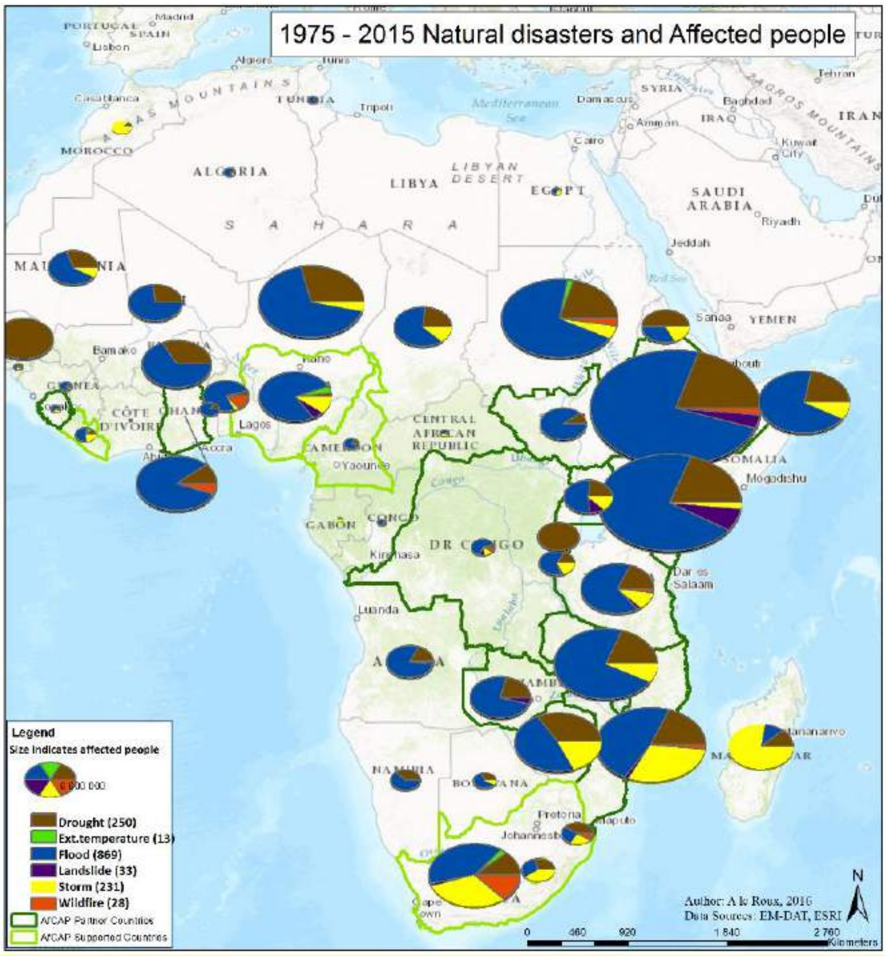


Figure 1: Recorded weather-related disasters and affected populations.
Source: CSIR, using EM-DAT (CRED, 2018) data

1.3 Socio-economic overview

Ghana is burdened by existing non-climatic development challenges, the effects of which are projected to be exacerbated by climate change. These challenges include increasing rural poverty; rapid urbanization; growing urban and coastal neighbourhoods; insufficient infrastructure; poor resource management; inadequate accessibility leaving many people isolated; and declining ecosystems caused by unsustainable land use practices including desertification, land degradation and erosion (US AID, 2011; GFDRR, 2015). These development dynamics and demographic challenges put even more people at risk to the effects of disasters in Ghana. The high dependency on natural resources in rural areas, lack of secure livelihoods and limited informal and formal social safety nets (particularly in the marginalised north of the country) also contribute (GFDRR, 2015; GFDRR, 2011b).

Population growth and unsustainable land-use practices have also resulted in significant deforestation, desertification and coastal and soil erosion, coastal erosion a particular problem specifically along Ghana's eastern shoreline (GFDRR, 2011a). The risk of these climate threats significantly increase Ghana's vulnerability, especially given the courtiers dependence on agriculture as the mainstay of the economy, accounting for 33% of the country's GDP and employing more than half of the economically active population. This is particularly true among Ghana's rural population who lack the resources to moderate or adapt to drought, but who depend most strongly on rain-fed agriculture for subsistence livelihoods (EPA, 2012). The rapid growth of the urban population since the 1970's has gradually changed the spatial distribution pattern of Ghana's population as cities and towns have increasingly become the economic, industrial, commercial, technological and social centres of the modern economy. Over the last few decades, the urban population in Ghana increased from 29% in 1970 to 32% in 1984 and by 2015 was estimated to be at 54% (Figure 2). The increasing rate of urbanisation in Ghana, as in many countries in Africa, has been the combined result of high rates of natural population increase and net in-migration from rural to urban centres (Yankson & Bertrand, 2012; NPC, 2011). Ghana has experienced steadily increasing growth of over 7% per year on average since 2005 and projections indicate that by 2050, 70% of the total population of Ghana will live in urban areas (Cooke, Hague & McKay, 2016). However, the rural population is still expected to increase by 1.1 million people in the next 30 years, ever if the net proportion of rural to urban population decrease. This will place substantially more pressure on land and natural resource management as well as exposing more people, livelihoods and economic activity to weather-related hazards.

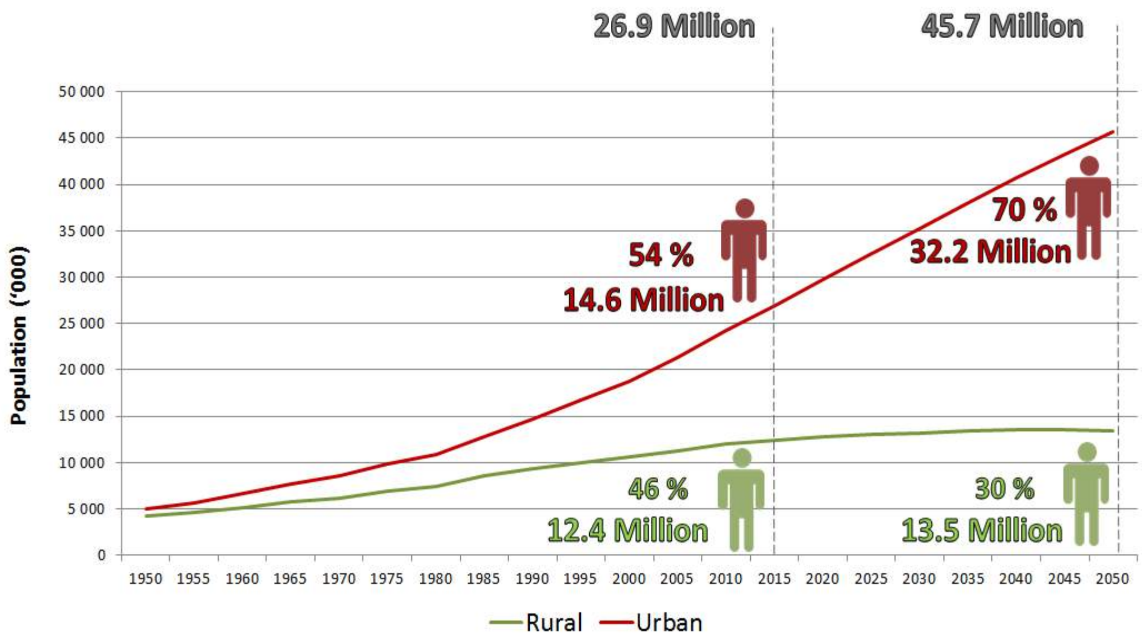


Figure 2: Projected changes in urban and rural population distribution (2015 – 2050)

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

Economic development in the country has been uneven, and a distinct north-south development divide is evident (Fuseini & Kemp, 2015). Geographically, colonial investment and planning created imbalanced spatial development with resource rich areas receiving most of the infrastructural development, while very little investment in the resource poor areas, notably northern Ghana. The result is that the north of the country is considerably more marginalised than the south, which also happens to correlate with the area of greatest Muslim population. The poverty that is prevalent in Ghana's rural communities is caused by isolation, which in turn is caused by rural households' inability to participate in markets and a lack of access to public services that could improve their standard of living (Asomani-Boateng, Fricano & Adarkwa, 2015). This disparity is reflected in the inequality of income, education, and accessibility, with infrastructure and access to goods and services generally being more equitable in the southern Ghana regions (BTI, 2016; Fuseini & Kemp, 2015).

Ghana is ranked 139th out of 188 countries in the 2015 Human Development Index (HDI). With a HDI score of 0.579, Ghana is placed in the group of countries with "medium human development" (UNDP, 2016). However when the HDI is adjusted for inequality, it drops to 0.391, well below the average for medium development countries and indicating that the distribution of wealth is relatively uneven throughout the county (UNDP, 2016; BTI, 2016). This is not surprising given the strong north-south development divide. Based on the 2010 Population and Housing Census, the most populous region is the country is Ashanti, with a population of almost 5 million people, representing 19.4% of the country's total population, followed by Greater Accra with a population of just over 4 million (16.3%). The least populous regions are in the north of the country, namely in the Upper West region with around 700 000 persons, constituting 2.8% of the total population and Upper East with just over 1 million persons or 4.2% of Ghana's population (Ghana Statistical Service, 2012).

Based on the last census, 25% of Ghana's population resides in the coastal zone, which accounts for about 7% of the country's land area and of those, close to 60% reside on the East Coast below the 30 m contour (Stanturf *et al.*, 2011). Population density averages at around 90 inhabitants/km^2 nationally. At the regional level, Greater Accra is the most densely populated region with a density of approximately 1 236 persons per km^2, followed by the Central region with a population density of 224 persons per km^2. The Northern region still remains the most sparsely populated region with a population density of 35 persons per km^2 (Ghana Statistical Service, 2012) (Figure 3).

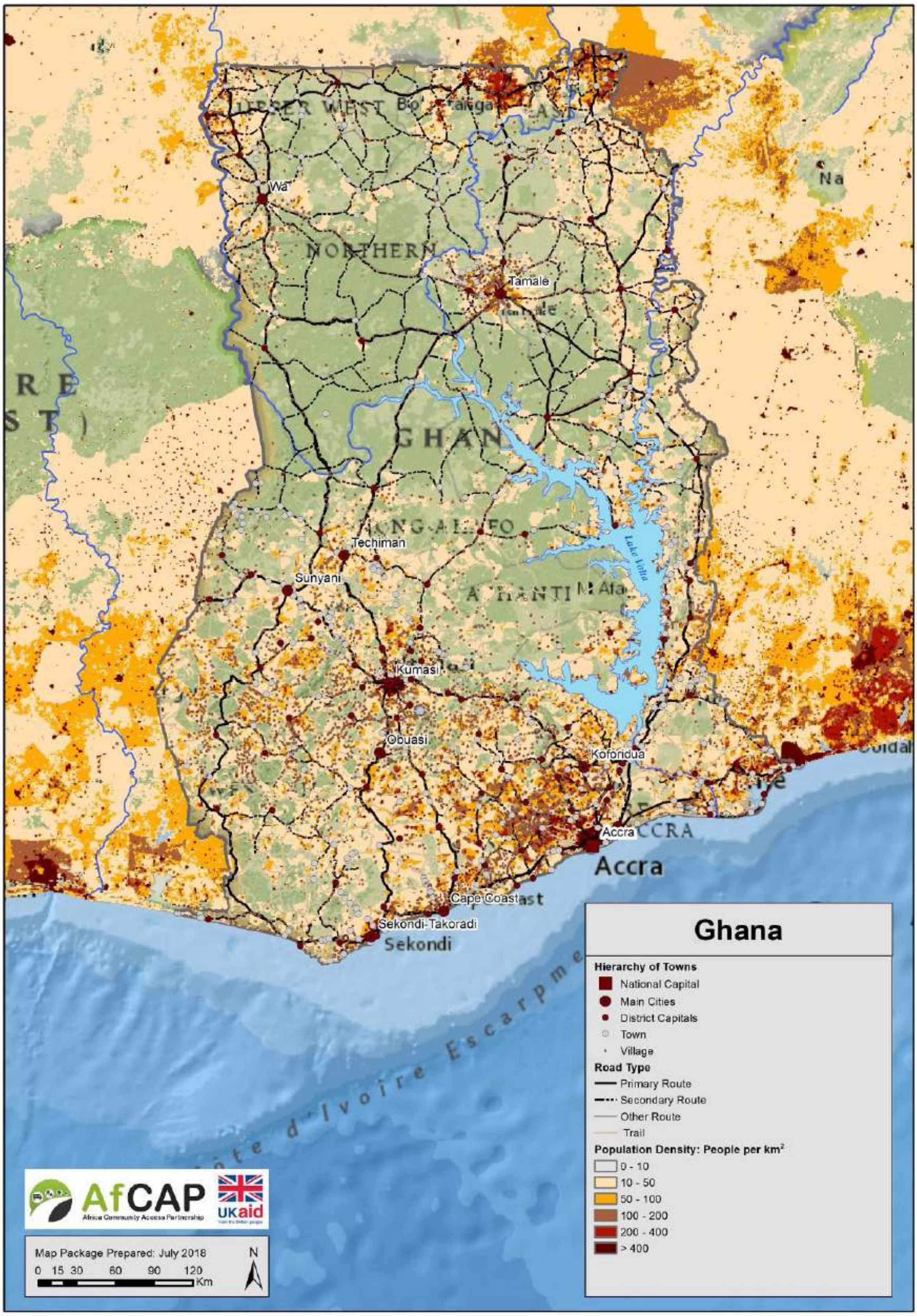


Figure 3: Population distribution in Ghana

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

1.4 Road network overview

Road transport is the predominant means of transport in Ghana and accounts for over 95 % of all transport supply in the country. Ghana's road transportation network is centred in the south, together with most of its population, especially around the resource rich areas where gold, cocoa, and timber are produced. Improvement in accessibility expanded Accra's sphere of influence as the most predominate city in the south. The most important roads radiating from it include the Accra-Winneba; AccraNsawam-Kumasi; Accra-Aburi-Dodowa; and Accra-Tema-Aflao roads (Yankson & Bertrand, 2012). The northern and central areas are connected through a major road system; however there are areas that remain isolated (Owusu-Bio, Frimpong & Duah, 2016; TNC, 2015). For the 46 % of population who live in rural areas, the primary means of transportation comprises trails and paths that link to feeder roads, which connect to urban and trunk roads (Asomani-Boateng, Fricano & Adarkwa, 2015) (Figure 4).

The national classified road network in Ghana comprises 71 063 km of roads and provides fair national coverage. About 30 % of the national classified network is paved. The network has increased by around 35 000 km since 2000, mainly due to urban sprawl and the increased need for rural accessibility. This expansion of the road network has invariably increased the need for accessibility for a large proportion of the population and the 2014 road accessibility index is estimated at around 63% (GhIE, 2016). However rapid economic development, demographic growth and regional dynamics have put increasing pressure on Ghana's transportation system over the past decade, and in a new report published by the Ghana Institution of Engineers (GhIE, 2016), Ghana's road infrastructure was graded as poor, lacking the capacity to meet international standards (GhIE, 2016).

The network is made up of 42 190 km of feeder roads, 14 000 km of urban roads and 14 873 km of trunk roads. Feeder roads make up about 60% of the network, while trunk road and urban roads have an even share of around 20% each. The proportion of gravel and earth roads to tar roads in the network is very high (almost 70%), rendering the majority of the road network susceptible to the effects of environmental and weather conditions. Large sections of the network experience periodic surface flooding, thereby increasing their deterioration (GhIE, 2016).

The road network condition was 40% good, 22% fair and 38% poor in 2006, and in 2014, the road condition mix was 39% in good condition, 32% fair condition and 29% in poor condition (GhIE, 2016). Considering the quality of rural roads (tertiary roads) in isolation gives an indication of where road quality issues are most acute, with only 13 % of Ghana's rural roads in a good condition, while 51 % are in a fair condition and 36 % being largely deteriorated or in poor condition (GhIE, 2016). The overall deterioration of the transport network over that past decade has been blamed for inhibiting the distribution of economic inputs and food as well as the transport of crucial exports (Owusu-Bio, Frimpong & Duah, 2016).

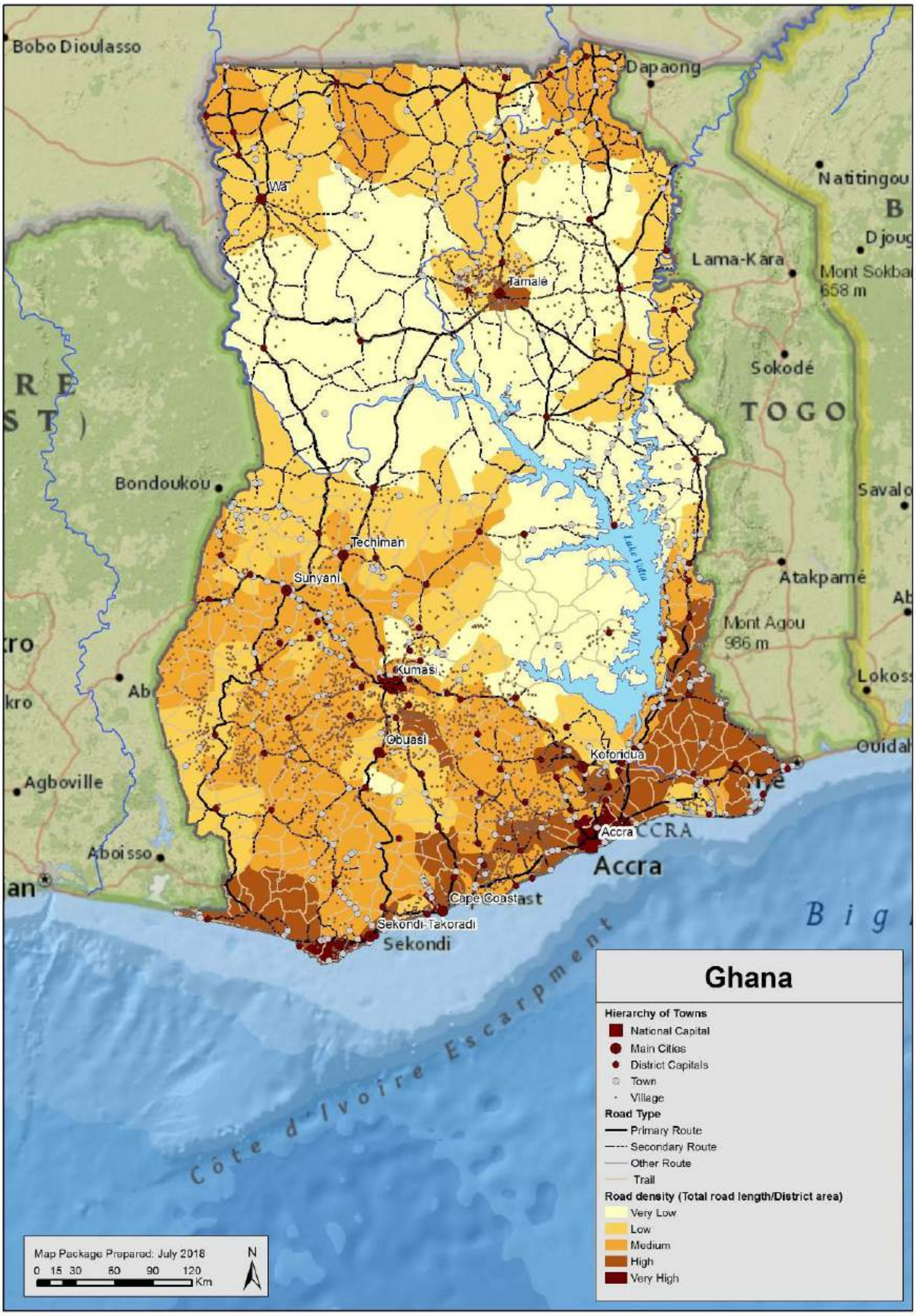


Figure 4: Ghana road network overview (density)

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

Ghana's inability to finance road development and maintenance is probably the most important challenge for the roads sector. The roads sector budget constitutes a significant proportion of the annual national budget. The consolidated fund and the Ghana Road fund are the main sources of local financing for roads. These sources are woefully inadequate for the construction and maintenance of the road network. The road fund is not in the position to finance the entire maintenance budget. Consistent arrears from spill over from previous projects distort the annual budget, affect project quality and eventually lead to poor roads (GhIE, 2016).

1.5 Overview of the AfCAP Climate Adaptation Project

The overall project aim is to deliver **sustainable enhancement in the capacity of AfCAP partner countries** to reduce current and future climate impacts on vulnerable rural 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 ***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 Ghana. It includes an analysis of the current and projected climate situations and the impacts on rural road infrastructure, as well as a summary of Ghana's socio-economic and policy environment. Finally, Change Management options to reduce risk in order that agreed actions can be implemented, are identified.

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

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

This chapter begins with the definition of disaster risk in the context of climate events and processes and their impact of road infrastructure. Climate modelling outputs and climate impacts on 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 illustrated 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);
- **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 a hazards (e.g. flood), 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 them particularly susceptible to the damaging effects imposed by hazards (i.e. rural access roads in poor condition). Poorly planned development, socio-economic vulnerability, environmental degradation and climate change are all pressures that increase the damaging effects of hazards (World Bank, 2013).

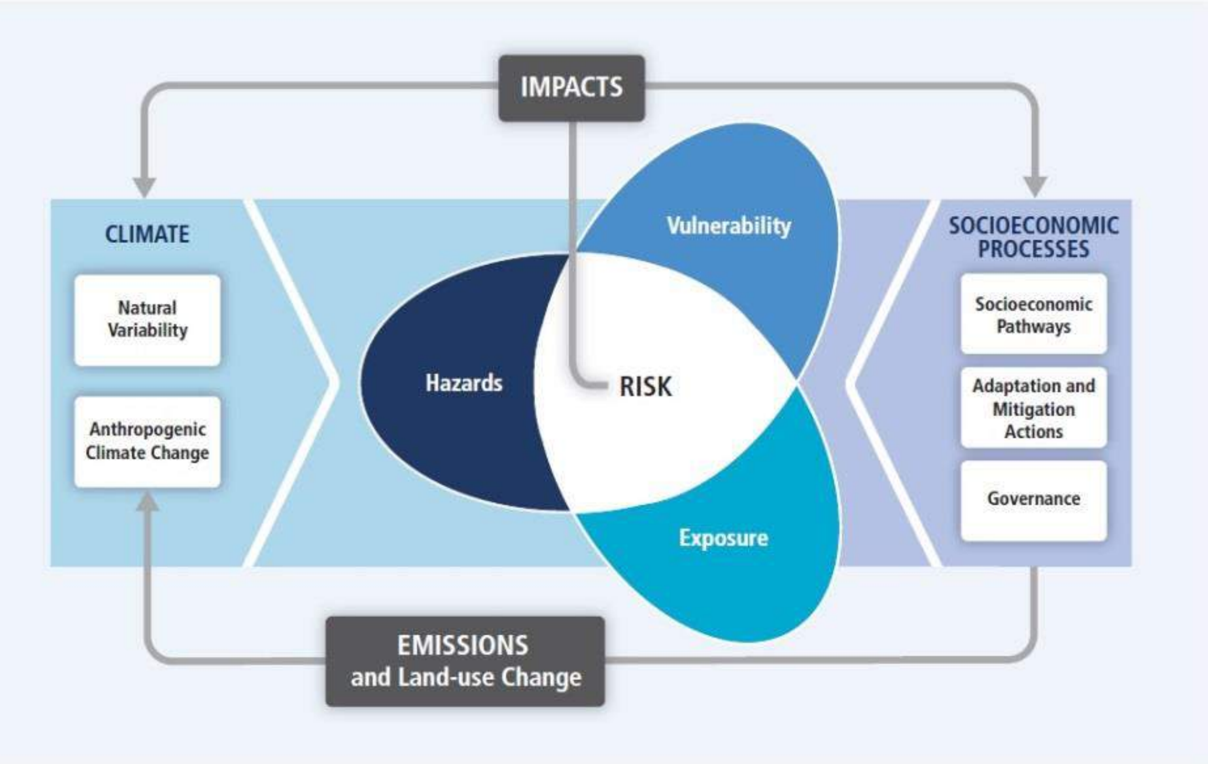


Figure 5: A conceptual framework for climate-related risk as an interaction between climate-related hazards, exposure and vulnerability of human and natural systems.

Source: Niang *et al*. (2014)

2.2 The downscaling of climate projection models

As part of the future scenario for Ghana (until 2100), detailed projected changes in climate were obtained by further 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[4]), were selected for further downscaling to a very high resolution over three AfCAP countries, including Ghana (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).

[4] Representative Concentration Pathways (RCP)

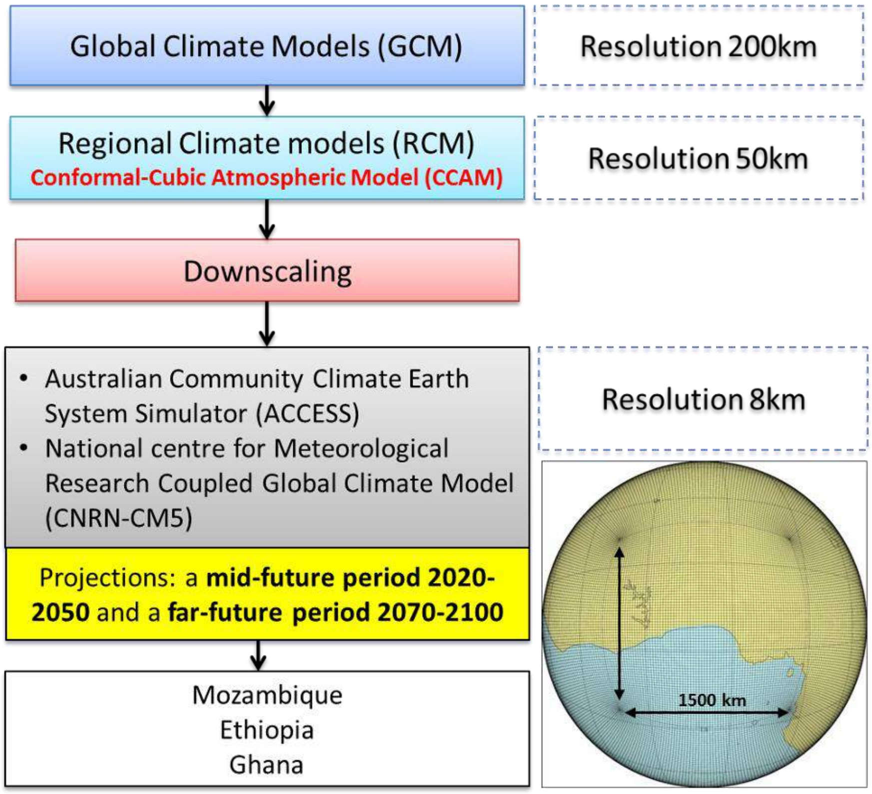


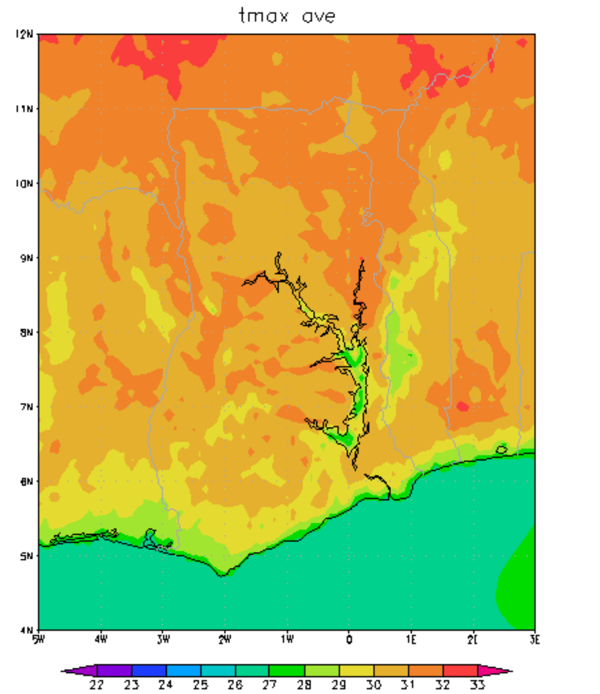
Figure 6: Climate model downscaling

The stretched conformal-cubic grid used to obtain the 8 km resolution model projections of future climate change over Ghana is displayed in Figure 6 (every second grid-point is shown). Centred over Lagos (Nigeria), 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 Ghana at 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). The result is a grid of 8 km resolution extended across Ghana that reflects the following items (see Figure 7):

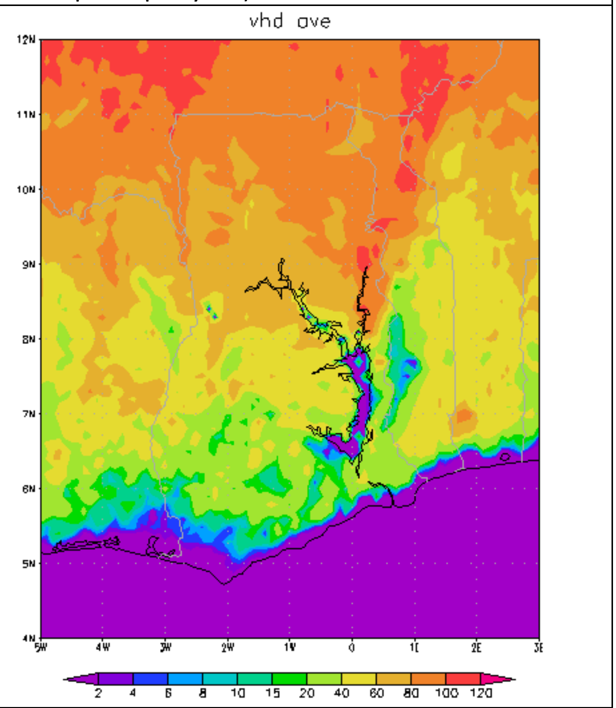
- Annual average maximum temperature (in °C);
- Very hot days (number of events per grid point per year when the daily maximum temperature exceeded 35°C);
- Annual rainfall totals (mm); and
- Extreme rainfall days (number of events per grid point per year where more than 20 mm of rain fell over a period of 24 hours).

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

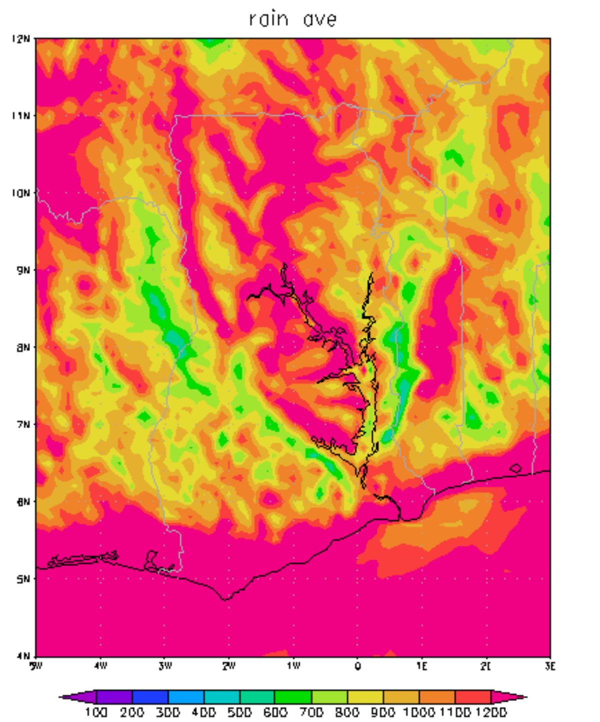
a) Annual average maximum temperature (°C)



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)

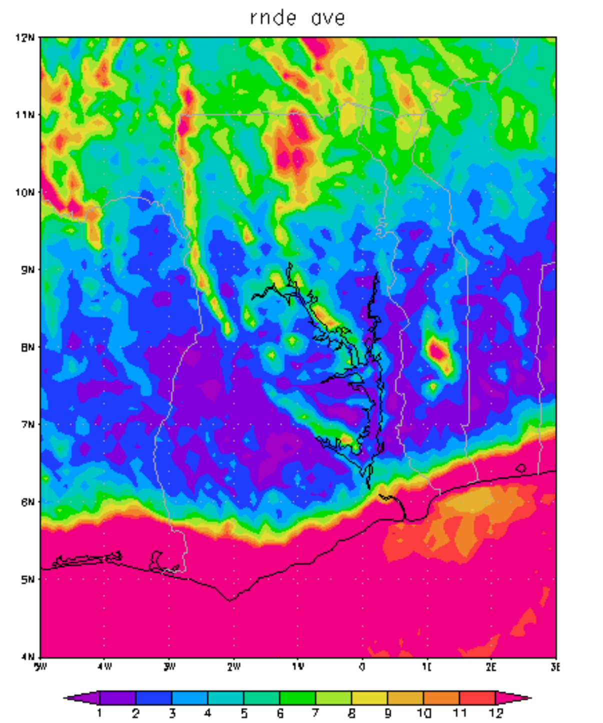


Figure 7: Present-day climatology (1971-2000) over Ghana

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

2.3 Current climate variability and observed trends

From the modelled present day climate for Ghana (Figure 7), it is observed that annual average maximum temperatures in the mid- to high twenties (°C) are simulated to occur along the coastline of Ghana, in correspondence with observations. Higher maximum temperatures are simulated to occur over the interior regions to the north. More than 100 very hot days are simulated to occur annually over the far northern interior regions of Ghana, but less than 10 of these days are simulated to occur annually (on the average) along the coastline, due to the moderating effects of the ocean. High average annual rainfall totals of more than 1 200 mm per year are simulated to occur all along the coastline of Ghana. This rainfall pattern exhibits the clear signature of strong sea-breeze circulations and the influence of larger-scale onshore monsoon winds. A strong south-north gradient in rainfall is simulated to occur to the north of the coastal belt, with local rainfall maxima over areas of steep topography and in the vicinity of inland lakes. 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 along the coastline.

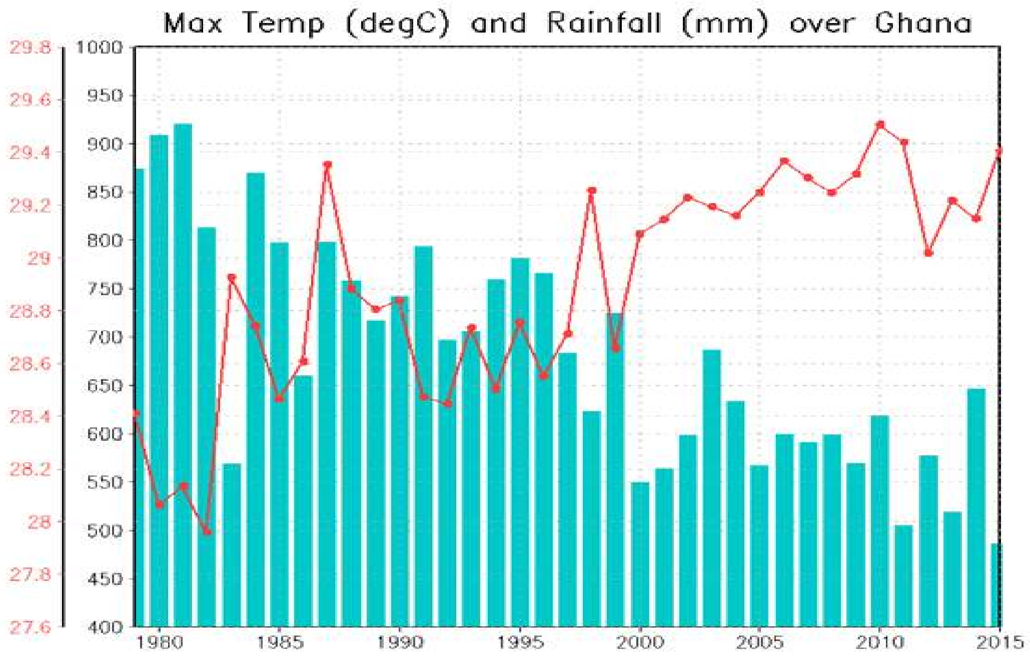
Over West Africa there is clear evidence of temperatures rising over the last five decades (Niang et al., 2014), with the rate of temperature increase over Ghana recently reported to be about 2°C/century (Engelbrecht et al., 2015). Moreover, over the larger West African region warm days are increasing in their frequency of occurrence, whilst cold nights are occurring less frequently (New et al., 2006). Pronounced and statistically significant decreases in rainfall has occurred over Ghana since the 1950s (Niang et al., 2014), although it is not clear whether these changes are the result of enhanced anthropogenic forcing or multi-decadal variability (i.e. weather variable over several decades).

The variability in maximum temperature and rainfall over Ghana 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 and decreases in rainfall. The numerical values of the observed and simulated trends are also represented in Figure 8.

2.4 Projected climate change

Located in tropical West Africa, Ghana's climate exhibits relatively small inter-annual variability in temperature. As a consequence of the regional response to global warming over the country, temperature increases under low mitigation may reach values unprecedented in terms of natural variability as early as in the 2030s (Mora et al., 2013; Niang et al., 2014). Under low mitigation the ensemble of CMIP5 GCMs project temperature increases to range between 3 and 4°C over the southern parts of Ghana including the coastal areas, with increases of more than 4°C projected for the northern interior regions. RCM projections are indicative of changes of similar amplitudes (Patricola & Cook, 2011; Mariotti et al., 2011; Vizy et al., 2013).

The CMIP5 GCM projections of future rainfall patterns over Ghana, and in fact the larger West African region, are uncertain. The projections do not only differ significantly in terms of the amplitude of change, but also on the direction of change (i.e. whether it will become drier or wetter) (Niang *et al*., 2015). This uncertainty may at least be partially attributed to the inability of GCMs to resolve convective rainfall (e.g. Biasutti *et al*., 2008) – a shortcoming that carries over to the CORDEX RCMs. Another possible cause for this wide uncertainty range are the systematic errors exhibited by most GCMs in the simulation of Atlantic ocean SSTs off the west coast of Africa, with implications for the model simulations of the West African monsoon. There is greater correspondence in GCM and RCM projections that extreme precipitation events over West Africa may increase under climate change (Seneviratne *et al*., 2012; Haensler *et al*., 2013), although the confidence in these projections is thought to still range only between low to medium.



Data set	Period	Temperature trend (°C/century)	Rainfall trend (mm/century)
CRUTEMP4v	1961-2010	2.3	Not available
ERA interim	1979-2015	2.8	-312

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

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

Figure 9 shows the projected changes in projected changes in annual average maximum temperatures (°C, top) and the annual number of very hot days (number of events per grid point per year, bottom) over Ghana, 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, relatively small temperature increases of about 1°C are projected to occur over most of Ghana, with increases reaching values up to 2°C in the north (all changes are calculated relative to the baseline period 1971-2000).

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 Ghana, 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 rainfall increases over the coastal belt and eastern interior for the mid-future, with rainfall decreases being projected for the western interior. 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 are projected to occur at locations all along the coastal belt (and increase of about 30% in the frequency of occurrence of these events), corresponding to the region of maximum increase of rainfall events.

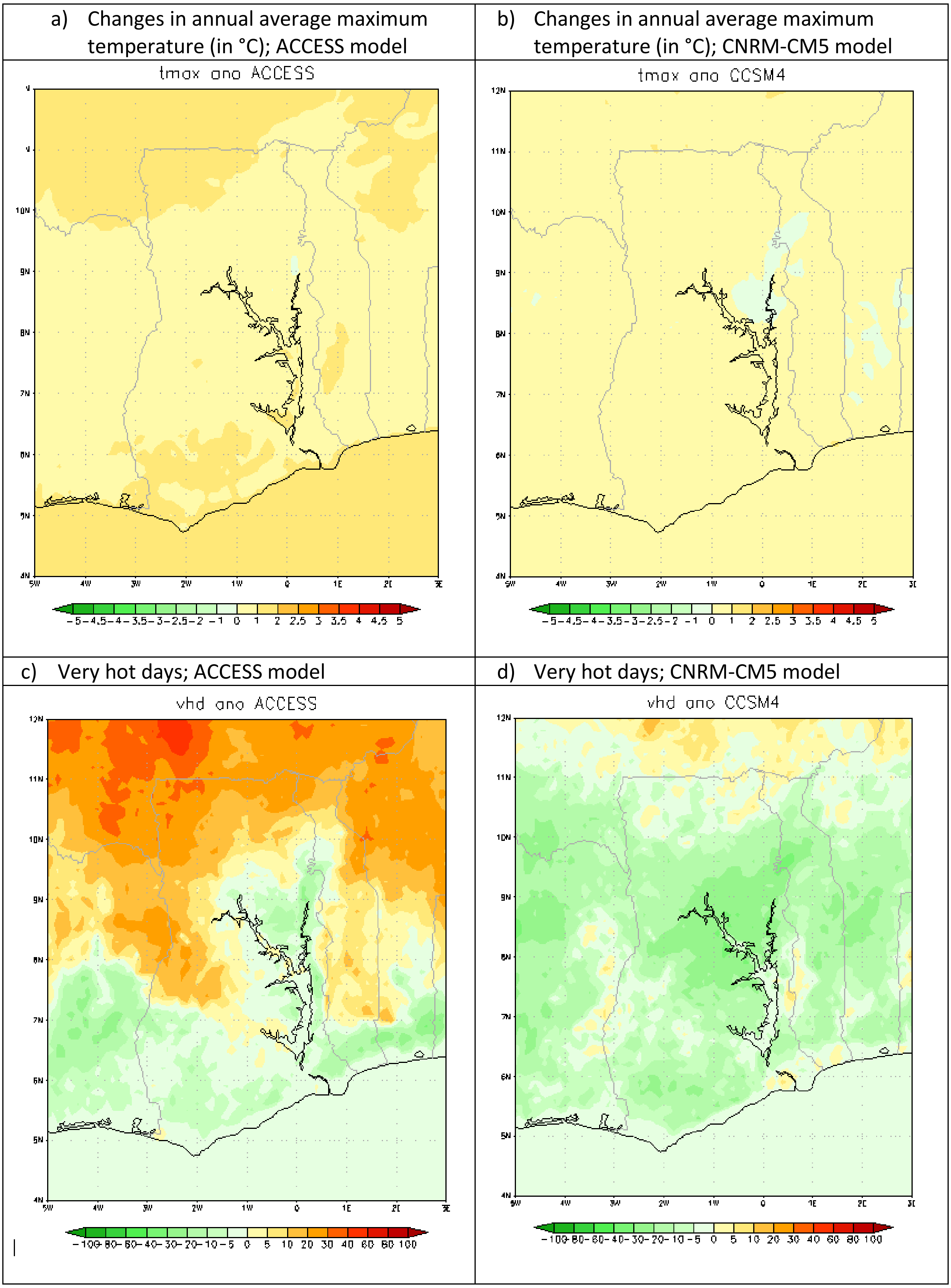
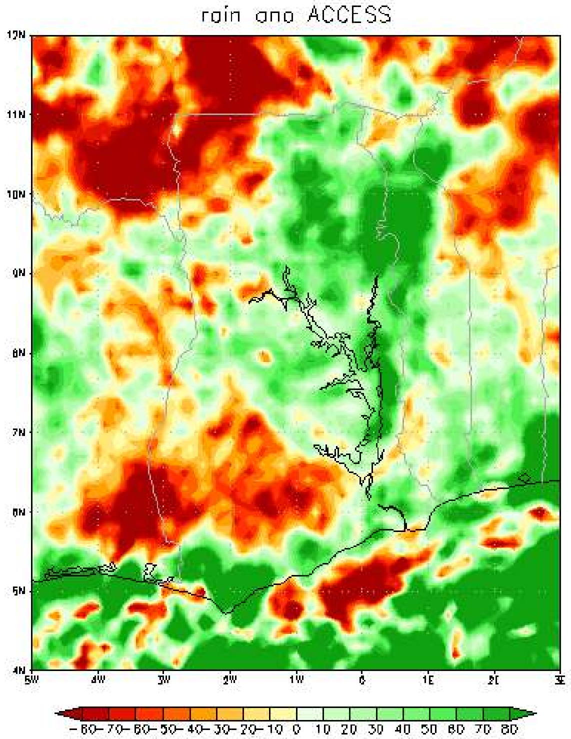


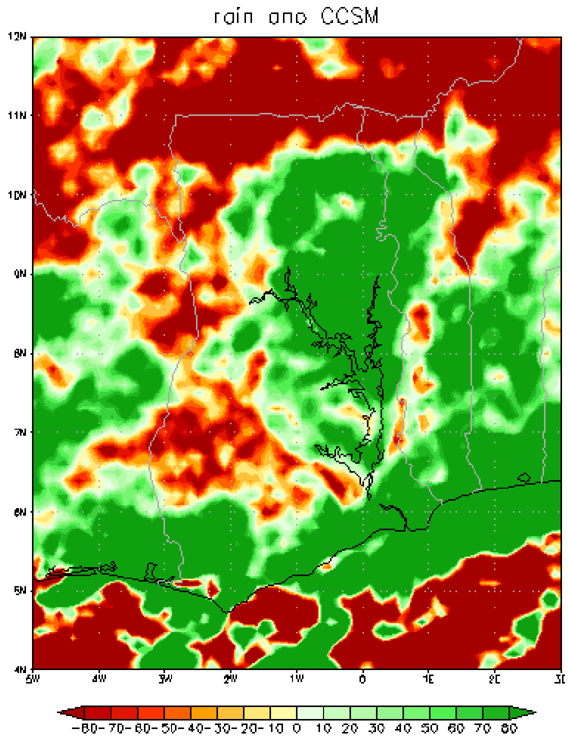
Figure 9: Projected changes in annual average maximum temperatures (Top) and very hot days (Bottom) (period of 2021-2050)

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

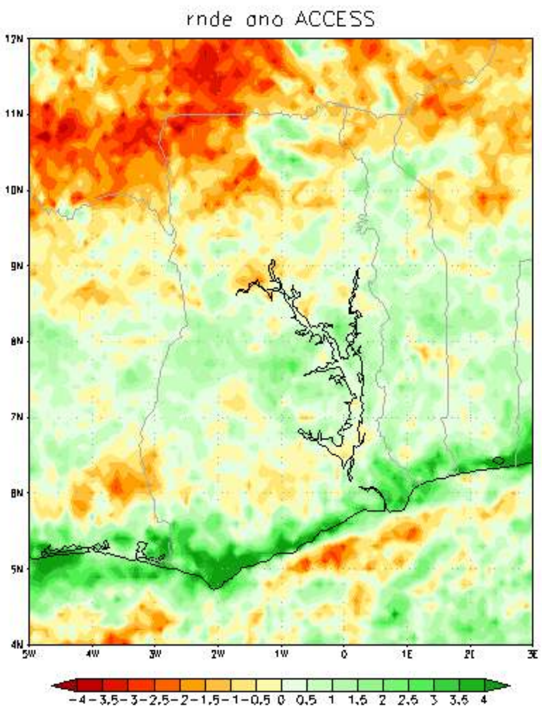
a) Changes in annual average maximum temperature (in °C); ACCESS model



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

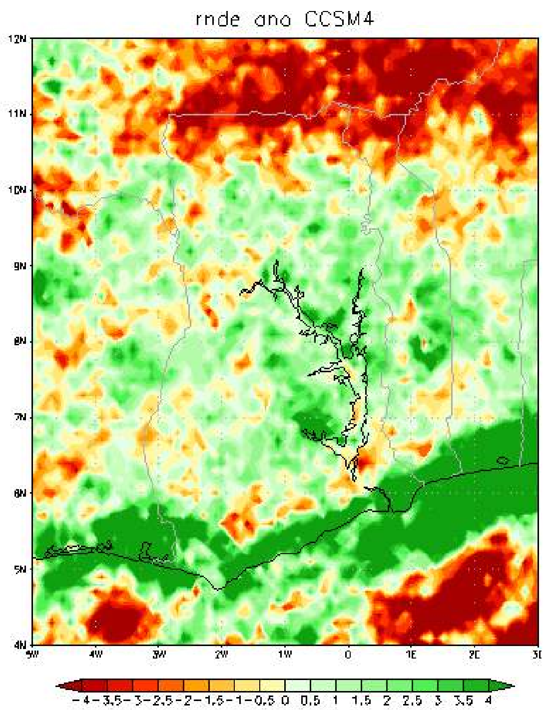


Figure 10: Projected changes in average rainfall (Top) and changes in extreme rainfall events (Bottom) (period of 2021-2050)

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

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 pergrid point per year, Figure 11 - bottom) over Ghana, 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). Large temperature increases, of more than 4°C, are projected for southern and central Ghana for the far-future period of 2071-2100 in the CCAM- ACCESS1-0 downscaling. Somewhat more conservative temperature increases are projected by the CCAM-CNRM-CM5 downscaling. Both downscalings are indicative of drastic increases in the number of very hot days occurring over the area of interest under climate change. These may increases may be as large as 100 days per year over the southern interior regions of the country.

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 Ghana, for the ACCESS1-0 (left) and CNRM-CM5 (right) downscalings. Both downscalings are also indicative of rainfall decreases along the coastline of Ghana and the Atlantic Ocean to the south in the far-future. General rainfall increases are projected for the interior regions of Ghana, with the exception of rainfall decreases that are projected for northern Ghana in the ACCESS1-0 downscaling. The projected pattern of changes in extreme rainfall events closely resembles that of the projected changes in annual average rainfall totals. Increases of 4 or more events per year (an increase of 30% or more) are projected to occur over the coastal belt, extending to the eastern interior regions.

2.5 Impacts of current climate variability

West Africa is prone to frequent floods and droughts due to the high variability in rainfall patterns. Rainfall is the most important element of Ghana’s climate, and within this context, Ghana (like many other countries in the sub-region) is prone to flooding. In the last four decades, the sub-region has witnessed a dramatic increase in flood events, with severe impacts on livelihoods, food security and ecological systems (Ahadzie & Proverbs, 2010; Armah et al., 2010; Asare-Kyei, Forkuor & Venus, 2015).

Among the riparian countries surrounding the Volta basin, Ghana has the highest risk of weather related hazards, including coastal storms, costal erosion, farmland flooding, urban flooding, wildfire and drought from prolonged dry spells. Over the past four decades 17.3 million people have been affected by weather related disasters in Ghana. Nineteen recorded flooding events have costs the lives of almost 450 people and affected an estimated 4.8 million people. While floods beyond the established floodplains are not common in West Africa, 2007 and 2009 brought extensive flooding to the Volta Basin, especially Northern Ghana (van de Giesen, Liebe & Jung, 2010). The unpredictable and severe floods in 2007 resulted in the loss of lives, displacement of vulnerable persons and the destruction of key infrastructure, food stocks and livestock throughout the region, affected around 332,600 people and causing the death of 56 people in the Upper East, Upper West and Northern regions and parts of Western region (Komi et al., 2016). Other major floods between 1991 and 2008 caused the destruction of thousands of hectares of farmlands, destruction to the ecology, critical infrastructure, agriculture and other properties as well as causing disruptions to the socio-economic system (EPA, 2012).

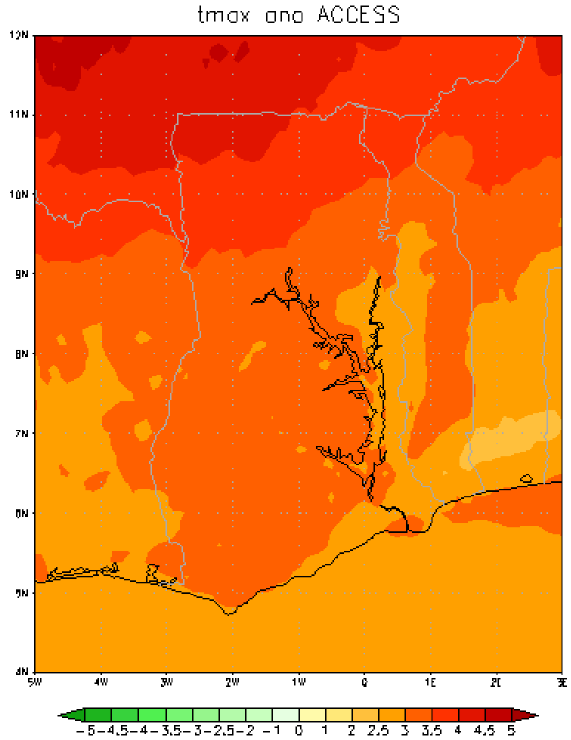
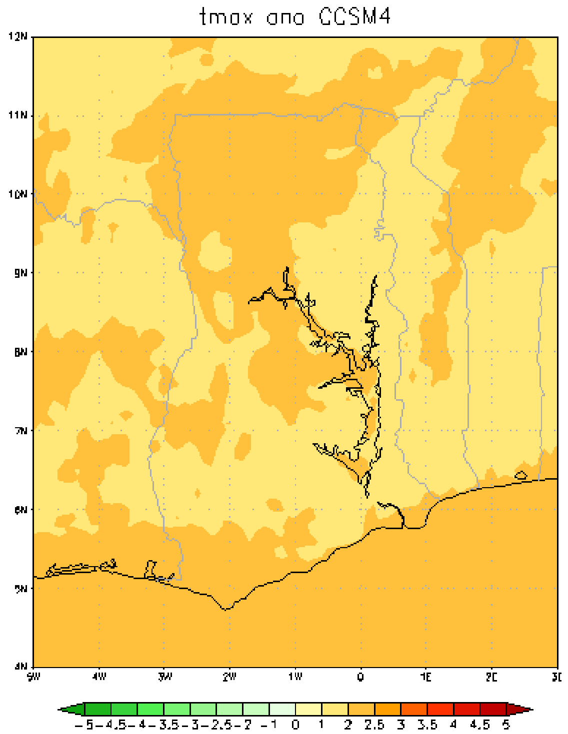
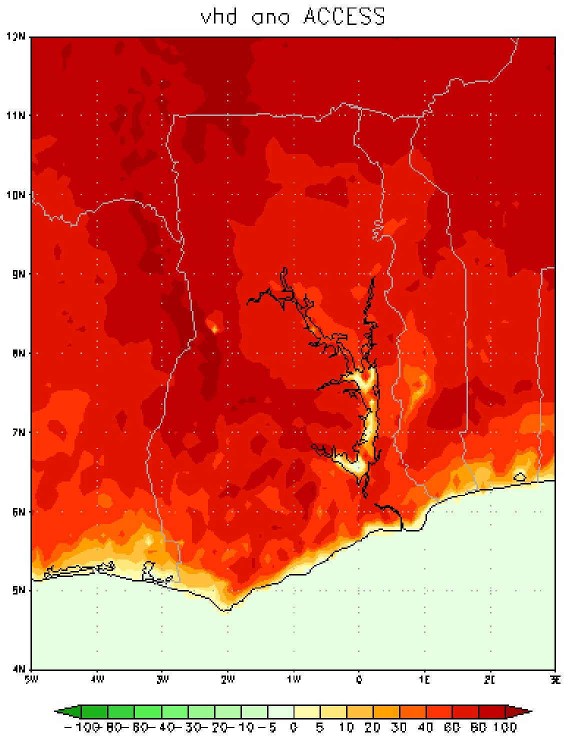
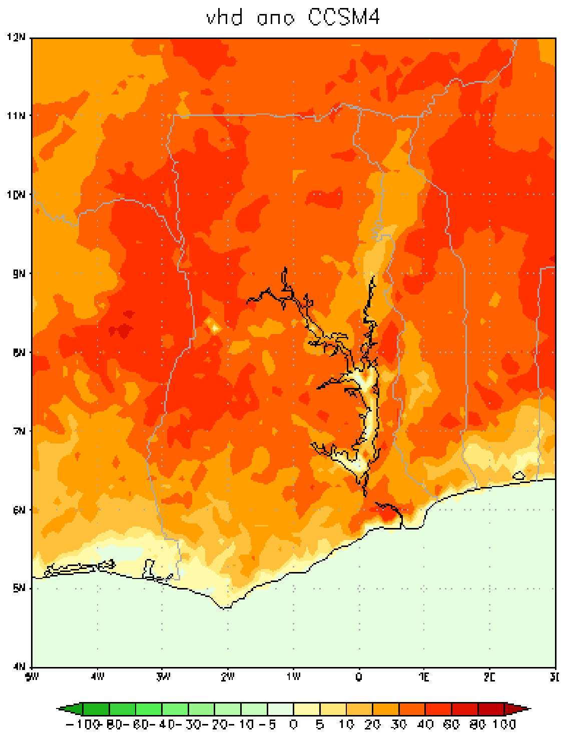
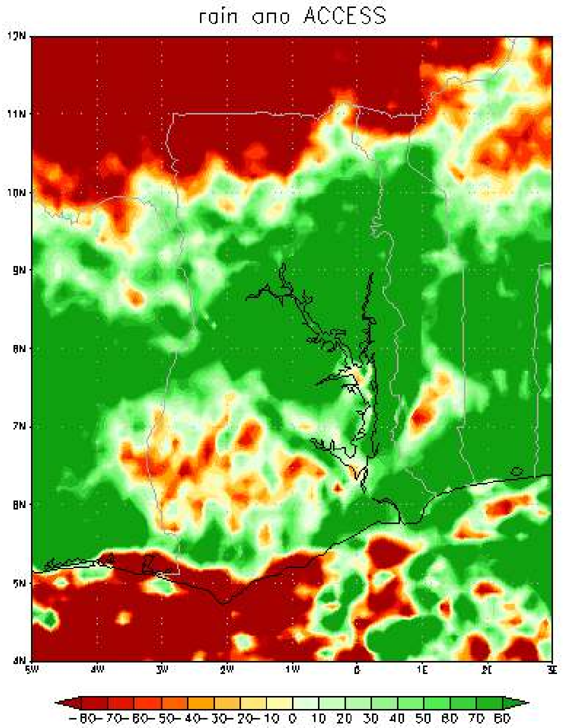
a) Changes in annual average maximum temperature (in °C); ACCESS model	b) Changes in annual average maximum temperature (in °C); CNRM-CM5 model
	
c) Changes in very hot days; ACCESS Model	d) Changes in very hot days; CNRM-CM5 model
	

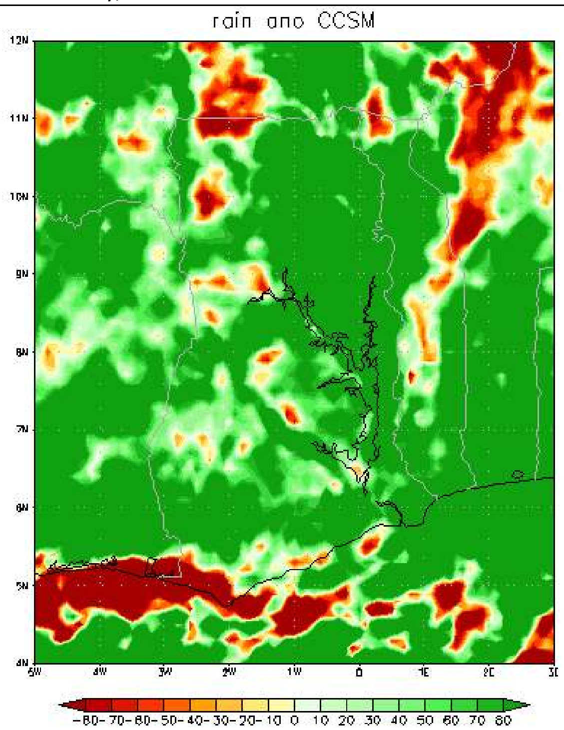
Figure 11: Projected changes in annual average maximum temperatures (Top) and very hot days (Bottom) (period of 2071-2100)

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

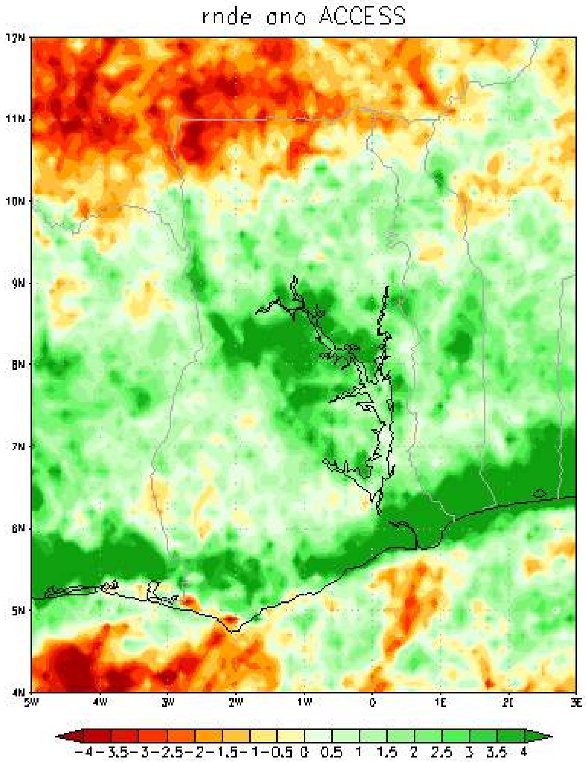
a) Changes in annual average rainfall (in mm); ACCESS model



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

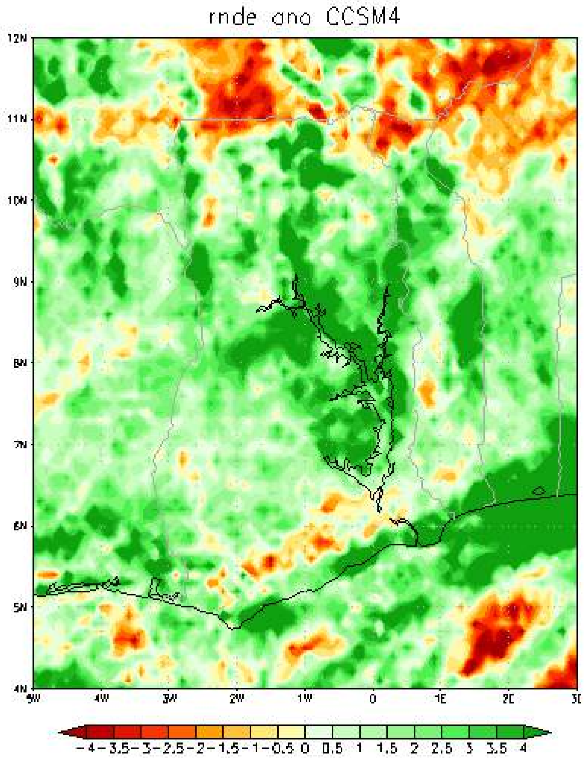


Figure 12: Projected changes in average rainfall (Top) and changes in extreme rainfall events (Bottom) (period of 2071-2100)

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

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

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

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

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

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

2.7 Cost of climate change on roads

A World Institute for Development Economics Research paper (Twerefou, Adjei-Mantey, & Strzepek, 2014) provides an assessment of the economic impact of climate change on road infrastructure in Ghana for the period 2020-2100 using the stressor-response methodology. The analysis indicated that it will cumulatively (2020-2100) cost Ghana US$473 million to maintain and repair damage caused to existing roads as a result of climate change when a no adaptation scenario applies. If the country adapts the designing and construction of new road infrastructure expected to occur over the asset's lifespan (the adapt scenario), the total cumulative cost will increase to US$678.47 million. The cost increase is due to the following based on a World Bank study (2010):

- Structures such as bridges could increase to provide for adding additional flood protection. This could include armouring sub-structures to prevent washout from scouring or to create flood relief channels.
- Drainage is an item that is expected to increase in investment in order to cope with the increased flooding events. An increase in culverts may be an associated requirement of raising the roadway. It follows that raising the road-way will create a damming effect, and therefore more drainage structures will need to be installed to alleviate flooding.
- The increased rainfall may lead to increased ground water levels, which may have a negative impact on expansive soils. This will either require the increased removal of problem soils, increased use of chemical stabilizers in the native material such as lime or cement, or increasing the fill embankment height to raise the road surface.
- In areas with high rainfall, it may be beneficial to seal the roads with water-proof bitumen, rather than use a gravel wearing course in order to protect the investments to the sub grade stabilization and sub base materials.
- The cost of maintenance is expected to climb drastically under the new climate scenarios. The frequency of large storm events is expected to increase by up to six times in the Ghana wet scenario. It is estimated that maintenance budgets, monitoring and repair for drainage elements and structures is expected to need to be increased close to 100% in order to ensure that the existing drainage infrastructure is able to accommodate such an increase.

2.8 Reported problems resulting from climate change

The amount of rainfall and where and when it falls largely depends on the interaction of the tropical continental and maritime masses. Although the heaviest rainfall occurs in the South and along the coast of Ghana (Ahadzie & Proverbs, 2010). Above normal rainfall amounts at the peak of the rainy season frequently lead to severe floods, and cause many of the major rivers (including the Volta river) to overflow their banks (Asare-Kyei, Forkuor & Venus, 2015). Flash floods following heavy rains are something Ghanaians, especially residents of the capital and major cities and towns are used to. In addition to being in an area of high annual rainfall, Accra is situated on a plain facing the Gulf of Guinea and this low-lying area experiences flooding every rainy season. This is mainly due to haphazard construction of residential buildings within the flood plains of watercourses; inadequate drainage and a poor waste management system which chokes the open drains with refuse (UNCT, 2015).

But flooding is not limited to the coastal area of Ghana. In the Volta River Basin, flooding has been one of the most damaging natural hazards during the last few decades (Komi et al., 2016), although the Volta Basin is most often hit by droughts and less frequent floods (van de Giesen, Liebe & Jung, 2010). Among the riparian countries surrounding the Volta basin, Ghana has the highest risk of weather related hazards, including landslides, coastal erosion, urban floods, farmland flooding and dry spells. While floods beyond the established floodplains are not common in West Africa, 2007 and 2009 brought extensive flooding to the Volta Basin, especially Northern Ghana (van de Giesen, Liebe & Jung, 2010). The unpredictable and severe floods in 2007 resulted in the loss of lives, displacement of vulnerable persons and the destruction of key infrastructure, food stocks and livestock throughout the region, affected around 332 600 people and causing the death of 56 people in the Upper East, Upper West and Northern regions and parts of Western region (Komi et al., 2016). Other major floods between 1991 and 2008 caused the destruction of thousands of hectares of farmlands, destruction to the ecology, critical infrastructure, agriculture and other properties as well as causing disruptions to the socio-economic system (EPA, 2012). Flash floods (most commonly from the spillage of excess water upstream from the Bagre Reservoir in Burkina Faso) and seasonal river floods from prolonged excessive rainfall thus pose a significant challenge to Ghana's already vulnerable communities (GFDRR, 2011b; Armah et al., 2010).

2.9 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 favorable 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 Ghana

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 for Ghana's 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 (Figure 13) was developed that delineates on a national level where roads are most vulnerable to a changing climate and provides key geographic information aimed towards supporting decision makers in identifying high-risk areas (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 Ghana. 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. These results, which ideally should be imported into the national Road Asset Management System (RAMS) (see Phase 4 of the framework, Figure 13), may also be used to determine where in-depth local level road risk and vulnerability assessments would be most beneficial.

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).

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 Ghanaian case study, however, road condition data that were available at the time of undertaking the assessment were not used due to incompleteness as there were no records for certain districts. 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 quality of available road condition data. The quality of road condition data can be improved through the use of **resilience field assessment forms** similar to the one described in the *Engineering Adaptation Guidelines* by Paige-Green et al., (2018) which can be completed by road engineers during their routine road assessment surveys.

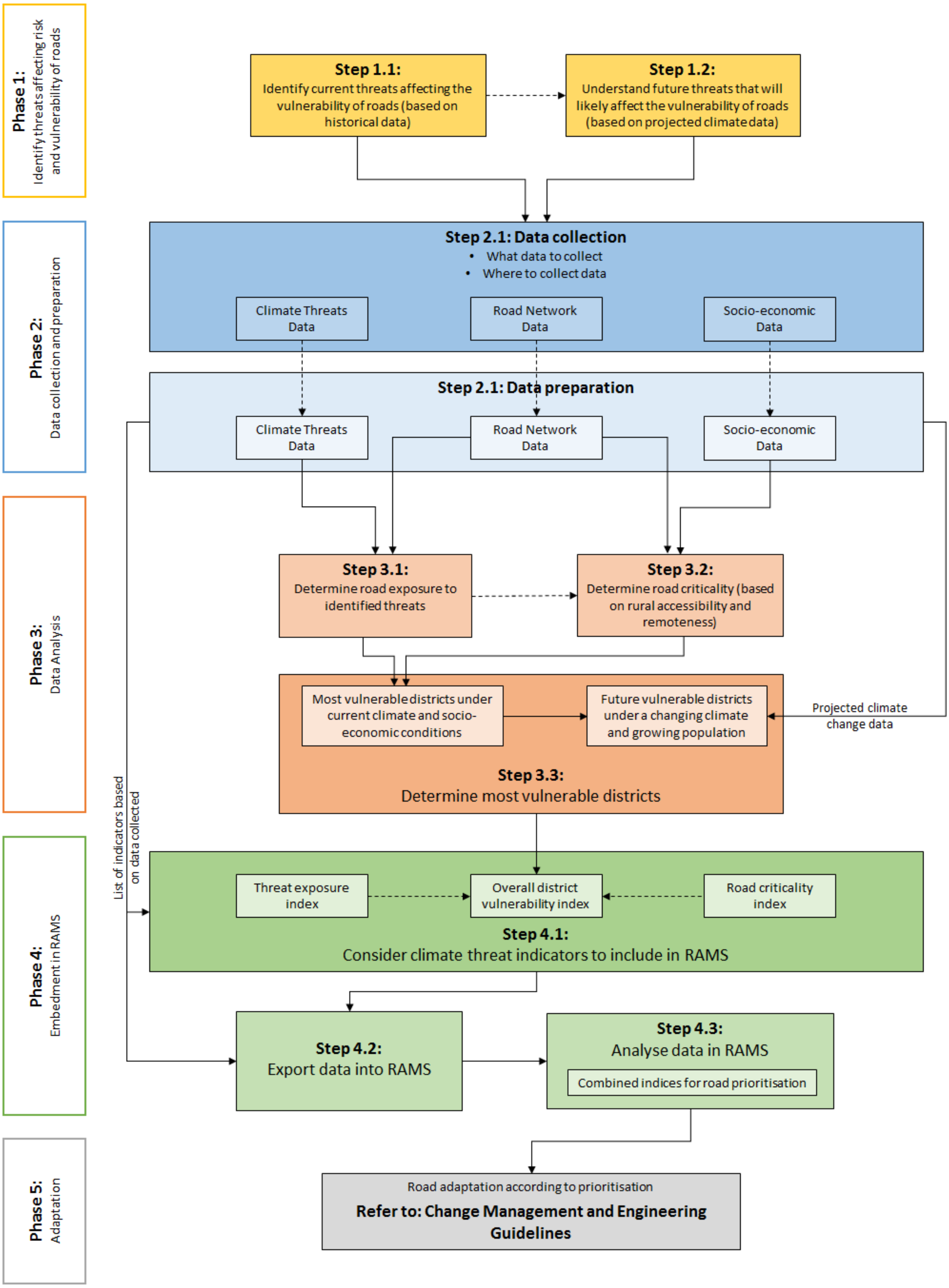


Figure 13: Framework for the rural access road risk and vulnerability assessment
Source: Le Roux *et al*. (2018)

3.2 Sources of information and data

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

- Firstly, it is assumed that national data on historical climate threats are maintained and archived by the relevant national meteorological department and/or disaster management office. As the starting point, data should be sourced from these national authorities.
- Secondly, technical reports by the Intergovernmental Panel on Climate Change (IPCC) and The Nature Conservancy[5] (TNC) can be consulted for background information.
- Lastly, knowledge sharing workshops should be conducted with active role-players such as the national meteorological department and disaster management office.

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

Table 2 outlines the possible data required to perform a district-level risk and vulnerability analysis, together with suggested national authorities in Ghana who should be responsible for maintaining specific custodian data. In the absence of such data, open source data repositories, where data can be sourced freely, are listed. It is recommended to source and use national scale GIS datasets from national departmental authorities as a first priority. In the absence of such data, open source data repositories might be used as a second choice. As a starting point, country specific custodian data might be sourced from the following places:

- National departmental authorities (e.g. National Disaster Management Organisation (NADMO), Ghana Meteorological Agency (GMA));
- Road asset management systems (Ministry of Roads and Highways);
- Country wide SDI (if implemented);
- Country specific assessment reports (e.g. by development partners e.g. World Bank reports);
- Previous studies; and
- Commercial data vendors.

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

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

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

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 Management Organisation (NADMO) – Ghana Meteorological Agency (GMA)	– EM-DAT – ERA-Interim – CRUTEMP4v
	Specific hazard data for main identified climate threats (e.g. Flood history) (District Scale)	– National Disaster Management Organisation (NADMO) – Ghana Meteorological Agency (GMA) – Ministry of Environment, Science, Technology & Innovation	– Dartmouth Flood Observatory
	Projected climate change data (Resolution as fine as possible e.g. 8km resolution)	– Ghana Meteorological Agency (GMA)	– ACCESS1-0 – CNRM-CM5
Socio-Economic	Population data	– Ghana Statistical Service	– WorldPop
	Settlements, towns and main cities	– Ministry of Lands and Natural Resources, Survey and Mapping Division	– Diva-GIS
	Population projections	– Ghana Statistical Service	– UN ESA
Analysis Supporting Data	District boundaries	– Ministry of Lands and Natural Resources, Survey and Mapping Division	– Diva-GIS
	Satellite images	– Ghana Space Science & Technology Centre	– 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. Roads 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

Ghana ranks high amongst African countries left highly exposed and vulnerable to the threats imposed by multiple weather-related hazards, frequently hit by floods and droughts across the country, with 17.3 million people being affected by weather related disasters over the past four decades. Flood epidemics have accounted for the greatest loss of life and economic damages of all extreme natural hazards nationally, while droughts have historically affected the most number of people (Table 3) and these changes in climatic extremes point to potential future threats. 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 including Ghana, focus is narrowed to hazards caused by rainfall and temperature anomalies, namely floods and very hot days. Over the past four decades nineteen recorded flooding events have cost the lives of approximately 450 people and affected an estimated 4.8 million people nationally (Table 3). Six of these were classified as major floods. The northern savanna zone is highly susceptible to both flood epidemics and droughts, and the recurrence of both is becoming a common phenomenon. Of late, floods in the northern regions of the country have become unpredictable and severe, resulting in high numbers of human fatalities as well as destruction of ecology, critical infrastructure and agriculture throughout the region. Of particular mention are the 'northern' and '2nd northern' floods of 1999 and 2007 that caused large scale devastation affecting more than 650 000 people cumulatively and killing approximately 110 people (Figure 14). The 2007 flood alone caused an estimated damage of over $ 130 million, not including long term losses (EPA, 2012). These floods in northern Ghana followed a period of drought that damaged the initial crop harvests (Stanturf et al., 2011). Urban floods also regularly affect major cities in the country, and the south-eastern region is highly exposed to flooding - the last major event occurring in Accra in October 2011 (GFDRR, 2015).

Table 3: Hazard frequency and impact in Ghana (1977–2017)
Source: CSIR, using EM-DAT (CRED, 2018) data

Hazard	Number of events (1977–2017)	Total deaths	Total affected
Drought	2	0	12 500 000
Riverine flood	16	409	3 85 ,990
Other flood	3	35	1 005 000
Storm	1	20	12
Wildfire	1	4	1 500
Total	**23**	**468**	**17 366 502**

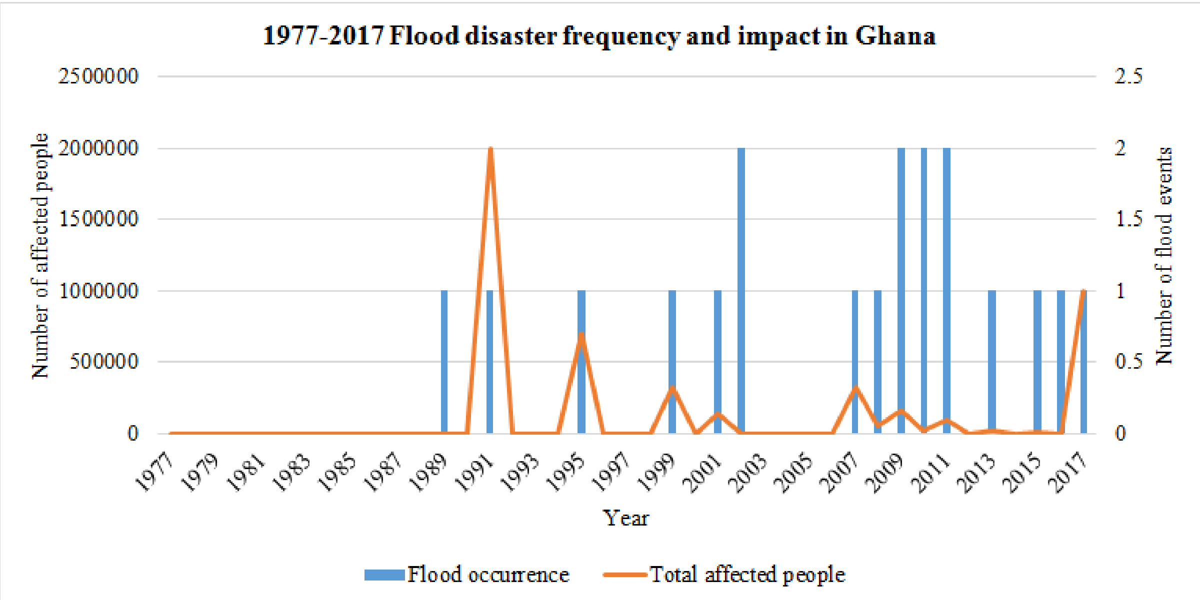


Figure 14: Flood disaster frequency and impact in Ghana between 1977 and 2017
Source: CSIR, using data from EM-DAT (CRED, 2018)

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 used and the output analysis of the flood exposure index is illustrated in Figure 15. Details on compiling the flood exposure index can be found in Arnold *et al*. (2018). Largescale floods occur mostly in the area surrounding Lake Volta and along the coast where flooding has been one of the most damaging natural hazards during the last few decades. Forty-three out of Ghana's 137 districts have experienced 9 or more flooding events in the last four decades.

The amount of rainfall and where and when it falls largely depends on the interaction of the tropical continental and maritime masses. The heaviest rainfall occurs in the South and along the coast of Ghana (Figure 15). Above normal rainfall amounts at the peak of the rainy season frequently lead to severe floods, and cause many of the major rivers (including the Volta river) to overflow their banks (Figure 15). Flash floods following heavy rains are something Ghanaians, especially residents of the capital and major cities and towns are used to. In addition to being in an area of high annual rainfall, Accra is situated on a plain facing the Gulf of Guinea and this low-lying area experiences flooding every rainy season. This is mainly due to haphazard construction of residential buildings within the flood plains of watercourses; inadequate drainage and a poor waste management system which chokes the open drains with refuse (UNCT, 2015). In the Northern region, flash floods (most commonly from the spillage of excess water upstream from the Bagre Reservoir in Burkina Faso) and seasonal river floods from prolonged excessive rainfall pose a significant challenge to Ghana's already vulnerable communities in the north.

3.5 Road asset criticality

The Rural Access Index (RAI) calculated for Ghana is depicted in Figure 16. The index considers people within 2 km of an access road. Ghana's road network has relatively good connectivity, but the road transportation network is centred in the south. The northern and central areas are connected through a major road system; however there are areas that remain isolated. Rural roads play a vital role in connecting isolated rural communities with economic centres, markets and basic social services, but 17 of Ghana's 137 districts have a RAI of 50% or lower, most of which are in the Volta basin or the Northern region. Krachi East on the north-eastern banks of Lake Volta in the Volta province is the most isolated district (in terms of percentage people without access to a road within 2 km), followed closely by Afram Plains district in the Eastern Province. In both of these districts more than 70% of the population living there are more than 2 km away from a road, leaving these regions isolated from readily accessing economic centres, markets and basic social services.

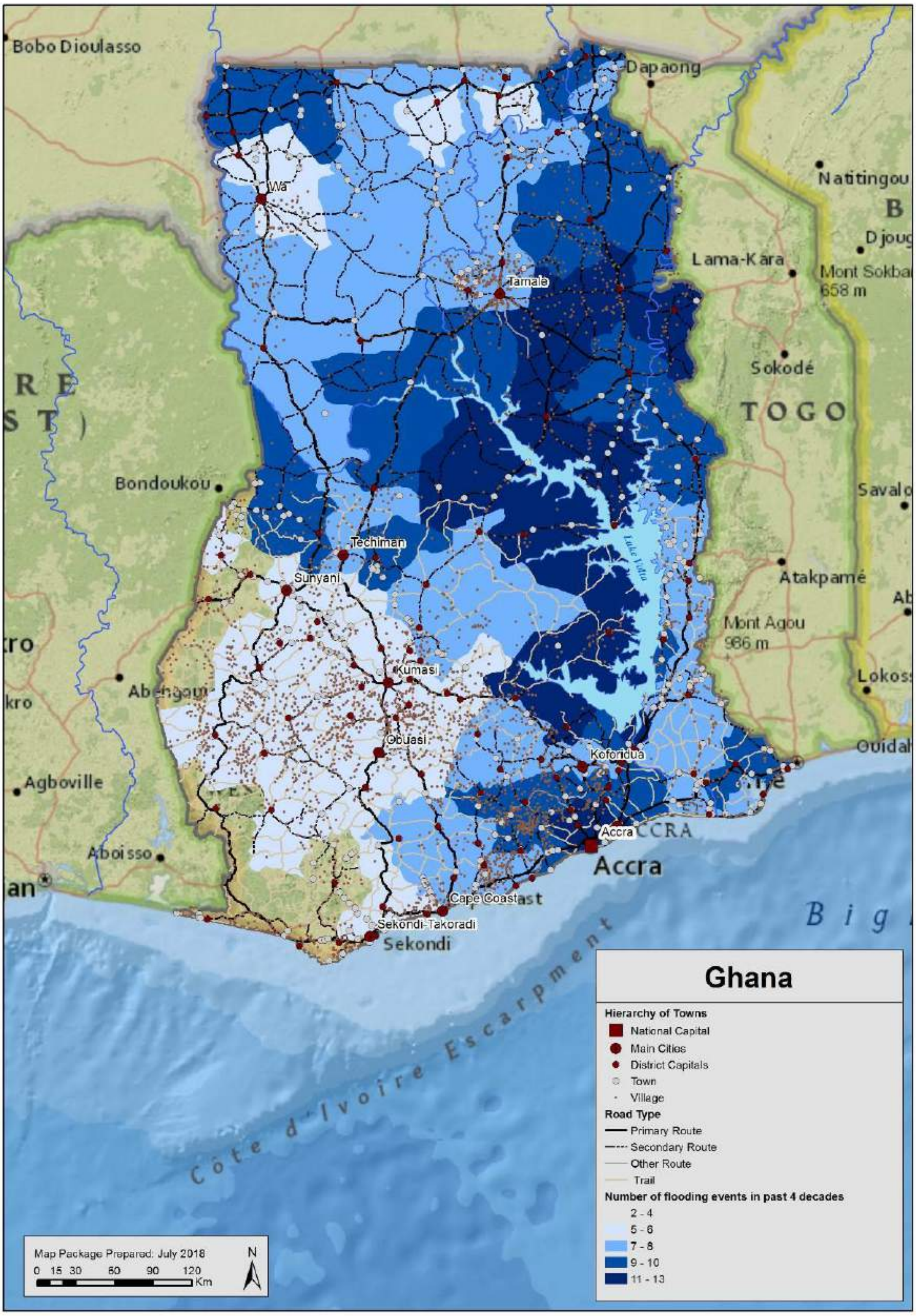


Figure 15: Ghana's most flood-affected areas over the past four decades
Source: CSIR, using flood data from Dartmouth Flood Observatory (2017)

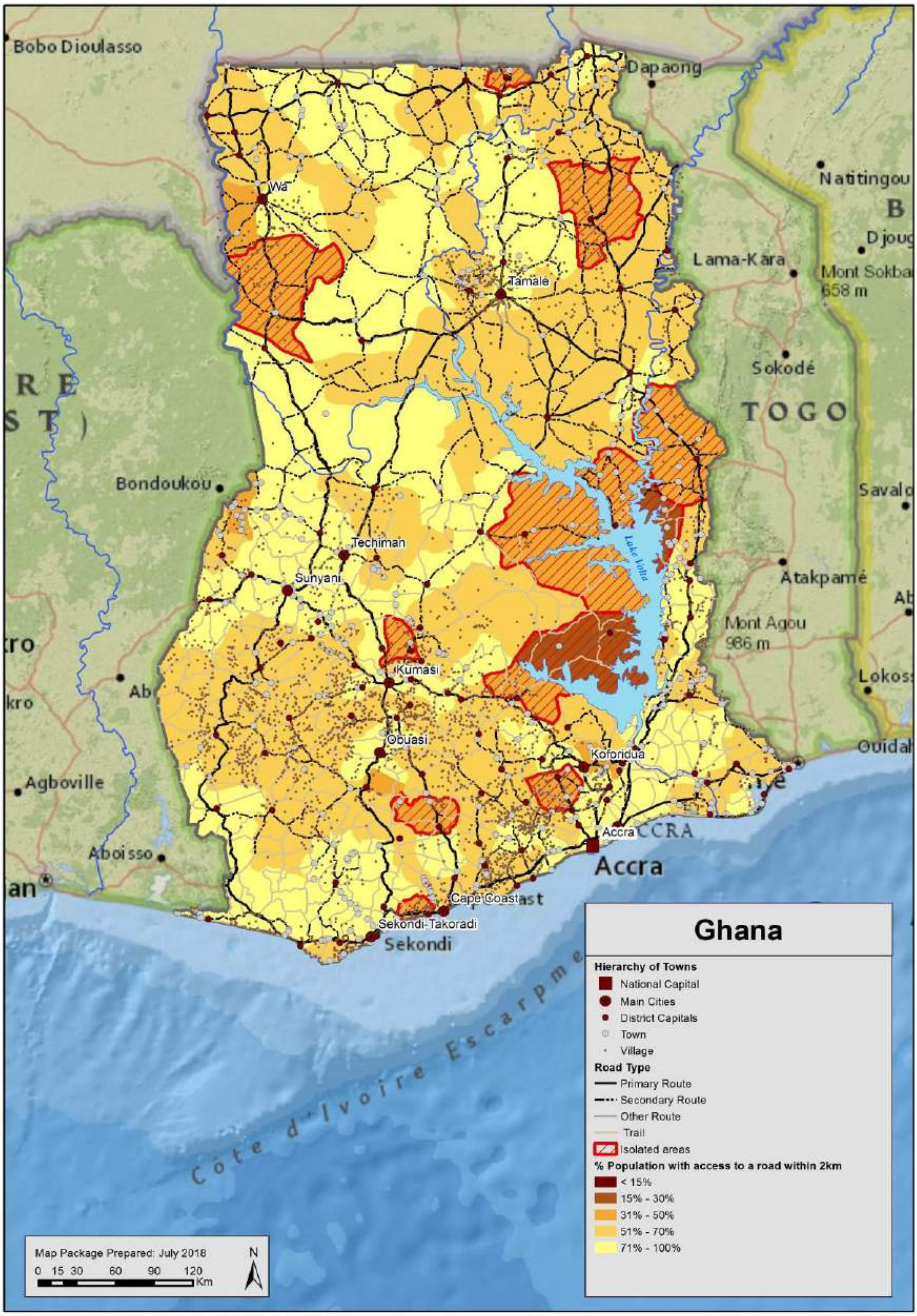


Figure 16: Rural Access Index and isolated regions calculated for Ghana
Source: CSIR, using population data from WorldPop (2017)

3.6 Highly vulnerable districts in terms of climate impacts on roads

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

Although Ghana's expansive national road network, together with its comprehensive national climate adaptation policies make the county less vulnerable to climate related hazards than other countries in Africa, almost 30% of districts in Ghana are classified as vulnerable (41 districts) due to their high exposure to frequent and severe flooding as well as their low rural accessibility and high isolation rates, with 8 districts being classified as highly or very highly vulnerable (Figure 17). Here, areas in darker red depict 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 centre of the country, located in and around the Volta river basin and its tributaries, with the most highly vulnerable districts being located on the banks of Lake Volta in Volta province, in the Afram Plains. In particular, vulnerable areas are located around Lake Volta (namely the Sene, Krachi, Krachi East, Kwahu South and Nkwanta districts) and in the Northern region around Gushiegu. The Suhum Kraboa Coaltar district, just north of Accra in the Eastern province is the most vulnerable district in the southern region of the country, while Bongo on the border with Bukina Fase is also highly vulnerable.

5.4.2 Future vulnerable districts to the impacts of a changing climate and growing population

The climate projections from the CNRM-CM5 (Figure 18) and ACCESS1-0 (Figure 19) downscaling indicate that the frequency of occurrence of days where the maximum temperature exceeds 35 °C will increase throughout the country, although bigger increases are projected to occur towards the west of the country around Sunyani and Wa, and along the border with the Ivory Coast. Smaller increases are projected in the south and around the Volta river basin. The CNRM-CM5 (Figure 18) downscaling projected significant increase in the north, to the north-east of Tamale. The projections are for the period 2021-2050 relative to 1971-2000 under low mitigation (RCP8.5) scenario.

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 assets, the softening of bitumen and concrete expansion are also critical considerations.

The climate projections from the CNRM-CM5 (Figure 20) and ACCESS1-0 (Figure 21) downscaling were used to map the annual number of extreme rainfall days (number of events per grid point per year) over Ghana, together with the vulnerable districts as an example of the risks that extreme rainfall events may plausibly pose to Ghana. 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 increase around the Volta river basin, and along its connecting tributaries. The already highly vulnerable communities around the Lake Volta may be affected most by such increases in extreme rainfall events. An increase in extreme rainfall events may be associated with increases in the likelihood of flash flooding.

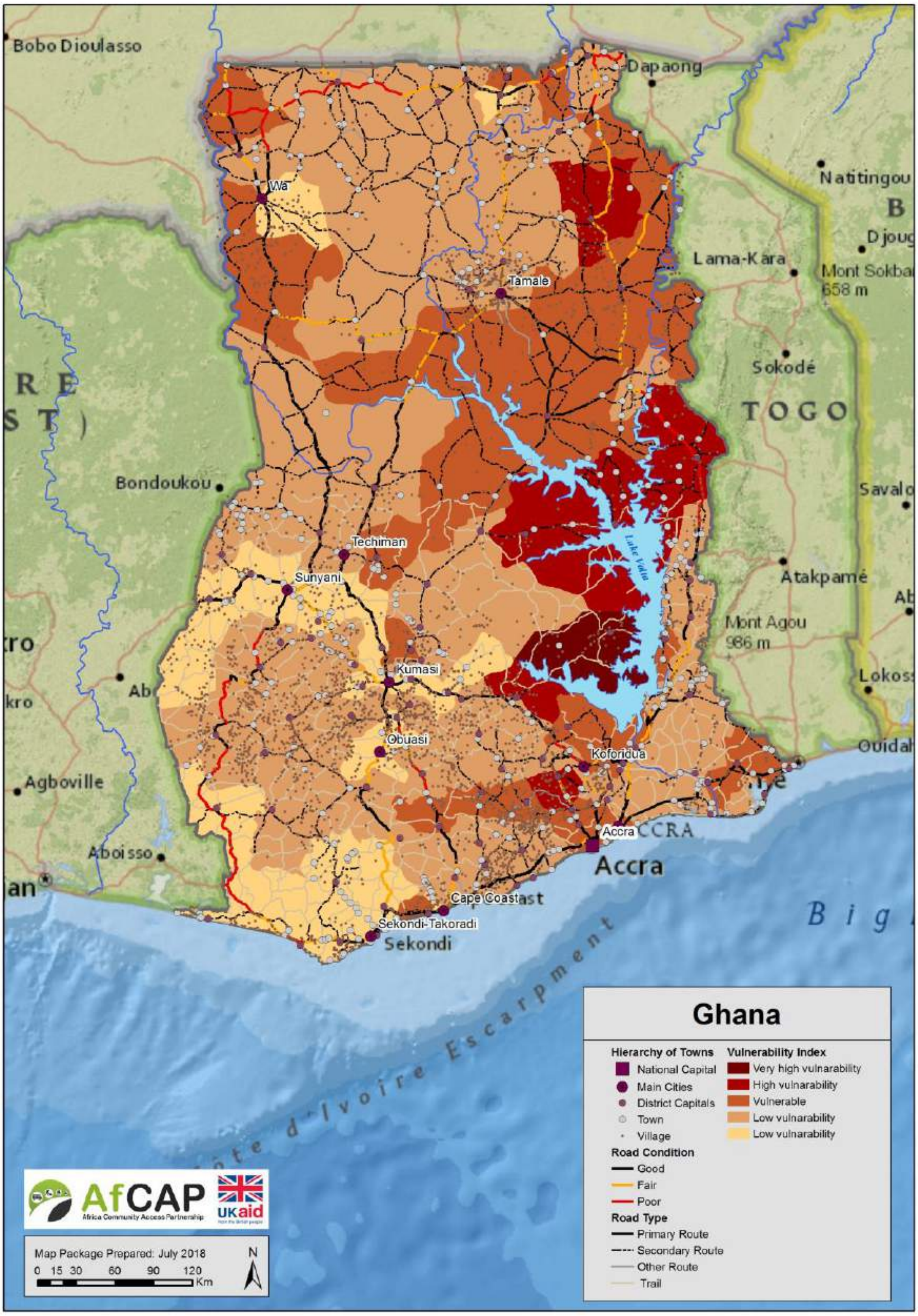


Figure 17: Ghana's most vulnerable districts in terms of flood exposure and road
Source: CSIR custom analysis, using Diva GIS (2017) and Tecsult International Limited (2009)

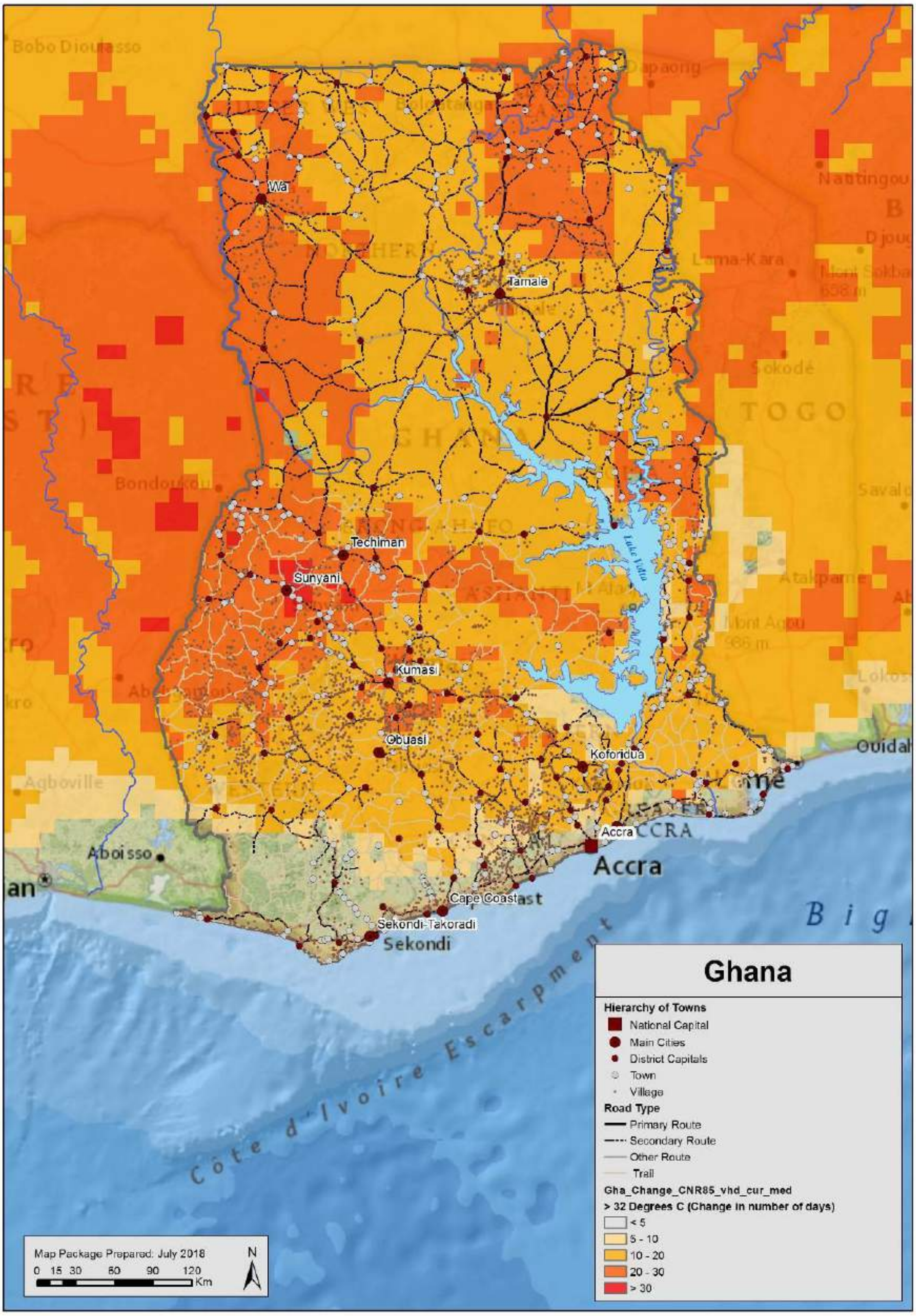


Figure 18: Exposure of Ghana's vulnerable communities to increases in very hot days (CNRM-CM5 downscaling)

Source: CSIR

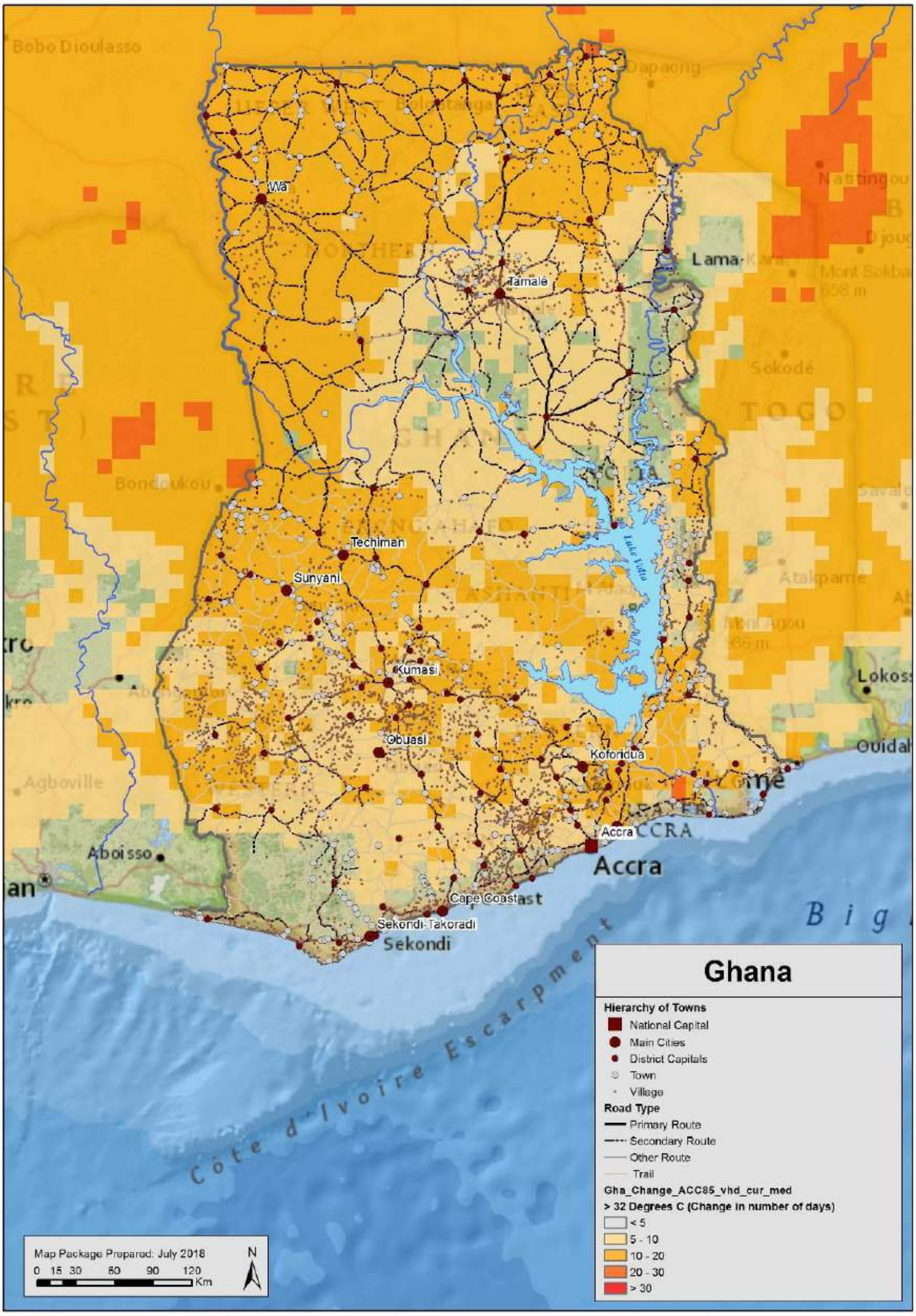


Figure 19: Exposure of Ghana's vulnerable communities to increases in very hot days (ACCESS1-0 downscaling)
Source: CSIR

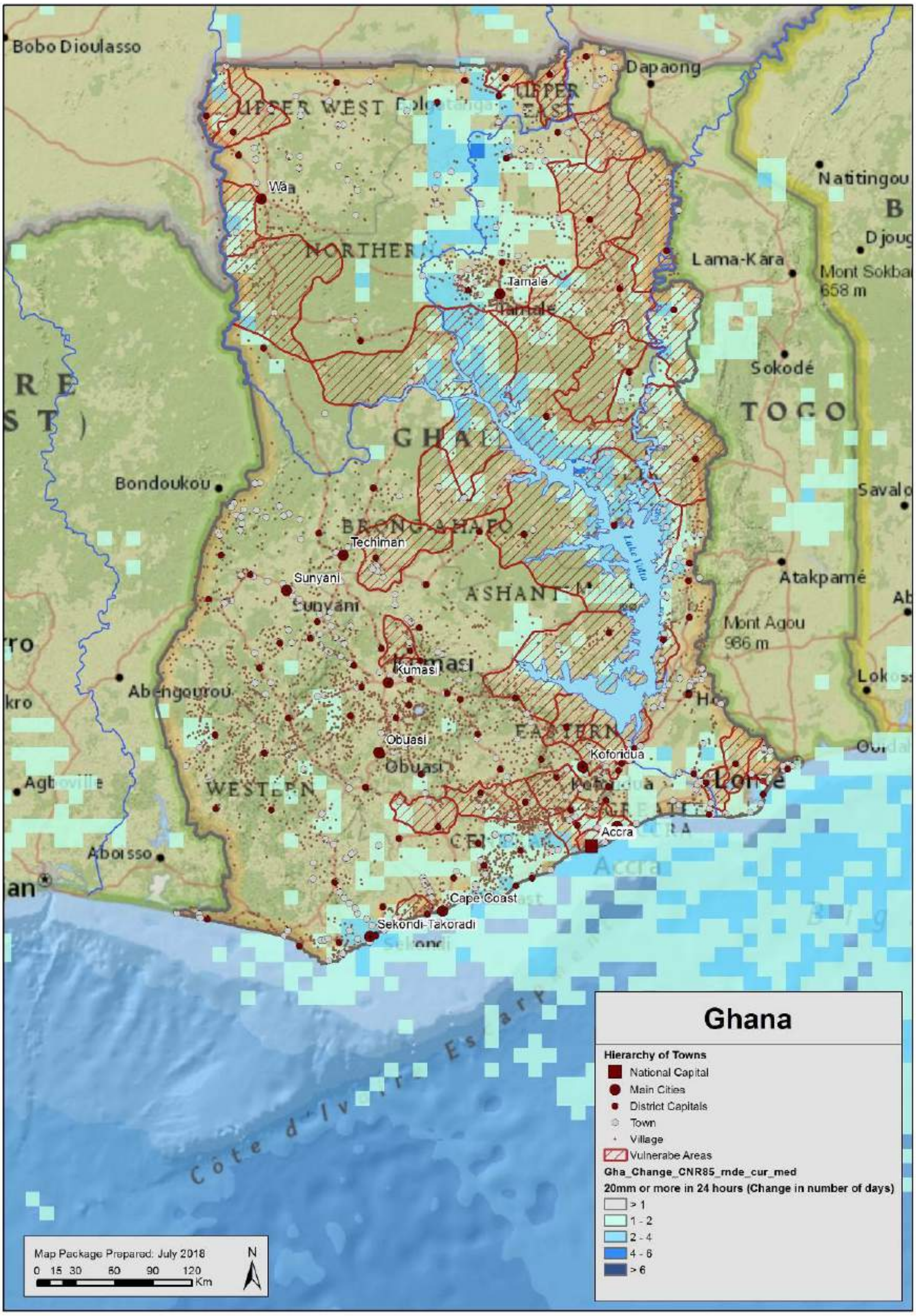


Figure 20: Exposure of Ghana's vulnerable communities to increases in extreme rainfall events (CNRM-CM5 downscaling)

Source: CSIR

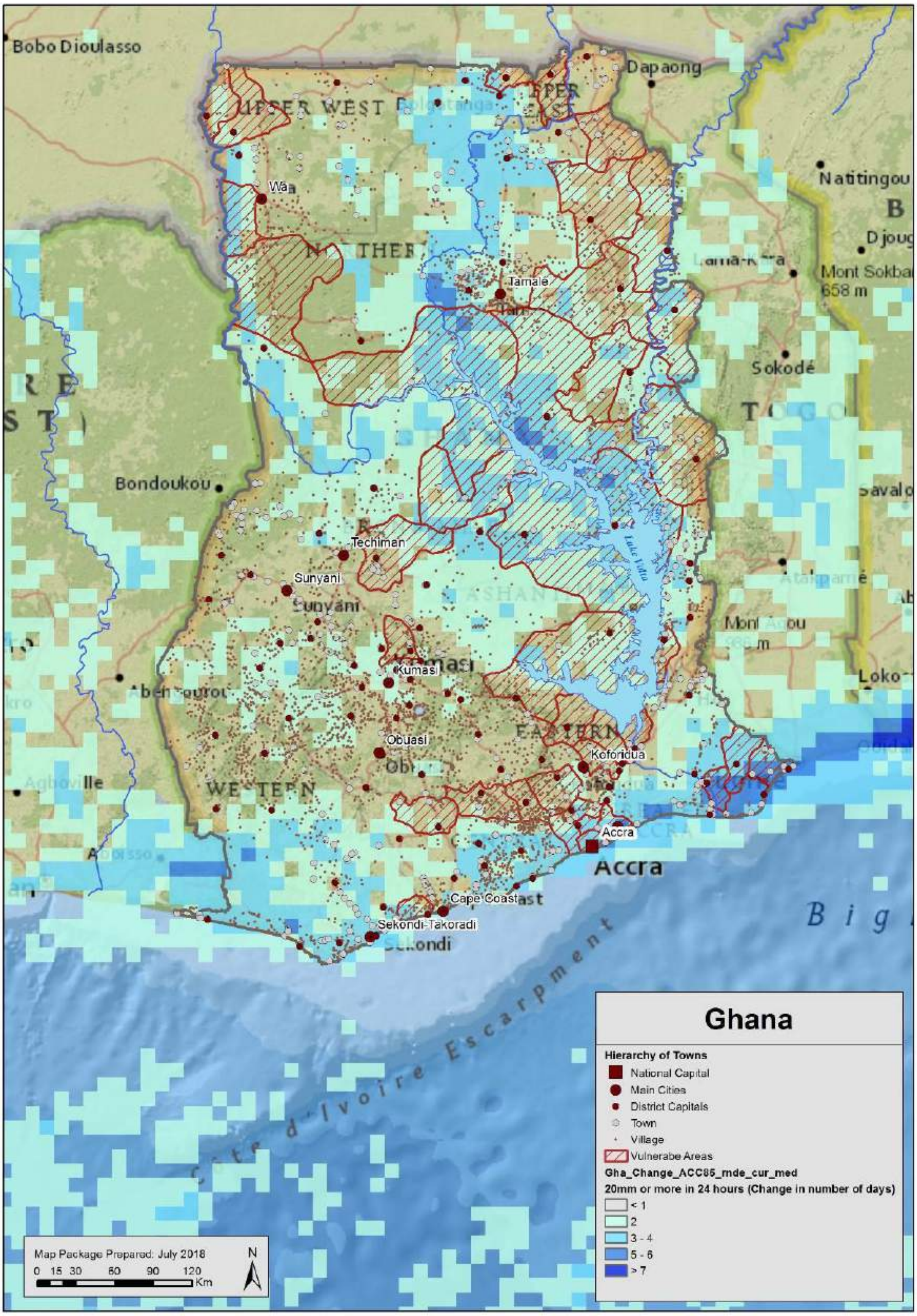


Figure 21: Exposure of Ghana's vulnerable communities to increases in extreme rainfall events (ACCESS1-0 downscaling)

Source: CSIR

4 The Ghanaian Climate Change Policy Environment

4.1 Overview of the climate change policy environment

Ghana has established a practical though ambitious policy programme. Its strategies are well documented and its adaptation programme has been underway for some years. However, links to transport and road infrastructure are weak as some of the policies etc. only refer to "infrastructure".

Several key government policy areas that would normally incorporate climate adaptation matters and associated strategies are due for revision. The National Transport Policy (2008) is being updated presently6 and the National Climate Change Plan (2010-2020) is also currently under revision. The 2014-2017 Medium-Term Plan has expired and the new Medium Term Plan is due for submission.

The National Environmental Policy (2012) recognises the threat from Climate Change. It identifies the following characteristics that need interventions *inter alia*:

- Changes in rainfall patterns with associated floods and disasters;
- Increased coastal erosion due to storms and sea level rises; and
- Drought in Sahelian with associated migration.

Disaster risk management and reduction interventions comprise:

- National Disaster Management Organization (NADMO) in place;
- Educational programmes to create public awareness; and
- Integrated watershed management to combat desertification.

The National Climate Change Adaptation Strategy (UNDP, 2016) sets out goals, objectives, strategies, programmes and actions. It reaffirms commitments under the United Nations Framework Convention on Climate Change (UNFCCC) as the fundamental role expected of Parties (national governments) to ensure that climate change issues are taken into consideration in national development planning.

The National Climate Change Committee (NCCC) is multi-sectoral but does not currently embrace members of the transport or roads community. It is understood that the National Climate Change Committee is to be reconstituted.

4.2 Vulnerability and adaptation policies

Ghana's economy relies heavily on the climate sensitive sectors of agriculture, energy and forestry. About 70% of the population depends directly or indirectly on agriculture (fisheries, crop and animal farming etc.) and the forest sector for both timber and non-timber forest products. Any anomaly in the climate therefore tends to affect the economy of Ghana, particularly the vulnerable people. The limited use of irrigation facilities and high dependence on unfavourable climatic conditions for the realisation of good harvests tend to introduce huge instability in the standards of living of the people. The percentage of cultivated land under irrigation in Ghana is 0.89%. This is equivalent to

[6] Presents an opportunity to incorporate Climate Change matters.

23 657 ha. Consequently, the majority of Ghanaians, who live in the rural areas and thrive mainly on rain-fed farming in rural communities, become disproportionately vulnerable since they are most exposed to hazards such as bush fires, flooding and droughts and are least capable of adapting to such (UNDP, 2016).

Broad government policy addresses, inter alia, economic and social infrastructure development; and sustainable and transparent management of natural and environmental resources. Policy development has aimed to reduce vulnerability and improve the wellbeing of Ghanaians through the implementation of measures for adaptation and climate risk reduction, mitigation with the active participation of stakeholders in the environmental and economic sectors. The National Environmental Policy (Ministry of Environment Science and Technology, 2012) recognises the threat from Climate Change and a National Climate Change Plan (2010-2020) has been developed. The Ministry of Environment, Science, Technology and Innovation is a supervisory agency tasked with establishment of institutional mechanisms to implement the National Climate Change Adaptation Strategy and liaising with the National Development Planning Commission to mainstream the Adaptation Strategy into national development planning processes and to coordinate the efforts of the other Government agencies, the private sector and civil society organizations.

Due to weak coordination between transport/road with other key sectors and limited capacity for mainstreaming, Climate Adaptation in planning and budgeting documents has not resulted in effective adaptation and mitigation activities. Instead, independent, actions have been sporadic, despite the inclusion of mitigation and adaptation policies and strategies in the environmental sections of central- and district-level Government.

4.3 Role of climate change policies, strategies and programmes

The government of Ghana has undertaken a fair amount of work on the issue of Climate change and they have established a number of policies that consider climate change. Ghana, as a signatory to international requirements of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, has recognized the risks of global warming to its economy and has committed to take appropriate responsive actions through national policies and plans. In addition to its two key adaptation policy documents, National Climate Change Adaptation Strategy (NCCAS), 2012, and the National Climate Change Policy, 2014, there are a number of other national documents that provide complementary adaptive actions for prioritized sectors. The emphasis of these policies has been on three sectors namely agriculture, forestry and energy. Naturally due to the strong focus on these sectors a number of adaptation programmes are under way in these sectors.

A review of Ghana's climate change policies conducted by Mensah and Nelson (Mensah & Nelson, 2016) has clearly highlighted the importance of improved quality and access to information, which has critical implications for stakeholders who need to make evidence based decisions. The dissemination of information to the local government where implementation is to occur is still ongoing. Asante et al., (2015) also indicated that responsibilities allocated by the National Climate Change Policy to Metropolitan, Municipal and District Assemblies (MMDAs) had not yet been recognized by the local level offices, who were also limited in their experience of the actual implementation of the proposed strategies.

According to Mensah and Nelson (2016) considering the different policies, there is similarity of national priorities in protecting and increasing the resilience of built and natural infrastructure, water resources, and agriculture, as well as improved service delivery, and livelihood diversification. Despite inherent challenges of poor baseline data, inadequate human and institutional capacities and limited funding that is mainly donor driven, there are recognized opportunities in that adaptation is being more incorporated into planning processes with more support by leadership from key ministries and cross-sectoral institutions, political will and establishment and staffing of climate change units within government (Padgham, 2014). The decentralization of planning in Ghana, where ministerial and other government functions have been devolved to the districts, also provides the opportunity for effective implementation at the local levels.

Another issue that has affected broad national climate change adaptation is periodic lack of coordination between sectors. This has resulted in lost opportunities for sectors to collaborate when dealing with data, implementation and planning and budgeting.

4.4 Ghanaian policies, strategies and programmes to deal with climate change

Climate change is being mainstreamed into Ghana's Shared Growth and Development Agenda and coordinated by the National Development Planning Commission (NDPC). The Ministry of Environment, Science Technology and Innovation (MESTI) hosts the National Committee on Climate Change. Representatives from relevant ministries, universities, research institutions, the private sector, and NGOs serve on the committee. The NCCC is responsible for formulating a National Climate Change Policy for Ghana that includes mitigation and adaptation actions that are to be integrated into planning processes at national, regional, and district levels. Other duties of the NCCC are recommending areas of study to the MESTI for comparing climate change adaptation strategies; identifying skills deficiencies and training needs; and developing harmonized climate change programs in the key sectors (US AID, 2011).

Ghana as a signatory to the international requirements of the UNFCCC, committed to take actions through national policies and plans. Ghana responded by developing two key documents namely the National Climate Change Adaptation Strategy (2012), and the National Climate Change Policy (2014) which provides a clearly defined pathway for dealing with the challenges of climate change. It, in turn was developed from the National Climate Change Policy Framework.

4.4.1 National Climate Change Adaptation Strategy

The **National Climate Change Adaptation Strategy (NCCAS)** (UNDP, 2016) sets out goals, objectives, strategies, programmes and actions. It reaffirms commitments under the United Nations Framework Convention on Climate Change (UNFCCC) as the fundamental role expected of Parties (national governments) to ensure that climate change issues are taken into consideration in national development planning. 2010-2020. Ministries, Departments and Agencies at the national level are responsible for policy, planning, monitoring and evaluation of development programmes and projects while execution of such programmes and projects are undertaken at the subnational levels, i.e., the government agencies and the district assemblies.

The National Climate Change Adaptation Strategy (UNDP, 2016) intends to enhance Ghana's current and future development by strengthening its adaptive capacity and building resilience of the society and ecosystems. It is anticipated to be reviewed and used by all stakeholders including the

Presidency, Cabinet, Members of Parliament, Members of the National Climate Change Committee, the Ministries, Departments and Agencies (MDAs).

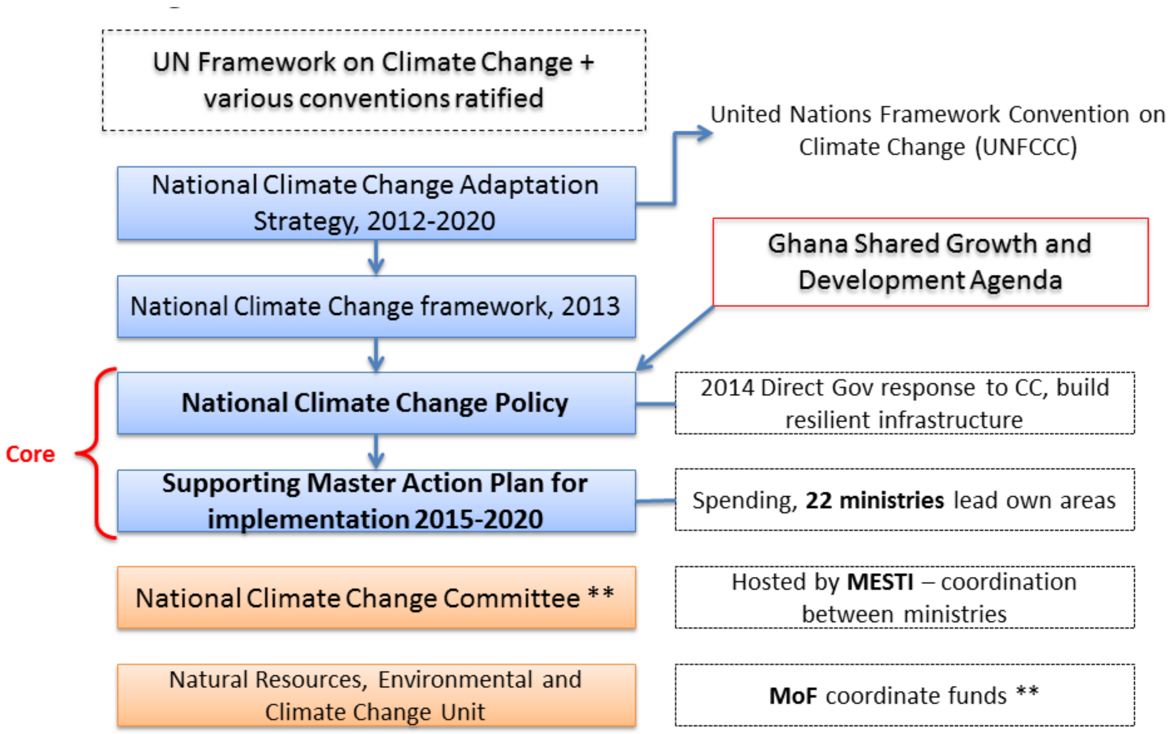


Figure 22: Key policies, strategies and programmes to deal with Climate Change

The NCCAS, which is operational from 2010 to 2020, intends to (i) ensure a consistent, comprehensive and targeted approach to increasing climate resilience and decreasing vulnerability; (ii) deepen public awareness, and in particular the awareness of policy makers, about the critical role of adaptation in national development; (iii) position Ghana so as to access funding for national adaptation requirements; (iv) strengthen Ghana's international recognition, in order to facilitate action; (v) facilitate the mainstreaming of climate change and disaster risk reduction into national development.

4.4.2 National Climate Change Policy

The **National Climate Change Policy** (NCCP) was developed from the National Climate Change Policy Framework (NCCPF). The National Climate Change Policy (NCCP) is Ghana’s integrated response to climate change. It has been prepared and designed within the context of national sustainable development priorities, including achieving the objectives of the Ghana Shared Growth and Development Agenda (GSGDA) 2010–2013. The NCCP promotes the understanding of climate change issues among policymakers and implementers across all sectors. This helps to integrate the climate change agenda into policies and interventions at all levels and across the high risk sectors

In July 2014, the government of Ghana launched a National Climate Change Policy (NCCP) of Ghana which seeks to essentially ensure a coherent and pragmatic approach in dealing with the impact of climate change on the socio-economic development agenda of the economy. The NCCP process identified ten Policy Focus Areas for addressing Ghana’s climate change challenges and opportunities. Each of these areas has a number of specific programmes for addressing the critical actions necessary to achieve the desired objectives.

The Policy Focus Areas are:

- Develop climate-resilient agriculture and food security systems;
- Build climate-resilient infrastructure;
- Increase resilience of vulnerable communities to climate-related risks;
- Increase carbon sinks;
- Improve management and resilience of terrestrial, aquatic and marine ecosystems;
- Address the impact of climate change on human health;
- Minimize the impact of climate change on access to water and sanitation;
- Address gender issues in climate change;
- Address climate change and migration; and
- Minimize greenhouse gas emissions.

It is the focus area dealing with climate resilient infrastructure that is most relevant to the roads sector. This policy does mention roads and action to be taken to improve adaptation strategies. It does however not go into details.

4.4.3 Climate Change Master Plan Action Programmes for Implementation

The **Ghana National Climate Change Master Plan Action Programmes for Implementation**: 2015 – 2020 (MESTI, 2015) has been produced under the guidance of the National Climate Change Committee (NCCC) for the Ministry of Environment, Science, Technology and Innovation. It sets out, by sector, the initiatives and programmes identified in the NCCP in the form of Action Programmes for implementation. The NCCP Action Programme for Implementation includes the details of initiatives and programmes to achieve the objectives of each Policy Focus Area. Under **Policy Focus Area 2: Build Climate-resilient Infrastructure**, it recognises the following challenges:

- Insufficient attention given to integrating climate change and its consequent disasters into Ghana's national development planning and budgeting process;
- Duplication of effort and limited allocation of resources to climate change activities;
- Inadequate capacity and ineffective coordination at all levels (national, sectoral, district);
- A low level of awareness of hazards and knowledge about how to manage them;
- The high level of poverty, especially in the most vulnerable communities; and
- Inadequate capacity.

It sets out proposed activities on the way forward as follows:

- Effectively mainstream climate change and disaster risk reduction issues into Ghana's national policy planning and budgetary issues to build a society resilient to disasters for sustainable development.
- To develop consensus, build capacity and adopt a participatory approach to climate change and disaster risk reduction issues at all times.

It sets out seven programme areas with associated actions (including costs and timelines), as follows (MESTI, 2015):

- Build Capacity to Design Climate Resilient Infrastructure:
    - Ensure that design standards, relevant codes and spatial planning include parameters related to climate change and variability, and future scenarios.
    - Strengthen the administrative and technical capacity of stakeholder organizations in the planning, design, building and construction industry to integrate climate change adaptation and disaster risk reduction in their development agenda.
    - Support research into appropriate infrastructure design standards for climate-related events.
- Knowledge Management and coordination:
    - Improve institutional coordination in hydro-meteorological networks to provide better climate data and information that is easily accessible to the general public.
    - Use information and communications technology (ICT) in monitoring and evaluating climate events and providing an early warning system.
    - Support the establishment of a community of practice as a knowledge management tool at all levels (national, regional, district).
    - Develop and improve upon mechanisms for effective coordination of climate change adaptation and disaster risk reduction at the national, regional and local levels.
- Climate -resilient Sectorial and Local Development Planning:
    - Develop and strengthen inter-sectoral linkages and collaboration for effective climate change adaptation and mitigation.
    - Provide an enabling policy environment to include and enforce climate resilience in land-use planning, construction, and codes and regulations.
    - Develop competencies of local authorities and communities on hazard, vulnerability and risk assessment.
    - Encourage private sector participation in climate change adaptation and mitigation at the local level.
- Ensure that Existing Key Infrastructure is Climate Proof:
    - Ensure that the vulnerability of existing infrastructure, especially those facilities that provide key services, is properly assessed.
    - Ensure the retrofitting of existing key infrastructure based on the order of priority.
    - Establish an appropriate reward scheme to encourage good retrofitting and maintenance practices.
- Flood Prevention Measures:
    - Support relocation of settlements and economic activities to non-flood areas.
    - Construct adequate storm drainage systems, buffer zones and riverbank protection, undertake afforestation along embankments, and desilt waterways to reduce flooding.
    - Construct channels, water-collection reservoirs and dams to contain floods and store water for the dry season.

- Develop Climate -resilient Infrastructure for Key Services:
  - Support the development of climate-proof infrastructure that provides key services to increase the resilience of communities during extreme climate events.
  - Ensure a safe and constant water supply, including during times of flood and drought.
  - Ensure that rural communities have access to all-weather roads and reliable access to markets and key services.
- Protection of Coastal Resources and Communities:
  - Collect relevant data on coastal zone geomorphology, surface water flows and groundwater for modelling coastal flooding and seawater intrusion.
  - Improve legislation and the institutional framework for effective coastal zone management.
  - Construct climate-resilient key coastal infrastructure to protect the communities from storm surges, coastal flooding, sea level rise and ecosystem degradation such as deforestation.
  - Promote an enabling environment for coastal dwellers to adopt best practices.

For each action, a detailed implementation matrix is presented covering purpose, outputs, indicators, assumptions and related tasks. In the programme areas listed roads and related infrastructure features under several programme areas. It remains the responsibility of the relevant Ministry or Department to take these actions and internalise and embed it in the functions and activities of the institution.

4.5 Policies and plans related to transport infrastructure

The Ministry of Transport has the overall responsibility for transport sector policy development and coordination. It is also responsible for coordinating and integrating sector plans and strategies, including integration with other sector ministries. The Ministry of Roads and Highways is responsible for the road network and its mandate is: policy formulation, sector coordination and oversight, and sector performance monitoring and evaluation of the following broad areas:

- Road Infrastructure development and maintenance; and
- Road Maintenance Financing.

The agencies operating under the Roads Ministry are;

- Ghana Highway Authority (GHA);
- Department of Feeder Roads (DFR);
- Department of Urban Roads (DUR);
- Koforidua Training Centre (KTC); and
- Ghana Road Fund Secretariat.

Ghana's Investment Promotion Centre estimates that road transport accounts for 96% of combined domestic passenger- and freight transport (Oxford Business Group, 2018). Although increased budget allocations has been made to the road transport sector (considering the 2016-17 period), there is still a funding backlog to deal with road maintenance (including backlogs). As it is unlikely to be resolved in the foreseeable, other option have to be considered. The 'Do nothing or do minimal' approach then becomes a necessary option. Detailed guidance is needed to manage this approach as effectively as possible. Within the transport sector the following policies, plans etc. are relevant when considering the issue of climate change.

4.5.1 The National Transport Policy (2008)

This National Transport Policy is the guiding document for the development of Transport in Ghana. It aims to describe the need for transport infrastructure and services in the context of Ghana's sub-regional, national and local growth objectives. It should also provide guidance on government priorities and strategic objectives for transport to key stakeholders and institutions involved in planning, financing, developing, providing, maintaining and regulating transport infrastructure and services. The policy did however not reflect the issue of Climate change. A future update of this policy should include climate change adaptation (Ministry of Transport, 2008).

4.5.2 The Integrated Transport Plan for Ghana (2010)

The Plan includes strategies and actions to be undertaken between 2011 and 2015 for all modes of transport including many institutional and regulatory measures aiming to improve performance and bring about better integration throughout Government's transport planning environment The Transport Sector goals were formulated to address issues affecting the sector and were identified through a wide ranging strategic review of transport sector performance undertaken between 2005 and 2007. In this case, the Government of Ghana has adopted the use of the Strategic Environmental Assessment (SEA) methodology as the means to ensure the operational integration of environmental quality objectives, economic efficiency principles, and social equity goals in planning and decision-making. This plan does reflect the issue of Climate Change. It indicates that Climate change is a phenomenon that is likely to have implications for the planning, design and implementation of initiatives in the transport sector and that transport policies, programs, plans as well as projects will have to consider the integration of concerns about climate change. It reflected on the need to build climate change capacity within ministries and agencies in the transport sector. The planning, design and implementation of project should also consider climate change, thus referring to the need to consider added criteria (Ministry of Finance and Economic Planning, 2010).

4.5.3 Road Sector Medium Term Development Plan

The Ministry of Road & Highways Sector Medium Term Development Plan (SMTDP Draft): 2014-2017 reviews policy objectives including network condition, Institutional Capacity, issues and challenges. It sets out an annual Action Plan and a Monitoring and Evaluation plan. The plan is aligned to the government's development agenda (Ghana Shared Growth and Development Agenda).

The principal objective of the transport sector is to ensure the provision of an integrated, well managed and sustainable transport infrastructure and services that meet national and international standards. The road sector policy objectives drawn from the National Transport Policy are directly linked to four out of the seven GSGDA thematic areas as shown in Table 4 below.

Table 4: Linkages of Sector Objectives with GSGDA Thematic Areas
Source: Ministery of Transport (2008)

Ghana Shared Growth and Development Agenda Thematic Areas	Sectors Objectives
Thematic area2: Enhancing Competitiveness of Ghana Private Sector	**Sector goal 4**: Create a vibrant investment and performance-based management environment that maximizes benefits for public and private sector investors
Thematic Area 5: Infrastructure and Human Settlement Development	**Sector Goal 1**: Establish Ghana as a Transportation Hub for the West African Sub-Region **Sector Goal 2**: Create a sustainable, accessible, affordable, reliable, effective and efficient transport system that meets user needs **Sector Goal 3**: Integrate land use, transport planning, development planning and service provision **Sector Goal 6**: Ensure Sustainable Development in the Transport Sector
Thematic Area 6: Human Resource Development, productivity and employment	**Sector goal 7**: Develop adequate Human Resources and apply new Technology
Thematic Area 7: Transparent and Accountable Governance	**Sector goal 4**: Create a vibrant investment and performance-based management environment that maximizes benefits for public and private sector investors **Sector Goal 5:** Develop and implement comprehensive and integrated Policy, Governance and Institutional Frameworks

The sector is also putting together its strategy towards mitigation and adaptation to the effects of climate change. It is taking steps to include climate change mitigation and adaption into its plans and programmes. Although the plan reflects the stronger inclusion of climate change, it does not provide details. Referring to maintenance of existing infrastructure, it indicates that currently there is not sufficient design knowhow to address the deterioration caused by climate change. These issues should be addressed in the next RSMTDP plan.

4.6 Important institutions dealing with Climate Change in Ghana

In Ghana, climate change is being mainstreamed into national development frameworks, such as the Ghana Shared Growth and Development Agenda (GSGDA) (2010–2013) coordinated by the National Development Planning Commission (NDPC). Practically every arm of government is affected by climate change either directly or through secondary effects or even by changes in central budget allocation as a result of government response to climate change. A large number of policies reflect Ghana's response to deal with it. The following highlights other key departments and their roles (relevant to the roads sector) (Ministry of Environment Science Technology and Innovation, 2013):

4.6.1 Ministry of Environment, Science, technology and Innovation (MESTI)

It is the core supervisory ministry dealing with climate change in Ghana. It is responsible for coordinating the CC efforts of the other Government agencies, the private sector and civil society organizations and to ensure that the programmes and projects under the strategy are in line with sectoral government policies and strategies. It also has to liaise with the National Development Planning Commission to mainstream the Adaptation Strategy into national development planning processes. It also operates institutions such as the Council for Scientific and Industrial Research (CSIR), The Ghana Environmental Protection Agency (EPA), The Town and Country Planning Department (TCPD). In addition, the National Climate Change Committee (NCCC) is hosted by MESTI through the EPA. This committee is made up of representatives from relevant ministries, universities, research institutions, the private sector and NGOs, and has been mandated under a ministerial directive. The NCCC has the mandate of reviewing policies and programmes to complement national priorities and contribute to actions for mitigation and adaption.

The EPA is the lead institution for UNFCCC activities in the country and is the main institution for country implementation and for technical coordination of activities on climate change and other environmental conventions ratified by Ghana.

4.6.2 Ministry of Finance and Economic Planning (MoFEP)

The Ministry coordinates all forms of support (domestic and international) to climate-change–related activities in Ghana. This is to avoid potential overlaps and potential duplication of efforts and above all to distribute resources to where they are most needed. MoFEP is also engaged in the process of developing national climate change budgeting guidelines to facilitate mainstreaming climate change into national planning.

4.6.3 National Development Planning Commission (NDPC)

The NDPC is mandated to advise the President of the Republic of Ghana on development planning policy and strategy. NDPC, working in close collaboration with EPA, MESTI and MoFEP, has ensured the reflection of climate change issues in the current Medium-Term Development Policy Framework. As part of its mandate, NDPC has translated climate change issues into planning guidelines and subsequently trained all the Metropolitan, Municipal and District Assemblies, on how to mainstream climate change issues into development plans.

4.6.4 Ghana Meteorological Services Agency (GMet)

The primary function of GMet is to provide efficient weather services through the collection, processing, storage and dissemination of meteorological data to end users. It is also responsible to collect climate information for further development into useable products for the country for further use by other institutions. It also supports hydrological modelling (which is relevant for future local level climate risk screening and assessments).

4.6.5 National Disaster Management Organization (NADMO)

The National Disaster Management Organization (NADMO) within the Ministry of the Interior (MOI) is responsible for the management of disasters and similar emergencies. In addition, NADMO is charged with ensuring Ghana is prepared to prevent disasters and to manage them well when they occur. With support from UNDP, EPA in collaboration with NDPC and the National Disaster Management Organization (NADMO) is facilitating initiatives to mainstream climate change and disaster risk reduction into national development at all planning levels (i.e., national, regional, district and across sectors).

4.6.6 Regional and district level implementation

District Level will be the most crucial level for the strategy implementation. The District Assemblies will be given guidelines concerning the preparation of climate change adaptation programmes and projects at the district level, selection of programmes/projects and the sharing of implementation responsibilities between the district Assemblies and the sub-district local authorities at the community levels. The District Assemblies will also be assisted by the decentralized departments, NGOs, CBO's, traditional authorities and the private sector in the preparation of detailed action plans and their implementation (Ministry of Environment Science Technology and Innovation, 2013).

The District Assemblies should ensure that they incorporate the programmes/projects of the district Disaster plans into their Adaptation plans. The District Assemblies will directly undertake adaptation programme/project of Community Level At this level, the Town/Area councils and unit committees should also prepare their own climate change adaptation plans and submit them to the District Assemblies for incorporation into the District Plans.

At the Regional level, the Regional Coordination Council (RCC) will be responsible for monitoring and evaluating District Climate Change Adaptation Strategy and will liaise with monitoring staff of National Climate Change Committee to remove bottlenecks in the implementation of District programmes.

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 Ghana to address climate resilience. It must be noted that Ghana 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 for embedment as indicated in the following diagram (Figure 23) is within the roads sector. It is however important to note that there is a strong linkage with the broader national climate change environment.

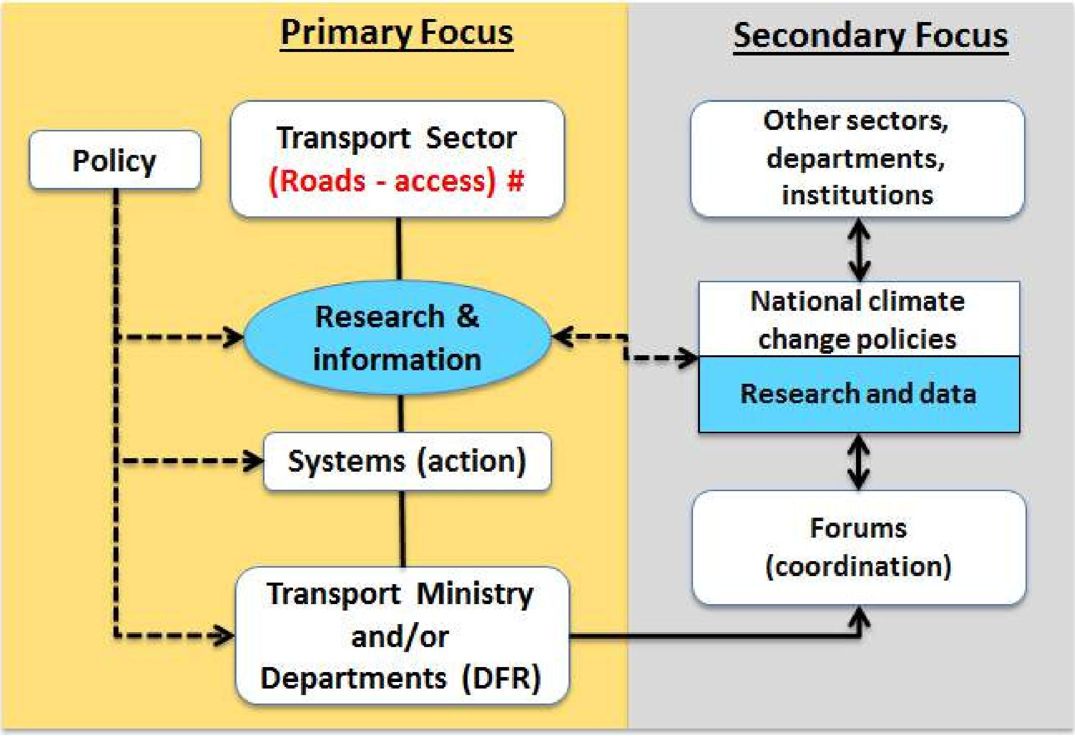


Figure 23: The dual focus of embedment

The roads sector does not stand separately from other sectors and there needs to be a strong relationship between all sectors when dealing with the challenges of climate change and the required adaptation. A number of structures have been established as indicated previously to address climate change challenges in Ghana. These structures have to be utilised as best as possible to incorporate the challenges addressed in the roads sector. The following will 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 policies and strategies of central- and district-level Government. The following actions are set out for discussion and agreement.

5.1 Change Management Options for Adaptation

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

5.1.1 Situational Analysis

A survey, followed by meetings with Government and at Workshops, established the following experiences and needs to be addressed:

- Road damage backlogs from climatic effects are increasing at an alarming rate and need appropriate guidance to address;
- Maintenance budgets are not adequate to deal effectively with climate effects requiring better Return on Investment and help with a Do Nothing / Do Minimal approach;
- Appropriate new policies and strategies need to be embedded in relevant plans, programmes and projects;
- Knowledge and capacity on climate adaptation needs strengthening;
- Relevant climate-related data needs to be collected to support a new approach;
- Training should be all levels and across all relevant stakeholders; and
- Need to provide assistance to allow more effective engagement with, for instance, the African Development Bank, Asian Development Bank, European Union, World Bank; Nordic Development Fund; Japan International Cooperation Agency; UKAid, with evidence to support funding applications.

Key challenges can be itemised as follows (CCDARE, 2016) - Poor and Inadequate Infrastructure with inadequate financial resources/Low budgetary allocation, limited Human Resource Capacity and a weak sub-regional network, flooding with associated siltation of river beds, high run-off, land degradation along the river banks and absence of proper flood management systems. This is exacerbated by drought and deforestation. Other constraints include:

- Lack of framework, inadequate human and financial capacity and logistics for the water resources management in the river basins;
- Inadequate water harvesting systems;
- Farming along the river banks causing siltation and reducing the carrying and storage capacities of the rivers; and
- Higher temperatures, in combination with favourable rainfall patterns, could prolong disease transmission seasons in some locations where certain diseases already exist. In other locations, climate change will decrease transmission via reductions in rainfall or temperatures that are too high for transmission.

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;
- 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.

5.1.2 Integrated Approach

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.

Improved network management will be achieved through the introduction of asset management policies that encourage better investment decisions and improved management of risk. Incorporate procedures to augment operational management covering:

- Road weather programmes;
- Disaster preparedness planning;
- Alternative transportation access; and
- Evacuation planning.

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.
- 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. This is a labour-intensive program supporting female-based employment for gender mainstreaming in the provinces.

Coordination between institutions engaged in the systematic collection of climate data is poor; the dispersed and inaccessible data collection network and its high maintenance costs; the lack of standardization; the irregularity and low quality of climate data; and incipient research programmes with minimal financing. Priority actions for research and systematic observation include those listed below. 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;
- Establish a peer review system for climate research;
- 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;
- Promote regional and international exchange; and
- Strengthen institutions that collect data.

5.2 Policies and strategies

Ghana has made commitments to address climate change as is evident from numerous national and sectoral policies and plans. Much progress has been made, over a relatively short period of time, to develop a national policy framework for climate change in Ghana. The National Climate change policy sits at the core of all the policies and plans and it aims to provide an understanding of the Climate Change across all sectors. The national policy, together with its accompanying draft master plan, provides detailed guidance to address the implementation challenges that confront the country's response to climate change (Asante, Bawakyillenuo, Bird, Trujillo, Addoquaye Tagoe, & Ashiabi, 2015).

Much needs to be done at the local government level to secure implementation. At present there is little awareness of what the national climate change policy is, what it requires of sub-national government, and the likely level of spending necessary. 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 Ghana there still exists a gap in dealing with climate change. Roads adaptation needs to be incorporated in the policies within the roads sector and then reflected in the sector strategy documents. The Ministry of Transport is responsible for the overall transport policy and it has to ensure that Climate Change issues are reflected in its policies. The Ministry and its departments need can reflect commitment to action by developing policy statements 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 the Department of Feeder roads there needs to be a responsible department and person that can lead implementation across the institution. Such a department can also lead cross-sectoral cooperation.

5.3 Collaboration

Dealing with climate change in Ghana is not a new development, several national and sector departments have undertaken to develop policies, strategies and plans. Through these efforts a number of networks have been established to deal with undertaking research and sharing information. It might therefore be beneficial to join such networks rather than to establish many new ones. It is suggested that the National Climate Adaptation Committee (once reconstituted), which is being hosted by MESTI, be joined.

In view of collaboration, it is suggested that contacts be established with the following:

- Environmental Protection Agency (part of the Energy and climate change unit in MESTI);
- National Meteorological Agency;
- National Disaster Management Organisation (NDMO); and
- EPA and National Development Planning Commission for Policy Action Programme Implementation.

The importance of climate change adaptation in the road sector needs to be promoted beyond Ghana, extending 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.

5.4 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 shared benefit of such efforts is not achieved. 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. Ghana 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 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 **Ghana meteorological department, and CERSGIS;**
- Road network coverage, criticality and accessibility analysis should be done and updated annually by the **Department of Feeder Roads and Ministry of Roads and Highways;**
- Current climate trends and climate change projections recorded and analysed by the **Ghana meteorological department**, **and CERSGIS**; and
- Socio-economic data and population trends to be captured by a national census conducted at regular intervals, overseen by the **national statistical service**.

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

Ghana is in the fortunate position that is has several institutions that can undertake climate research and provide climate data outputs. The main challenge is to work and share information across institutions.

- The systematization of observations and collection of data relevant to research, in order to produce information that helps with decisions related to the implementation of appropriate measures; and
- Capacity-building through training, education and awareness-raising at all levels, and in involvement with international processes.

5.5 Asset Management Systems – state of readiness

The Ghana Highway Authority (GHA), the Department of Feeder Roads (DFR) and the Department of Urban Roads (DUR) in the Ministry of Roads and Highways (MRH) are charged with the responsibility for the administration, planning, control, development and maintenance of trunk roads, feeder roads and urban roads respectively in Ghana. These different departments handle asset management differently and there is currently no single system being used across all departments within the ministry. The Department of Feeder Roads (DFR), which is the department responsible for the lower order rural access road network (feeder roads), is currently using a GIS system for road asset management. It is not only a GIS, but it is also linked to an Access database that contains inventory and condition data for roads and structures (bridges and culverts). The GIS and database interface allows the DFR to draw reports and statistics. The GIS and database interface currently serves as the DFR's road asset management system. The GIS also contains social facility locations such as schools, health facilities, markets, etc.

The DFR also has an MS Excel-based Maintenance Wizard that is used for routine road maintenance planning and budgeting. The Maintenance Wizard uses condition data from the GIS based RAMS to calculate maintenance requirements and budgets. The wizard makes provision for three levels of maintenance, namely minimum, basic and standard. It contains unit costs for these three maintenance levels for four different climate zones. It also includes traffic information. Routine road maintenance is only done on the engineered and partially engineered networks, while the un-engineered network is not maintained.

Road condition data is recorded at district level. Relying on this distributed assessment approach does have constraints and part of the challenge is applying a consistent form of evaluation across many districts. This requires training to ensure a standard measure is applied. The DFR also experimented (with the assistance of CERSGIS) to see if the combination of satellite and drone technology could be used to measure road condition. This project is still underway and could be a way to accelerate road condition assessments.

The Research, Statistics and Information Management (RSIM) Directorate in the MRH is busy with a project for GIS Support for Transport Infrastructure Management. This project involves the creation of an enterprise GIS for the MRH. The project commenced in April 2014 and Phase 2 was finalized in June 2015.The outputs of Phase 2 of the project are a GIS enterprise database, GIS Desktop capabilities, a core Web GIS solution and knowledge transfer. The GIS system consists of a combination of Commercial off-the-shelf (COTS) and Open Source (OS) components. The proprietary software is underpinned by the ESRI ArcGIS software and QGIS is the Open Source software component selected to be integrated into the COTS stack to support data production. It will also include the use of web services (a means to expose the spatial information via the internet to other spatial data users). During the next phase of the project, data in the database will be cleaned-up; the database will be populated with data from designated/selected areas; and a RAMS will be developed or procured that would draw from the GIS backbone.

The development of this enterprise GIS and the implementation of a MRH RAMS could present an opportunity to include other spatial information such as the climate risk and related information in the GIS and the RAMS.

5.6 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 captured periodically 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:

- Distributing responsibilities to the ad-hoc reporting group, and disseminating their reports (according to the National System);

- 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 this is also applicable to the Department of Feeder Roads 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; and
- 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.

5.7 Agreed actions

The abovementioned items reflects broadly on a range of items 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 access road network (DFR). It is clear that the roads sector in Ghana is divided among several departments (under the ministry of roads and highways). Ideally as the lead institution - the ministry of roads and highways - should ensure that its departments should coordinate and collaborate when dealing with climate change research. Similarly when considering issues of design and maintenance that would be overlap between the feeder roads, urban roads and highways departments. During July 2018 a series of mini-workshops, technical sessions and engagements were held in Accra. A number of items were addressed and subsequent actions agreed. These are described below.

<u>Contribution to the new National Transport Strategy</u>

This item was raised during a number of discussions as well as during the workshops. This is a current World Bank funded project to draft a new National Transport Strategy. This therefore provides the ideal opportunity to incorporate climate change issues. The previous policy did not reflect climate issues at all. Currently the consultant responsible is preparing the draft Green Paper for validation by stakeholders. When the Draft Green Paper is made available to the project steering committee a copy will be forwarded to the AfCAP team for comments. The Draft Green Paper is expected to be submitted by the end of July (Agyeman-Boakye, 2018). Once this has been sent to the AfCAP team comments can be prepared.

<u>Spatial information transfer</u>

During the second day of the workshop and engagements a session was held with the Mr Richmond Ankrah (Head of the GIS/IT Section in DFR). The geospatial map package was provided to him and he was also taken through the contents and the accompanying documentation. A further set was provided on a USB data stick to Dr. Patrick Bekoe for further distribution as well as for those not able to use the prepared DVD disks. Regarding the hosting of the geospatial information at MRH, it was concluded that it would best be suited within the GIS/IT Section in DFR.

These activities therefor concluded the transfer of the prepared spatial information to MRH.

MRH Road Asset Management System and Climate Assessments

The DFR road asset management system is a GIS-based system being used by Mr. Mr Richmond Ankrah and his colleagues. In the short term they will continue to use this system to manage and plan their road projects and maintenance. As the geospatial map package had been provided to him it is therefore also available to be drawn into the road asset management system. The spatial information currently available (at district level) could form the first round of information embedment. For the longer term it was indicated that MRH is currently investigating a comprehensive Road Asset Management system that can possible be sourced and implemented by all the departments within the ministry. It is in an exploratory phase with a final decision still to be made.

Currently MRH does not have a climate change adaptation (CCA) policy. In order to fully operationalise climate change adaptation in MRH, such a policy would have to be adopted. In the interim added information to the road asset management system (GIS-based) can assist in the prioritisation of projects.

Risk and climate threat vulnerability assessment: sharing the information

Although spatial information has been supplied to MRH (See Item 2) it still raises several questions, such as:

- How can the spatial information linkages between MRH and other institutions be established, and with whom?
- Who in MRH will be the key person responsible for climate change information etc.?

As a result of the AfCAP work in phase 1 (and expanded in phase 2), climate change spatial data items are available for use by MRH (and other departments). The issue was the mechanism that could be used by MRH to make this climate change information available to other ministries and state agencies.

Mr Obeng concurred that MRH needs to encourage the relationship with departments and agencies that are involved in climate science such as NADMO, ETA and others. He indicated that they will invite them to MRH to also explore in more detail what information they have, and how they could possibly support MRH. This will be an action initiated by MRH. This will also address the sharing the AfCAP geospatial information with the wider Climate Change community, this could also be the institutions to start (as part of a collaboration possibly).

One forum where climate change work can also be shared and discussed (focussed on the roads sector is in the Transport Sector Working Group which meets quarterly and is coordinated by the World Bank and Ministry of Transport. Mr Richardson (WB representative) indicated that AfCAP could be invited to such a meeting to inform the group on the AfCAP work.

Research material/outputs provided

The Handbook and its associated guidelines were provided to MRH both in printed copies during the 2 workshop days as well as in electronic format. The 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. Mr Obeng indicated they would look at the documents and provide comments where feasible.

(A separate meeting was held with Mr John Richardson from the World Bank, he indicated that they would also provide comments/feedback)

Assistance with a MRH Research Policy to incorporate climate science elements:

Mr. Obeng also raised the importance of developing a research policy for MRH – this had already commenced but it could also draw on the climate science work done by AFCAP as well as other ministries and agencies. He requested that once they have progressed and drafted a basic policy, that AfCAP could make comment etc. He requested the AfCAP team consider this contribution (also in light of the AFCAP work and related policy embedment aims). He would make this draft policy available to AfCAP for comments.

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