

The Gambia National Transport System Climate Risk Assessment

Technical report

15 March 2026



GLOBAL
CENTER ON
ADAPTATION

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Acknowledgements :

This report builds on analyses conducted by GCA under the Africa Adaptation Acceleration Program (AAP), an initiative launched by the GCA in collaboration with the African Development Bank, endorsed by the African Union. The work benefited from collaboration with the World Bank teams for The Gambia Infrastructure Project and CCDR, as well as insights shared by the Ministry of Transport Works & Infrastructure, the Ministry of Environment and Climate Change, the Department of Water Resources, and the National Roads Authority of The Gambia.



**GLOBAL
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ABOUT THE GLOBAL CENTER ON ADAPTATION

The Global Center on Adaptation (GCA) is an international organization, hosted by the Netherlands, which works as a solutions broker to accelerate action and support for adaptation solutions from the international to the local, in partnership with the public and private sector, to ensure we learn from each other and work together for a climate resilient future.



AFRICA ADAPTATION ACCELERATION PROGRAM

GCA is providing technical assistance under the African Adaptation Acceleration Program (AAP), a joint initiative launched by the GCA and the African Development Bank in 2021.

In Partnership with:



WORLD BANK GROUP

Consultants:



CONTEXT

The Global Center on Adaptation (GCA) is an international organization working to accelerate action on adapting to climate change and building resilient economies.

Under the African Adaptation Acceleration Program (AAAP), GCA supports The Gambia in embedding climate resilience into national planning and infrastructure investment projects – including The World Bank Gambia Infrastructure Project, The African Development Bank Banjul Port 4th Expansion and Senegambia Bridge Asset Recycling projects. Since 2024, GCA has partnered with IFIs, the Ministry of Transport Works and Infrastructure, the Ministry of Environment and Climate Change, NAWEC, the Water Resources Department and the National Roads Authority of The Gambia to assess climate risks to the transport sector, water resources, identify adaptation solutions, and strengthen local capacity through training activities.

In this context, GCA is supporting the World Bank and governmental institutions on a \$50 million investment to enhance climate resilience in The Gambia's transport and energy infrastructure. The project focuses on improving last-mile connectivity by expanding low-voltage electricity access in 225 rural communities, strengthening urban energy grid redundancy, and upgrading 150 kilometers of seasonal roads to ensure reliable year-round access. Additionally, the project focuses on strengthening The Gambia's transport and energy sectors through policy reforms, institutional capacity building, and improved planning for sustainability, resilience, and universal access. It includes support for road sector management, climate-resilient design standards, and enabling frameworks for renewable energy investment, energy efficiency, and private sector participation.

GCA's support focuses on prioritizing infrastructure investments from an adaptation perspective, with the aim of strengthening connectivity, identifying and assessing targeted adaptation measures, and developing implementation guidelines to improve existing design standards. In parallel, GCA is contributing to related initiatives. This work seeks to reinforce sectoral ambitions by integrating climate change considerations with development objectives, while promoting the incorporation of long-term strategies for climate resilience.

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EXECUTIVE SUMMARY

Introduction

The Gambia is highly vulnerable to climate risks. Under the Africa Adaptation Acceleration Program (AAAP), the Global Center on Adaptation (GCA) is providing technical assistance support to integrate climate adaptation into the transport, energy and water resource sectors in The Gambia.

This Report documents the assessment of nation-wide climate risk screening and preliminary prioritization of adaptation options for the transport sector. Building upon a previous climate hazard assessment (GCA, 2024) which analysed flooding, drought, wildfire, extreme temperature, precipitation, and wind hazards across two climate scenarios (RCP4.5 and RCP8.5) and four future time horizons (2030, 2050, 2070, and 2090), this assessment describes the impacts and qualitatively assesses the risk to The Gambia's transport systems from current and projected climate hazards.

This risk screening identifies the most urgent climate hazards and most vulnerable infrastructure assets, providing an identification of the most at-risk transport assets, the high-risk areas within The Gambia and the critical transport connections within the infrastructure network.

Climate Risk

The climate risk screening described the impacts and qualitatively assessed the risk to the transport network due to current and future projected climate hazards. This allows to identify the key climate hazards and most vulnerable infrastructure assets, providing an identification of the most at-risk transport assets, the high-risk areas within The Gambia and the critical transport connections within the infrastructure network.

The climate risk screening evaluates the following impacts on The Gambia's transport network:

1. Direct risk, or the physical damage.
2. Socio-economic impacts, or the disruptive impacts to key facilities for the population, economics and tourism.

The direct risk assessment revealed that a significant portion of roads in The Gambia are exposed to flooding. For fluvial flooding, 38% of roads and for pluvial flooding, 56% of roads have a low direct risk score (between 0-10). A smaller percentage of roads have a risk score of 10 or higher (5% for fluvial and <1% for pluvial). This suggest that most exposed roads experience shallow flooding during high-frequency events. The direct risk assessment showed that for extreme temperature, the entire paved road network in The Gambia is at direct risk, with risk scores ranging from 60-80 inland and not exceeding 30 along the coast.

Climate change projections indicate an increase in direct risk scores for both flooding and extreme temperatures. The increase in risk score for flooding showed that certain roads currently at no flood risk expected to become exposed to flooding by 2050. For fluvial flooding, this is an increase from 43% to 45% of all roads in The Gambia from the baseline to 2050. For pluvial flooding, the increase is from 57% to 61%, and for coastal flooding, it's from 1.1% to 1.6%. The risk scores for extreme temperatures, which are already high, are projected to further increase throughout The Gambia by 2050.

Although many roads in The Gambia have a low direct risk score for flooding, due to flood depths often remaining below 0.5m during high-frequency events, accessibility is significantly impacted as roads become inaccessible at a 0.3m threshold. Of the 3,251 km identified as critical for accessing social facilities, 279 km are classified as medium risk and only 41 km as high risk. When these roads become inaccessible during a flood event, 11% of the population is cut off from markets, 8% from schools, and 11% from hospitals.

To integrate direct risk and socio-economic impact results, critical roads (low, medium, or high criticality) with a direct risk score above 10 were selected. A total of 104 km of roads were identified with medium criticality and 8 km with high criticality.

Preliminary Adaptation Options

A long-list of potential climate adaptation measures that may address the key climate risks identified for The Gambian national transport network was made that comprises 35 adaptation options.

A short-list of 12 adaptation options were selected covering a range of climate risks and infrastructure asset types. These adaptation options were described in 1-page Project Briefs using details sourced through engagements with national stakeholders through the course of this assignment.

Way Forward

The insights and results arising from this Report can be used to support:

- the prioritization of road segments for inclusion in the World Bank's The Gambia Infrastructure Project;
- the development of the World Bank's Country Climate Strategy; and
- the Government of The Gambia (Ministry of Finance and Ministry of Transport, Works and Infrastructure) in integrating priority adaptation and resilience interventions, including Nature-Based Solutions (NBS), into the new Transport Masterplan for the roads and fluvial transport system network.
- the sourcing of funding and financing for the selected adaptation options described in the Project Briefs.

GLOSSARY

Acronyms	Definitions
AAAP	Africa Adaptation Acceleration Program
AfDB	African Development Bank
BIA	Banjul International Airport
CFSVA	Comprehensive Food Security and Vulnerability Analysis
FAO	Food and Agriculture Organization
FWI	Fire Weather Index
GBA	Greater Banjul Area
GCA	Global Center on Adaptation
GDP	Gross Domestic Product
GFSC	Gambia Ferry Services Company
GHG	Greenhouse Gas
GIS	Geographic Information System
ICESCR	International Covenant on Economic, Social and Cultural Rights
IWT	Inland Water Transport
LGA	Local Government Area
NBS	Nature-Based Solutions
NRA	National Road Authority
OSM	OpenStreetMap
RCP	Representative Concentration Pathway
RP	Return Period
SPEI	Standardised Precipitation and Evapotranspiration Index
SSP	Shared Socioeconomic Pathways
WB	World Bank

1. INTRODUCTION

1.1 Assignment Background

The Gambia is highly vulnerable to climate risks. Under the Africa Adaptation Acceleration Program (AAP), the Global Center on Adaptation (GCA) is providing technical assistance support to integrate climate adaptation into the transport, energy and water resource sectors in The Gambia.

Haskoning, in association with Rebel Group, Lobelia Earth, and CityScape Associates (together 'the Consultant'), has been appointed by the Global Center on Adaptation (GCA) ('the Client') to carry out the assignment: *Integrated Adaptation Options for Transport, Energy and Water Sectors in The Gambia*.

The broad objective of this assignment is to provide an assessment of climate risks and vulnerability of the transport sector (nation-wide and project-specific), water resource sector (nation-wide) and energy sector (project-specific), that in turn informs the definition of adaptation measures to address these risks. Furthermore, consideration of the implementation of these adaptation measures, and discussion in that regard with national stakeholders, will enable climate adaptation policy recommendations to be developed that can inform future discussions on national policy reform. To achieve these objectives, the assignment is structured into 5 components, as follows:

- Component 1: Climate Change Analysis
- Component 2: Transport systems climate-risks analysis and adaptation options for roads and fluvial network
- Component 3: Supporting specific transport and energy investment project to include climate risks and adaptation and resilience options
- Component 4: Water resource and risks related to climate change assessment
- Component 5: Policy Analysis for the Transport and Water sector

1.2 This Report

1.2.1 Report Objectives

This report relates to Component 2 of the assignment.

It documents the assessment of nation-wide climate risk screening and preliminary prioritization of adaptation options for the transport sector. Building upon a previous climate hazard assessment (GCA, 2024) which analysed flooding, drought, wildfire, extreme temperature, precipitation, and wind hazards across two climate scenarios (RCP4.5 and RCP8.5) and four future time horizons (2030, 2050, 2070, and 2090), this assessment describes the impacts and qualitatively assesses the risk to The Gambia's transport systems from current and projected climate hazards.

This risk screening identifies the most urgent climate hazards and most vulnerable infrastructure assets, providing an identification of the most at-risk transport assets, the high-risk areas within The Gambia and the critical transport connections within the infrastructure network.

The insights and results from the climate risk screening supports the identification and prioritization of adaptation and resilience options to support:

- the prioritization of road segments for inclusion in the World Bank's The Gambia Infrastructure Project;
- the development of the World Bank's Country Climate Strategy; and
- the Government of The Gambia (Ministry of Finance and Ministry of Transport, Works and Infrastructure) in integrating priority adaptation and resilience interventions, including Nature-Based Solutions (NBS), into the new Transport Masterplan for the roads and fluvial transport system network.

1.2.2 Report Structure

The report is structured as follows:

- **Chapter 2** presents the methodology used for the climate risk screening and for the preliminary adaptation investments options prioritization.
- **Chapter 3** discusses the climate and transport infrastructure data and assumptions made for the climate risk screening.
- **Chapter 4** presents the results of climate risk screening for roads and bridges.
- **Chapter 5** presents the results of climate risk screening for the Port of Banjul and river ferries.
- **Chapter 6** presents the results of the preliminary adaptation investments options identification and prioritization.
- **Chapter 7** provides 12 no. adaptation Project Briefs.
- **Chapter 8** provides key conclusions of the climate risk screening and preliminary adaptation options, and the way forward.

2. METHODOLOGY

In this chapter, the methodologies used for the climate risk screening, which consists of a direct risk calculation and the analysis of socio-economic impacts, and the methodology to assess adaptation investment options for a resilient transport network, are explained.

2.1 Climate Risk Screening

The climate risk screening aims to assess the potential consequences of climate hazards on The Gambia's transport network assets and population. The goals of this screening are to:

- Identify critical transport connections to prioritize segments/assets for adaptation.
- Determine at-risk areas, asset types, and communities vulnerable to climate hazards.

The climate risk screening evaluates the following impacts on The Gambia's transport network:

1. **Direct risk**, or the physical damage.
2. **Socio-economic impacts**, or the disruptive impacts to key facilities for the population, economics and tourism.

2.1.1 Direct risk

Direct risk refers to the direct cost of physical damage to infrastructure. Where risk is defined as:

Risk = Hazard x Exposure x Vulnerability.

It is the combination of the probability of natural hazards and the potential of damage to the different transport infrastructure assets.

For this Assignment, we calculate the direct risk quantitatively using a risk index score between 0 and 100 for the transport assets. The risk index score is calculated across the different climate scenarios, return periods, per hazard. Figure 2-1 illustrates the methodology applied, showing that for each climate hazard identified from the climate risk screening, a direct damage fraction is calculated for the infrastructure assets of The Gambia's transport network (exposure), considering their vulnerability. For each hazard scenario, a compound direct risk score was calculated

The risk index score is used to determine which transport assets are at high or low risk, allowing prioritization of investments in the assets most at risk. Each of the risk components (hazard, exposure, and vulnerability) and their application in calculating the risk index is explained in more detail below.

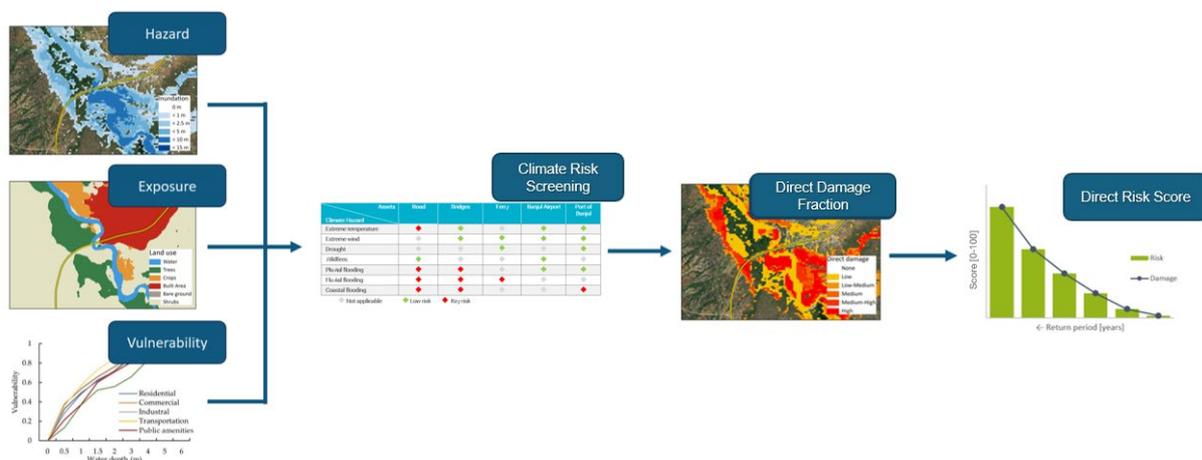


Figure 2-1: Methodology for development of the direct risk assessment.

Hazard

Hazard considers the climate hazard events that may impact the transport assets. The key climate hazards for The Gambia's existing infrastructure are identified with an initial climate risk screening. For each hazard, the intensity (e.g., number of days above 35°C and 40°C or flood depth) is calculated for different frequencies (i.e., return periods) to identify areas prone to these hazards. Hazard maps are calculated and developed for the baseline based on historical data and for future scenario based on climate change projections.

Exposure

The exposure data is based on open-source information from OpenStreetMap (OSM) and completed based on data collected from relevant agencies in the Gambia. A generic road profile and build-up based on locally available standards is assumed, our experience in projects within those countries, and the technical specifications for road works from NRA. This information helps us gain spatial and temporal insights into the influence of hazards on transport assets.

Vulnerability

Vulnerability of the transport assets to a hazard is captured in vulnerability functions. A vulnerability curve shows the relationship between the intensity of a hazard (i.e., flood depth) and the degree of damage or loss it causes (i.e., percentage of damage). It also shows how damage or loss increases with the intensity of the hazard. The curves vary depending on the transport asset differences such as difference in profile or materials used. Haskoning's experience in other projects in relevant countries across Africa contributes to ensure the applicability of these curves to the local context of the selected countries.

2.1.2 Socio-economic impacts

The climate-risk screening is supported by a network analysis, which defines the relative economic (trade route importance), social (impact on people from transport disruptions), and tourism significance of the transport network. This analysis identifies critical roads for accessibility and communities affected by climate hazards. The results highlight frequently used routes for socio-economic purposes, supplementing the climate risk screening by focusing on the expected impacts of network disruptions caused by climate hazards on communities, including economic, social, and food security impacts.

For the economic analysis, the network model will demonstrate how climate hazards affect national trade flows, particularly between main markets, border crossings, and the harbour. For example, a flood-blocked road would necessitate rerouting, increasing travel time. The social analysis assesses people's accessibility to crucial facilities, prioritizing key factors in the Gambian context, such as healthcare, markets, and education. For the tourism analysis the network between hotels and the airport is considered.

The network analysis is conducted for both the current situation and a 'hazard event' scenario. Only hazard events with an immediate threat to population connectivity are considered.

2.2 Preliminary Adaptation Investments Options Prioritization

The methodology to assess potential adaptation and resilience investment options for resilient transport infrastructure in The Gambia involves three steps:

- 1) identification of a long-list of potential measures per asset/hazard (informed by outcomes of the climate hazard assessment and the climate risk screening, which identified the key hazards and risks);
- 2) development of a short-list of measures, and
- 3) Prioritization of measures with a multi-criteria approach (where different measures are compared on cost-effectiveness, socioeconomic impact, environmental aspects, adaptation benefits and constraints. The outcome of this step is a prioritized set of measures that address the identified climate risk hotspots)

Each of these steps involved consultations with local stakeholders and expert knowledge from experience in the implementation of projects in The Gambia and other countries on the African continent.

3. CLIMATE AND TRANSPORT INFRASTRUCTURE DATA

This chapter discusses the climate and transport infrastructure data and assumptions made for the climate risk screening.

3.1 Hazard

3.1.1 Climate scenarios

This assessment considers the following two climate change scenarios, each aligned with a Representative Concentration Pathway (RCP) that outlines future greenhouse gas (GHG) concentrations:

- **RCP-4.5 – Intermediate scenario:** considers significant mitigation efforts within a future world with a notable but irregular reduction in the use of resources and energy together with moderate total population growth.
- **RCP-8.5 – Very high-emission scenario:** represents the upper end of the possible futures with no climate policies implemented worldwide due to enhanced greenhouse gas emissions

We assess climate change under different timeframes to understand possible future climate trajectories. For this assessment, a rolling 20-year window is used to evaluate changes in future climate from 2021 to 2100, encompassing the following time horizons:

- **2021-2040** (reference year 2030).
- **2041-2060** (reference year 2050).
- **2061-2080** (reference year 2070).
- **2081-2100** (reference year 2090).

3.1.2 Climate data

In the Climate Hazard Assessment (GCA, 2024) a comprehensive analysis of the hazards of drought, wildfire, extreme temperature, precipitation and wind is described. To assess the risks associated with these climate hazards, several independent sources of evidence were used, depending on data availability. Results per hazard are summarised below:

Extreme temperature: Future projections indicate a consistent warming trend in maximum temperatures across the country, supported by strong model agreement. Extreme temperature events are expected to become more intense. Inland areas will see a significant shift, with extreme temperatures that occurred every 25 years during the reference period projected to occur every 2 years by 2050 under the moderate emissions scenario. The coastal areas are expected to see a greater increase in the average number of days exceeding 35°C per year by 2050, whilst the northeastern region will experience the largest rise in the frequency of days exceeding 40°C.

Extreme precipitation: Extreme precipitation events with a return period of 25 years are expected to increase significantly, with rises of 17% in the west and 34% in the east under RCP4.5, and 17% in the west and 45% in the east under RCP8.5. By mid-century, the highest daily precipitation levels are projected to reach 130 mm/day in the eastern tip of the country under both scenarios, while in Banjul, extreme one-day precipitation is forecasted to reach 110 mm/day for both emission scenarios. Future model projections indicate no significant changes in the frequency of days with extreme precipitation, with model disagreement increasing over time for both scenarios, making projections for this indicator highly uncertain.

Extreme Wind: Future projections suggest that the average maximum wind gusts will remain largely unchanged across most of the country. For 25-year return period events, wind gusts are projected to peak mid-century, with increases of up to 10% under RCP4.5 by 2050 in the central regions, and returning to

values similar to the reference period under both emissions scenarios. The frequency of days with wind gusts exceeding the 90th percentile is projected to rise in the future. Years with extreme wind gust events for a 25-year return period are expected to see up to 90 days and 95 days of such occurrences, under RCP4.5 and RCP8.5 respectively, from the 60 days in the historical period.

Drought: Drought risk is expected to increase consistently over time. Based on a widely used drought indicator, the Standardised Precipitation and Evapotranspiration Index (SPEI), by 2050, droughts that occur once every two years are projected to decrease by 0.4 to 0.8 on the SPEI scale, shifting the whole country from today's Normal conditions to Moderately dry conditions (SPEI < -1). By the end of the century the increase trend in drought conditions will lead to most of the country reaching to levels of Severely dry conditions (SPEI < -1.5) under RCP4.5 and reaching in some areas Extremely dry conditions (SPEI < -2).

Wildfire: Future projections under mean conditions show a gradual westward expansion of very extreme wildfire risk zones under both RCP 4.5 and RCP 8.5 scenarios. By the mid-21st century, FWI is expected to increase uniformly by 2-3% across The Gambia, with a slightly greater increase under RCP 8.5. An increasing trend in the number of days per year when FWI surpasses the historical 90th percentile (dFWI90p) is projected across The Gambia, indicating a rise in the frequency of high-risk days. By the mid-21st century (2040–2060), dFWI90p is projected to increase by 30-39 days, resulting in 62-72 high-risk days annually.

3.2 Exposure

This section describes the assessed infrastructure assets, including their design and the assumptions used for the climate risk screening.

Furthermore, this chapters provides background information on the reasoning behind the chosen origin-destination combinations to conduct network analysis. The chosen origin-destination combinations provide insights into a broad spectrum of travel patterns.

3.2.1 Roads

The road network of The Gambia consists of:

- **Primary (all-season) road network:** This encompasses utility corridors, trade routes, and public transport routes. It mainly consists of the Trans-Gambia Highway, the major east-west highway along both banks of the Gambia River, including the North Bank Road (northern side) and the South Bank Road (southern side). This road connects economic centres to the international market through the harbour, airport and border crossings, as well as to the capital city of Banjul.
- **Rural roads:** These connect rural areas to all-season roads, linking villages to both the primary road network and river jetties in priority regions.

Traffic

According to the (NRA, 2020) light vehicles, including cars, taxis, pick-ups, and small buses, account for 91% of the total traffic volume. Medium vehicles, such as medium buses, large buses, and light and medium trucks, make up 7% of the traffic. Heavy vehicles constitute the remaining 1%. When looking specifically at the rural traffic flow, light vehicles are even more dominating, constituting 95% of traffic flow, with the remaining 5% being heavy vehicles.

Traffic volume typically fluctuates throughout the day and week. While weekday traffic volumes may not vary significantly, they can differ on weekends. From Monday to Sunday, traffic patterns in rural areas are generally consistent across most roads in the Greater Banjul Area, with more noticeable patterns from Friday to Sunday. These weekend patterns are likely to exhibit more seasonal variation compared to weekdays.

Figure 3-1 highlights the most used road segments identified in the NRA (2020) study. While traffic counts provide valuable data for roads that are used most often, they do not explain the reasons behind these travel patterns. The network study in this research focuses on the roads most frequently used for specific travel patterns, such as commuting from home to school. At this stage, traffic counts (which include all travel patterns) can be used as contextual information rather than being integrated into the network

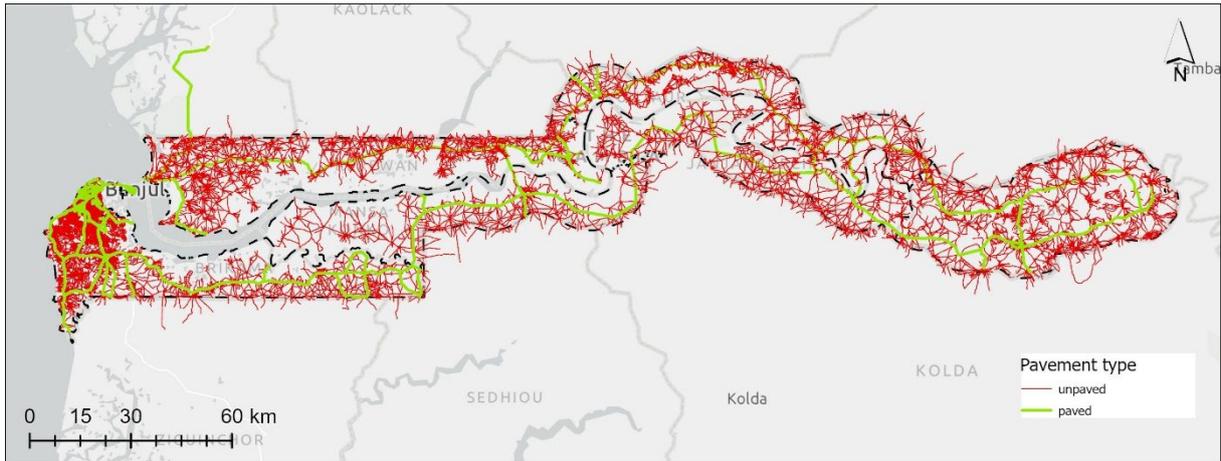


Figure 3-2: The road network categorized by pavement type (paved/unpaved).

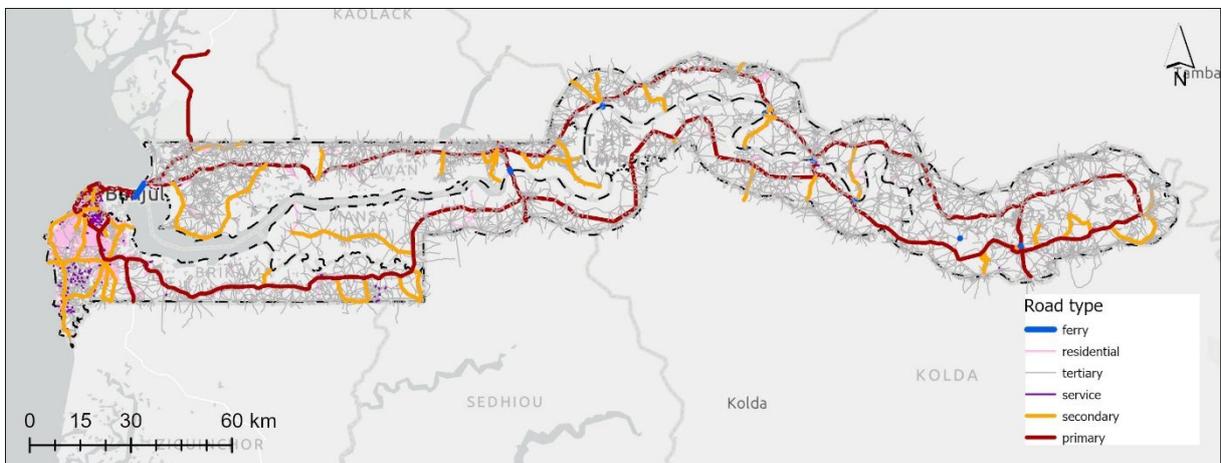


Figure 3-3: The road network categorized by road type (primary, secondary, tertiary, residential, service, ferry).

3.2.2 Inland Water Transport

The Gambia River, traversing the country, possesses substantial potential to boost The Gambia's economy through inland water transport and tourism. Currently, however, the river lacks inland transport for import or export. The efficiency of the Inland Water Transport (IWT) sector has been affected by public operating policies, costs, and water transport charges in a world where roads and automobiles symbolize growth and development. Despite its numerous advantages, inland water transport remains the least developed mode compared to road and rail transportation (Saidykhan, 2023).

The only existing river transport consists of ferry services. The most prominent ferry route connects Banjul and Barra, linking the capital city to the North Bank region and serving as a vital conduit for people, vehicles, and goods. Several ferry crossings further upstream facilitate transport in inland areas. Historically, the TransGambia crossing was also a critical point until the Senegambia bridge's construction.

The Gambia Ferry Services Company Ltd (GFSC) operates these ferries, providing cross-river services at various points along the Gambia River. GFSC is working to modernize operations by acquiring newer ferries and improving terminal infrastructure. However, the ferry services have encountered challenges, including maintenance and reliability issues.

3.2.3 Airport

Banjul International Airport is the only airport in The Gambia and manages all air transport into and out of the country (AfDB, 2013) Complementing the Port of Banjul's vital role in international trade, the airport

serves as a critical artery for The Gambia's economy. While the port handles the majority of sea-based commerce, the airport is essential for time-sensitive goods, tourism, and international business connections.

The airport facilitates the rapid movement of high-value exports, such as fresh produce and seafood, which are crucial for generating foreign exchange. It also supports the influx of essential imports, including pharmaceuticals, electronic components, and other goods critical for the nation's development.

Banjul International Airport is the primary gateway for The Gambia's thriving tourism sector, a significant contributor to the country's GDP. The airport's capacity to handle international flights directly impacts tourist arrivals, which in turn fuels local businesses, creates employment opportunities, and supports the broader economy.

3.2.4 Seaport

The Port of Banjul, the country's only major port, is a crucial link to neighbouring countries, handling over 80% of The Gambia's international trade (AfDB, 2013). Situated on the Gambia River estuary and bordered by the city of Banjul to the north, the port serves as the primary gateway for the country's export and import trade.

For the past two decades or more, ships destined to the Port of Banjul have increasingly been spending idle time at anchorage, given that the berth capacity is limited to cope with the demand, and the cargo handling and storage being equally limited by lack of adequate container terminals and contingent routes to, from, and within the Port facilities.

Currently, river transport along the Gambia River is absent. According to Saidykhan (2023), inland water transport has been neglected, leading to deteriorated river port infrastructure, reduced economic activity, and diminished river navigability.

The Port of Banjul is a service port specializing in containers and some break-bulk cargo. Imports, primarily containerized agriculture-related products like sugar, rice, flour, and tomato paste, constitute the main cargo type. Bulk imports consist mostly of cement-related and agricultural break-bulk products. The port's marine infrastructure includes two jetties and a ferry terminal.



Figure 3-4: View of Port of Banjul

3.2.5 Population

In 2024, The Gambia reportedly had about 2.5 million inhabitants (World Bank Group, 2024), primarily living in and around urban and peri-urban centres. For the network analysis, the population density maps from WorldPop (WorldPop, 2020) were used to spatially present the population distribution over the country, showing a 30 x 30 meter resolution.

3.2.6 Economic Mobility Patterns

Economic activity in The Gambia is mainly concentrated in the Brikama Local Government Area (LGA), which accounts for 37% of all enterprises, followed by the Kanifing Municipality (Greater Banjul Area - GBA) with 33%. The concentration of industrial and service activities in urban coastal areas has led to significant rural-to-urban migration among the youth (AfDB, 2020). Due to high urbanization and ongoing urban migration, the Greater Banjul/Brikama area in western Gambia now houses about 60% of the population, serving as the main hub for population, economic, and transport activities (AfDB, 2013). Agricultural activities are primarily located in rural areas around the North Bank, Lower River, and Central River Region, which have the highest poverty rates (AfDB, 2020). The primary and secondary roads system supports the economic activities that drive the Gambia's export-oriented strategy. Rural feeder roads connect the rural population to markets and social services, integrating them into the market economy (AfDB, 2013).

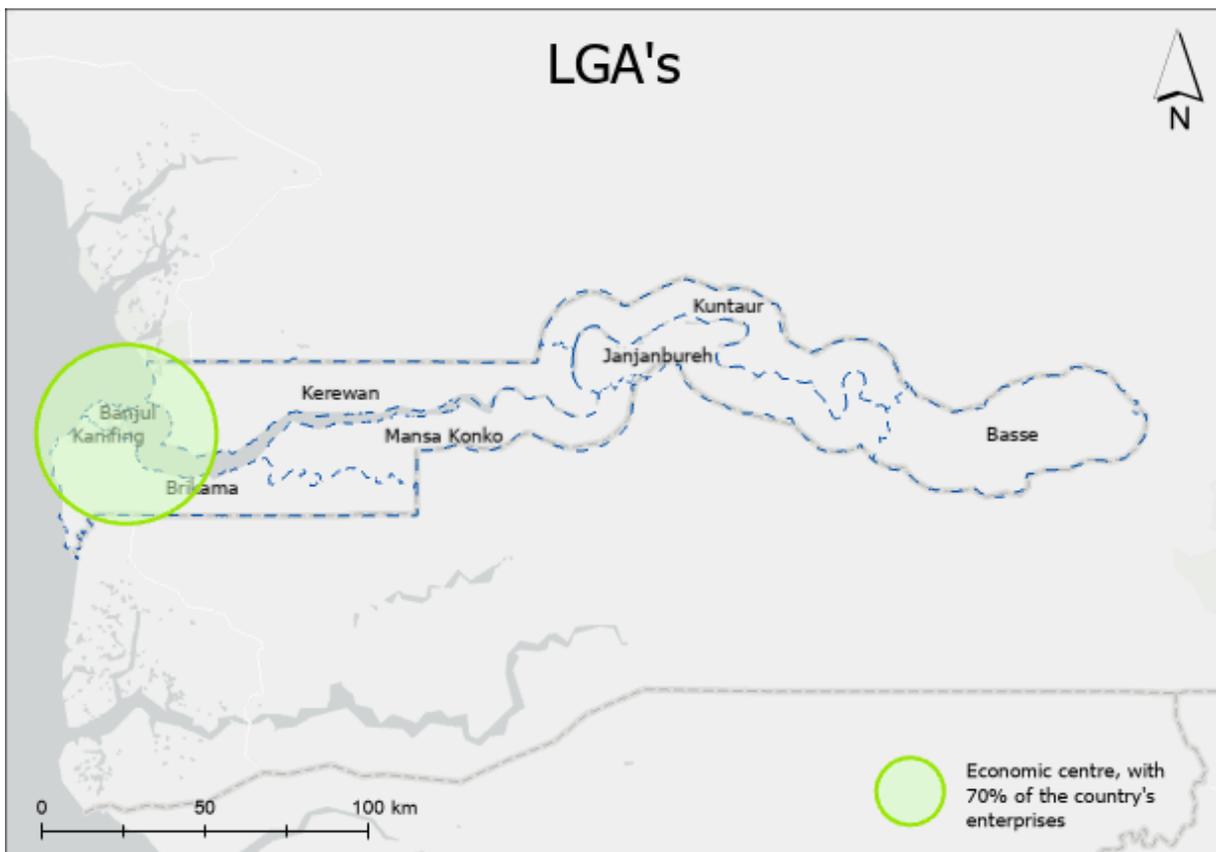


Figure 3-5: LGA's and the economic centre of the country.

The Gambia as a small open economy is known to be largely dependent on the international economy, sourcing almost all its major goods from other countries. The port of Banjul is of great importance to the country's economy, handling over 80% of the total country's imports and exports, while the other 20% is divided over road transport across the borders, and in a very small amount with air freight. The Gambia's top exports include Packaged Medicaments (\$299M), Cars (\$213M), and Harvesting Machinery (\$148M). These exports are primarily destined for Kazakhstan, Guinea-Bissau and China (\$44.8M). The Gambia's leading imports are Crude Petroleum (\$396M), Refined Petroleum (\$164M), Light Pure Woven Cotton (\$161M), Ferroalloys (\$123M), and Rice (\$106M). The main sources of these imports are Kazakhstan, China and Senegal (OEC World, 2025).

The main markets, distributed over the country as depicted in the Figure 3-6, act as distribution centres in the value chain between on the one hand, the imports and exports handled in the harbour and at the borders, and on the other hand the producers and consumers throughout the Gambia. These main

markets are generally functional, meaning that supplies are sufficient, regular and predictable at affordable and stable prices, according to Tsumura et al (2021).

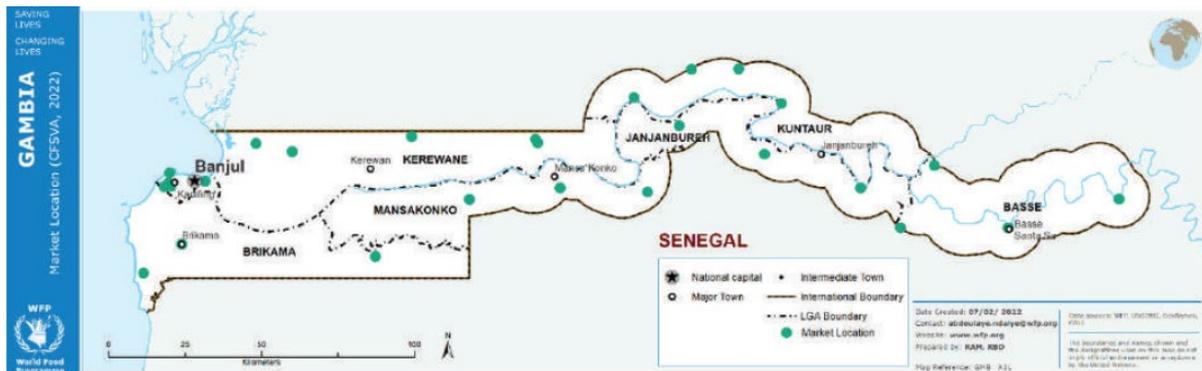


Figure 3-6: Distribution of markets throughout the country, retrieved from Tsumura et al., (2021).

Combining this information highlights the need to visualize travel patterns between the main markets and the port in Banjul. This illustrates trade patterns (both import/export and internal trade) between distribution centers and the capital city's harbor. A second simulation needed is to show the distribution of goods between key border crossing points and main markets. The locations needed for these analyses are presented in Figure 3-7 and Table 3-1. The routes used by people traveling to the markets are simulated in the social analysis, which will be detailed in the next chapter.

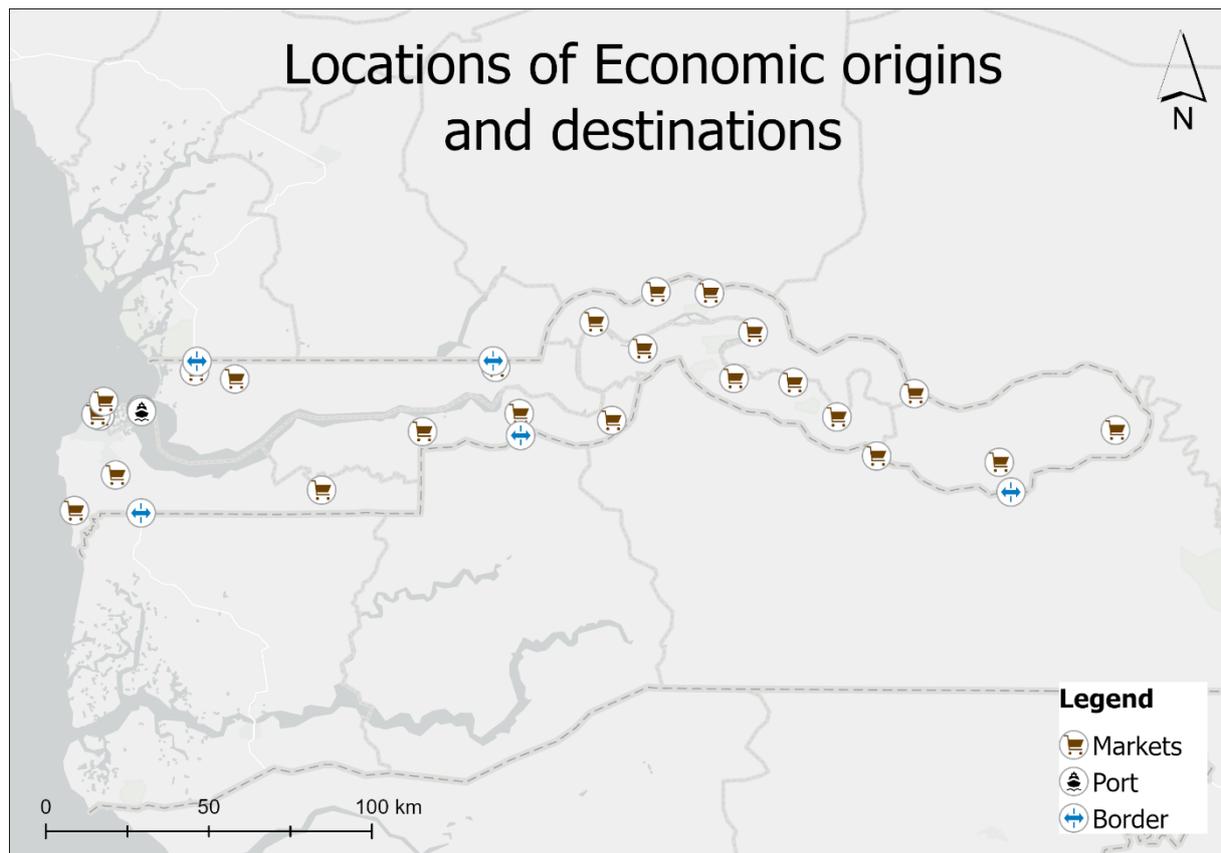


Figure 3-7: Locations of origins and destinations for economic analyses.

Table 3-1: Overview of economic important locations for the network analysis

Facility	Total	Data Source
Main Markets	25	OSM and Markets based on CFSVA (2021) ¹
Port	1	OSM
Border crossing points	5	OSM

3.2.7 Social Mobility Patterns

Social mobility patterns are quite broad, encompassing nearly all travel behaviours. To narrow the focus of this research, we concentrated on access to healthcare facilities, educational facilities, and markets.

The right to health is recognized as a fundamental human right in various international treaties and declarations, such as the International Covenant on Economic, Social and Cultural Rights (ICESCR). The Gambian government has implemented a framework to ensure equitable access to healthcare in both urban and rural areas. However, the system faces major obstacles, including insufficient healthcare infrastructure, limited financial resources, and a lack of skilled healthcare professionals. These issues hinder the provision of essential health services, especially in remote regions where medical facilities are scarce (Generis Online, 2024). Healthcare facilities are often under stocked on pharmaceutical products and medicine and poorly equipped and maintained. With only 4% of the population is covered by a health insurance scheme, many people are forced to spent high out of pocket costs to be able to access healthcare (Health Policy Plus, 2019). The right to education is enshrined in international human rights instruments, including the Universal Declaration of Human Rights. The Gambia’s Education Policy aligns with Sustainable Development Goal 4, emphasizing accessible, equitable, and inclusive quality education. The Constitution guarantees basic education as a right, ensuring it is free, compulsory, and universally available. However, the annual expansion of the education sector presents challenges for the government in meeting the increasing funding requirements for infrastructure, materials, and teachers (UNICEF, 2025). Nonetheless, over 46,000 Gambian children remain out of school in 2023 mainly due to poverty and financial constraints to cover the associated costs of education, facing a potentially challenging future due to a lack of education. Despite primary school enrolment reaching 428,053 children in 2023, these 46,000 children risk growing up without the necessary education or skills. With many children unable to complete the full cycle of schooling – primary school completion rate is at 88 percent, upper basic school at 65 percent, and senior secondary school at 47 percent (Jaw, 2024). One of the first steps in solving this issue, is ensuring physical access to school facilities.

Lastly, access to markets is crucial for economic reasons. The Comprehensive Food Security and Vulnerability Analysis (CFSVA) (2021) found that, on average, 48.7% of communities have a functional market within their villages. The remaining 51.3% of communities lack such markets and must travel an average of 6.4 km to buy or sell products, including food. This travel distance varies from 2 to 22 km from community to community, with the maximum distance to the market observed in Kuntaur at 12.4 km. Residents incur transportation costs to purchase food and non-food items from the market, which reduces their purchasing power, particularly among poorer individuals, forcing them to buy cheaper and/or less food. Similarly, transportation costs diminish farmers’ income when selling their products. Community members reported that market access, price hikes, lack of storage facilities both at the market and at home, and the unavailability of certain food items in the markets are significant challenges (State of food security in the Gambia: Comprehensive food security and vulnerability analysis, 2021).

The social mobility patterns are using the population density map, as mentioned in 3.2.5, as starting points, essentially showing which routes people take from their homes to the markets, education facilities and to the healthcare facilities. The locations of these destinations are indicated in Figure 3-8, and the supporting information is shown in Table 3-2.

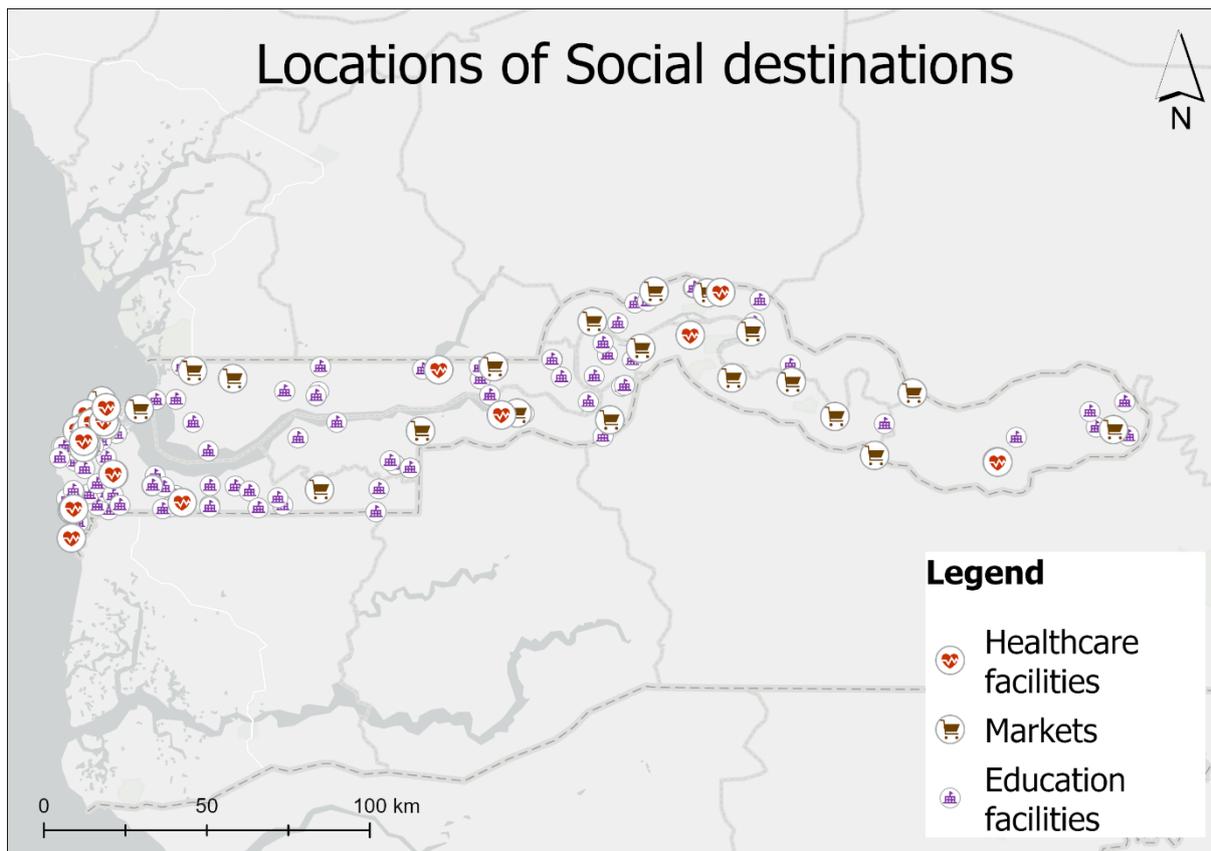


Figure 3-8: Locations of social facilities in the Gambia: education, markets, and hospitals.

Table 3-2: Overview of social facilities for the network analysis

Facility	Total	Data Source
Education facilities	162	OSM
Markets	25	OSM and Markets based on CFSVA (Tsumura et al., 2021)
Healthcare facilities	21	OSM

3.2.8 Tourism

The tourism industry is a significant contributor to The Gambia’s national economy, accounting for 16% to 20% of the GDP and supporting over 41,800 direct and 65,500 indirect jobs, which represents 18% of employment. Over the past five years, it has attracted US\$ 45 million in foreign investment, providing essential air cargo opportunities that support the development of other sub-sectors such as shellfish, horticulture, and international business activities. The tourism industry in The Gambia is seasonal, and the country has experienced steady growth in this sector (Nyassi, 2019).

Transport by air into and out of The Gambia is via the Banjul International Airport (BIA), situated at Yundum, about 24 kilometres to the south-east of Banjul and it is the only airport (AfDB, 2013). Because of the small size of the country, domestic air transport has not been part of the internal transport system. The transit between the airport and hotels, therefore, mainly takes place using the road network. These travel patterns are visualized in the network analysis, of which the origins and destinations are the hotels and the airport. The locations of these destinations are indicated in Figure 3-9, and the supporting information is shown in Table 3-3.

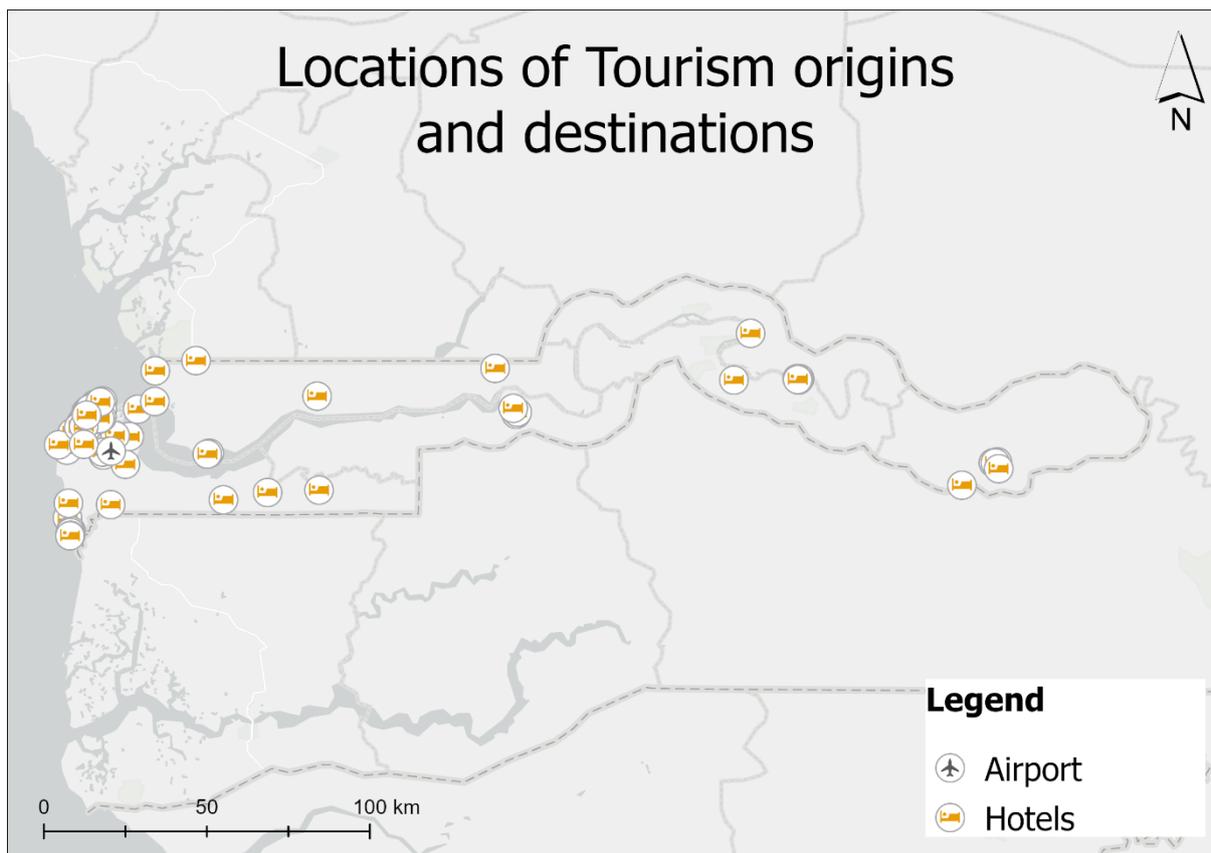


Figure 3-9: Locations of Tourism facilities in the Gambia: hotels and airport.

Table 3-3: Overview of social facilities for the network analysis

Facility	Total	Data Source
Airport	1	OSM
Hotels	89	OSM

3.2.9 Food Security

Food Security has varying definitions by different organisations. The UN Food and Agriculture Organization (FAO) define food insecurity as the “lack of regular access to enough safe and nutritious food for normal growth and development and an active and healthy life.” (FAO, 2023). Importantly, the definition extends beyond situations such as running out of food or skipping meals, to include insufficient access to healthy food options.

Food Security includes not only the level of food physically available (made available through trade and production), but also the economic access to food. The price of food drives economic access, and interplays closely with changes in supply and demand, meaning a more complex set of factors can influence food security.

Food security is a major issue in the Gambia. The agriculture sector engages approximately 80% of the country’s population, both directly and indirectly. It contributes to 70% of the nation’s foreign exchange earnings, yet national production is meeting only 50% of the country’s food requirements. Gambia relies for the rest of the food requirements on imports, particularly of the imports of rice. About 60% of the country’s population were at the borderline of food security and could drop down to the insecure category with any shock in 2021, whereas 13.4 percent of the population are already food insecure (Action Against Hunger, FAO, Govt. Gambia, UNICEF, & WFP, 2021).

In the Gambia, the primary food crops include millet, maize, sorghum, and rice, while semi-intensive cash crops such as groundnut, cotton, sesame, and horticultural products are also cultivated. Farmers typically engage in mixed farming, with a greater emphasis on crop production. Farming is predominantly subsistence-based, relying on rain-fed agriculture, and the country has a food self-sufficiency ratio of approximately 50% (Action Against Hunger, FAO, Govt. Gambia, UNICEF, & WFP, 2021). Agricultural production has declined in recent years due to declining crop yields. Between 2010 and 2016, yields dropped by 36% for rice, 26% for maize, 18% for millet, and 9% for peanuts, although yields for cassava and cashews increased. This decline has widened the gap with neighbouring countries in the sub-region. The decrease is attributed to unsuitable cultivation practices, irregular and insufficient rainfall, and soil salinization caused by seawater intrusion in the lowlands and the Gambia River (Cisse, Sienta, & Woldeyes, 2021). Food security in terms of availability, is therefore under much pressure.

Only a small number of farmers produce enough products to sell in the market, but even physically accessing markets is a challenge in the Gambia. Rural markets are often distant for many communities, poorly integrated, and subject to regular price fluctuations. In the absence of markets, farmers heavily rely on the middlemen to buy the products at a much lower price. Many farmers pay a huge amount of money on the transportation of produce to the markets far away from them.

The travel patterns illustrated in the economic analysis offer insights into the routes connecting markets to the harbour and vice versa. This simulates trade from markets to the capital for exports and the distribution of imported food from the harbour across the country. Similarly, trade patterns between markets and border crossing points provide comparable insights. The social analysis, which examines travel patterns between the population and markets, reveals the routes used to transport goods to the nearest markets and the travel patterns for purchasing food from these markets. As these analyses are already provided in the network analysis results, they will not be specified further for food security.

3.2.10 Mode of transport

In The Gambia, shared transport, including clandestine taxis and buses, are the most popular motorized vehicles, primarily serving the country's main routes and offering affordable transportation for most of the population. Private vehicles include cars, motorbikes, and trucks, mainly used for food transport. For example, a small town in central Gambia collectively purchased a car for transporting goods, materials, and people.

Looking at the secondary routes in the hinterland, walking, cycling and donkey- or horse carts are popular ways of transportation. When it comes to water transportation, there are plenty of (smaller) private boats that cross the river regularly, as well as ferries that can transport more people and perhaps one or two cars. According to the Gambia Bureau of Statistics (2020) there are eight official ferries in use, and maintained by the Gambian Ports Authority, located at: Banjul-Barra, Kaur, Janjanbureh, Barajali, Bansang, Basse, Fatoto and Baati. Many of these ferries are hand-pulled.

An exception is the ferry that crosses the river between Banjul and Barra, which is a larger ferry that has a maximum passenger capacity of 400 people and 25 vehicles, according to accessgambia.com (Banjul Ferry Terminal Services to Barra). Although the trip itself should take about 35 minutes, waiting times of eight hours are not uncommon. On average, the total trip takes 3 hours including waiting time based on local experience.

Besides the transport of people, some vehicles and products *across* the river, there is no transportation of significant means *along* the river.



Figure 3-10: Picture taken of a hand-pulled ferry in the Gambia.

3.2.11 Considered networks for the analysis

To illustrate the routes most often used for social, economic, and tourism connectivity, the network analysis was performed for different origin-destination combinations, as shown in Table 3-4. By overlaying the road network including bridges and ferries with flood maps, exposed infrastructure assets and areas were identified.

Table 3-4: Origins and destinations for the network analysis.

Class	Origin	Destination
Social	Residential houses	Education facilities
Social	Residential houses	Hospitals
Social	Residential houses	Main markets
Economic	Main markets	Port of Banjul
Economic	Main markets	Border crossing points
Tourism	Hotels	Banjul Airport

The network analysis was conducted on the current situation, as well as on a 'hazard event' scenario. The climate hazards are overlaid with the infrastructure assets. For this analysis, the focus lies on the disruptions caused by floods, as extreme temperature has caused gradual damages to the network and can therefore not be assessed as an event causing immediate disruption.

Because flooding is a common issue in The Gambia, high-frequency flood events were used to assess network impact, as shown in Table 3-5. For pluvial flooding, a flood map with a return period (RP) of 5 years was used, and for fluvial flooding and coastal flooding, a flood map with a return period of 10 years was used. The resulting loss of connectivity to social facilities underscores the need for prioritized adaptation options to deal with often occurring floods.

It was assumed that the primary roads are elevated and/or serviced with functional drainage systems, and are thus protected against a RP10 flood scenario. Similarly, any bridges, retrieved from the OSM, that were connected to a paved road and appeared to be well capable to handle a RP10 flood event (based on visible inspection from satellite imagery), were excluded from the possibility of getting flooded.

Lastly, the flood extent of coastal flooding (RP10) was analysed, which appeared to not overlap any origins, destinations or road segments. It was therefore excluded from any further simulations for the network analysis.

Table 3-5: Chosen flood events for the network analysis.

Disruption	Return period	Data source
Pluvial flooding	5 years	Flood hazard modelling output for Hazard Assessment (GCA, 2024)
Fluvial flooding	10 years	Flood hazard modelling output for Hazard Assessment (GCA, 2024)
Coastal flooding	10 years	Flood hazard modelling output for Hazard Assessment (GCA, 2024)

The base layer for this analysis is the road network with a classification in pavement type (paved or unpaved) and road type (primary, secondary, tertiary, residential, service, ferry). To be able to calculate the fastest routes, a maximum speed limit was assigned to these road categories, which is indicated in Table 3-6.

Since, according to our local partner, motorized vehicles are accessible to the majority of the population, the network analysis focusses on transit routes using motorized vehicles. Based on a previous AfDB report on the Gambian transport sector (AfDB, 2013), it is assumed that the river transport system does not play a significant role in the internal transport of goods, food and people between different towns and villages.

Table 3-6: Road type and assumed speed limits.

Road category	Speed limit assigned
Primary road – Paved	70 km/h
Secondary road – Paved	50 km/h
Secondary road – Unpaved	30 km/h
Tertiary road - Unpaved	30 km/h
Ferries	1.33 km/h

3.3 Initial Climate Risk Screening

An initial high-level climate risk screening was conducted for transport infrastructure assets to identify the key climate hazards to take further in the climate risk screening. Based on The Gambia's existing infrastructure and the hazards assessed in the Climate Hazard Assessment, a climate risk screening matrix was created (Table 3-7).

A screening matrix is set up that classifies the risk of all combinations of climate hazards and Project assets as either 'not applicable,' 'low risk,' or 'high risk.'

- **Not applicable** is assigned if the assets are in areas not susceptible to the climate hazard, or the assets are not at all vulnerable to the hazard.
- **Low risk** is assigned to climate hazard and asset combinations when the asset, although potentially vulnerable, is not expected to experience significant damage due to the climate hazard's intensity in The Gambia and the asset's design.
- **Key risk** is assigned to those hazard-asset combinations where a high risk of significant damage (direct and/or indirect) could be anticipated.

Those risks (hazard-asset combinations) identified as high risk are further assessed in the subsequent climate risk screening.

Table 3-7: Initial climate risk screening for the transport infrastructure assets.

Climate Hazard \ Assets	Road	Bridges	Ferry	Banjul Airport	Port of Banjul
Extreme temperature	◆	◆	◆	◆	◆
Extreme wind	◆	◆	◆	◆	◆
Drought	◆	◆	◆	◆	◆
Wildfires	◆	◆	◆	◆	◆
Pluvial flooding	◆	◆	◆	◆	◆
Fluvial flooding	◆	◆	◆	◆	◆
Coastal flooding	◆	◆	◆	◆	◆

◆ Not applicable ◆ Low risk ◆ Key risk

This initial risk identification highlighted the following key climate risks in The Gambia:

- **Extreme temperature** for roads.
- **Pluvial flooding** for roads and bridges.
- **Fluvial flooding** for roads, bridges, and ferries.
- **Coastal flooding** for roads, bridges, and the Port of Banjul.

A low risk was assigned to:

- **Extreme temperature** – The Gambia experiences consistently high temperatures, which can stress the population and potentially affect the well-being of port and airport workers, thereby impacting operations. However, since no physical damage to the airport or port is anticipated, this hazard was not further considered for these assets. In addition, high temperatures can affect bridge joint expansion. However, existing designs account for temperature variability. Exceeding those design limits is unlikely due to the absence of freeze-thaw cycles.
- **Extreme wind** – Damaging winds do not occur in The Gambia, and this is not projected to change in the future.
- **Drought** – Droughts are frequent in The Gambia leading to water scarcity nationwide. However, these droughts are unlikely to significantly influence water levels in the Gambia River or at the Port of Banjul, thus not affecting navigability. Therefore, this hazard was not further considered.
- **Wildfires** – Wildfires occur in The Gambia and can cause transport disruptions. However, these disruptions are expected to be temporary, lasting only during the wildfire. Furthermore, physical damage to transport systems is not anticipated, particularly as Banjul Airport and the Port of Banjul are located in an urban area less susceptible to wildfires.

3.4 Vulnerability

Vulnerability functions have been developed for each of the key climate hazards. Each sub-section below presents the vulnerability relationships for both the road and bridges per hazard. These relationships show the expected amount of damage to a road asset as percentage of the total value of the asset (i.e., the maximum damage value), versus the magnitude of the hazard, for which units differ by hazard.

3.4.1 Extreme Temperature

Roads can be damaged under influence of regular occurrence of extreme temperatures. This process of temperature-induced damage is complex and dependent on multiple different factors. Extreme temperatures of the asphalt can lead to rutting, flushing, and bleeding of bituminous surfaces. As the temperature of the asphalt mixture increases, the binder phase loses stiffness and the irreversible deformations caused by static or dynamic traffic loading will accumulate at a faster rate (Climate ADAPT, 2019) as can be seen in Figure 3-11.

Most roads in The Gambia are unpaved. Only the Trans-Gambia Highway is paved in rural areas, while Greater Banjul has more paved roads. Therefore, the focus is on assessing damage to paved roads. Unpaved roads face similar issues, where expansion, contraction, and drying of the top layer leads to ruts and washboarding. Extreme temperatures also cause cracking and drying, making these roads more prone to erosion and surface damage. Any chemical binders used in the top layers or foundation for stabilisation will lose their strength due to extreme heat, leading to damages. The sensitivity of unpaved roads to extreme heat is therefore considered similar. Due to the similarities in damaging mechanisms, the same calculation method has been applied to paved and unpaved roads.



Figure 3-11: Examples of roads with deformations caused by extreme temperatures in combination with heavy traffic loading.

Factors influencing extreme temperature risks, are the asphalt temperature (affected by the asphalt type, air temperature, solar radiation, and humidity), asphalt specifications (the stiffness of asphalt), how often extreme temperatures occur and traffic loading of the road. Increase in either of these factors increases the risk. Furthermore, other aspects such as high intensity rainfall can increase the development of pavement damage due to erosion processes. For this Assignment the asphalt thickness has been uniformly set to 50mm, which is found to be an average for the top layer used in many African countries. The road loading is also made uniform and has been set to 750 vehicles per day. These uniform values represent the average African road, for as far as there is an average African road, we acknowledge that there will be many exceptions. However, for the purpose of this analysis, which is to understand road vulnerability to different climate hazards (including heat-induced damages), using the same approach allows for the comparison between different roads and countries and a first insight on the most vulnerable roads. This also means that results should be interpreted with care, taking these assumptions into account.

The vulnerability relationship used in this study is shown in Figure 3-13, showing the relation between the expected rutting rate (mm/year), and the damage relationship for the pavement. Damage initiates at the top layer of the pavement. This top layer has an average thickness of 50 mm. Therefore, a rutting rate of 50 mm/year leads to a damage fraction of 100%, or the highest vulnerability to heat-induced damages. The methodology from (Yan Mu, 2020) is used to determine the damage function for extreme temperature. This approach was adopted as it uses latitude, air temperature, the number of days above certain threshold temperatures (in the case of this assessment, 35°C and 40°C), and traffic count as input parameters. Figure 3-12 shows the (not yet modified) relationship between the temperature and the rutting rate per traffic load. By focusing solely on climatological and traffic factors, this approach clarifies the relationship between heat and damage for both current and future climate scenarios. After the rutting depth for different scenarios is calculated, the risk score is calculated for both paved and unpaved roads. As can be seen in Figure 3-13, unpaved roads tend to reach higher scores quicker than the paved roads.

Note that bridges are not expected to incur any damage as they already include measures to allow for expansion.

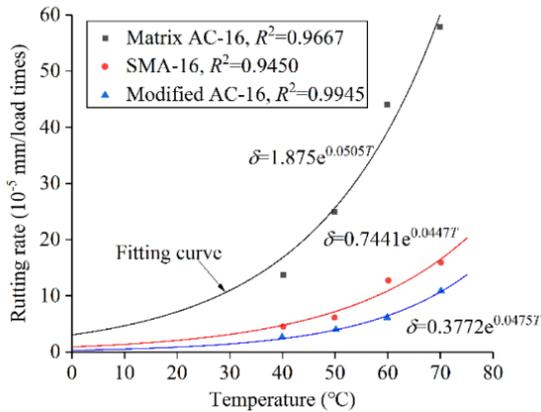


Figure 3-12: The relationship of temperature and rutting rate of three asphalt mixtures according to the paper of Mu et al., (2020).

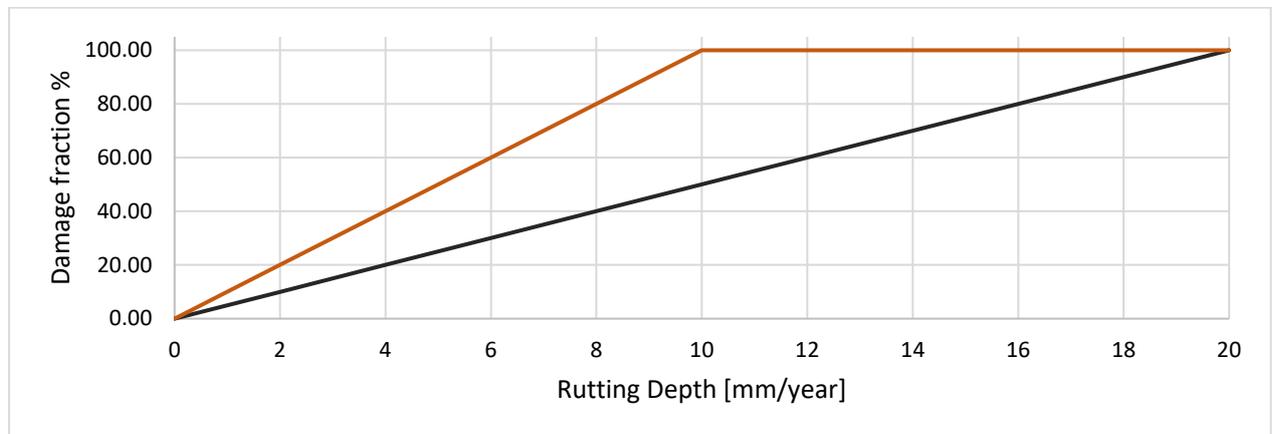


Figure 3-13: Vulnerability relation between extreme temperatures and damages for paved (black) and unpaved (orange).

3.4.2 Pluvial and Fluvial Flooding

Flooding of a road can cause damages to a road in many ways, varying from cleaning costs to complete erosion and failure of the road. To assess physical damages to the road, the global flood-depth damage functions for infrastructure by Huizinga, De Moel, & Szewczyk, 2017 are used as a reference. These curves have been developed based on global infrastructure damage datasets during flood events. The curves quickly show large damages for low inundation depths, primarily being caused by damaging of (electrical) road furniture.

In the context of African road networks, these damages are expected to be much lower. The main damage to consider for most Africa roads is structural damage to the road pavement, foundation, and shoulders. Therefore, vulnerability curves have been adjusted to the local context using reference cases of road damage ratios in Bangladesh (Figure 3-14) (Haque, Ikeuchi, Shrestha, Kawasaki, & Minamide, 2023) which are based on structural damage to the road, as well as Haskoning's previous project experiences in South Africa, Kenya, Senegal, Niger, Mozambique, Zambia, among many other countries. Large scale damage will start occurring when water depths exceed 2-3 meters as from this point the flow will have significant erosive power. Ultimately, 100% damage (i.e., the maximum damage value) is expected to occur if the road is completely washed away for which water depths of 5-6 meters are required. Figure 3-14 shows the developed vulnerability relationships used for the road network in this Assignment. A differentiation has been made between paved and unpaved roads, where for paved roads structural damage is expected to be much less during small floods, whereas unpaved roads may be quickly washed away.

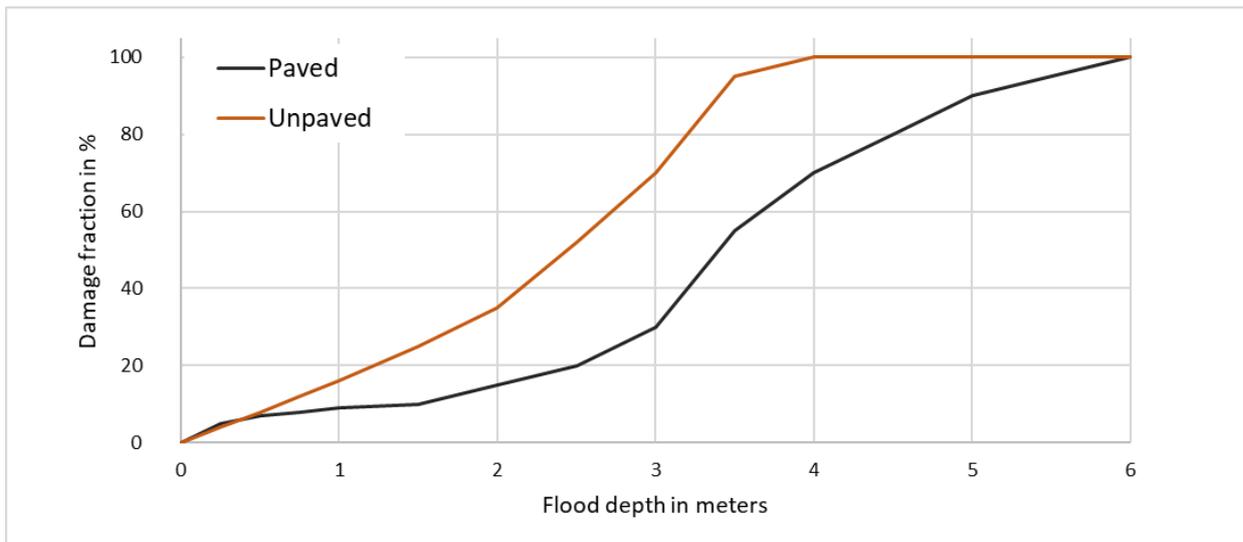


Figure 3-14: Vulnerability curves used for the relationship between road damage and flood depth.

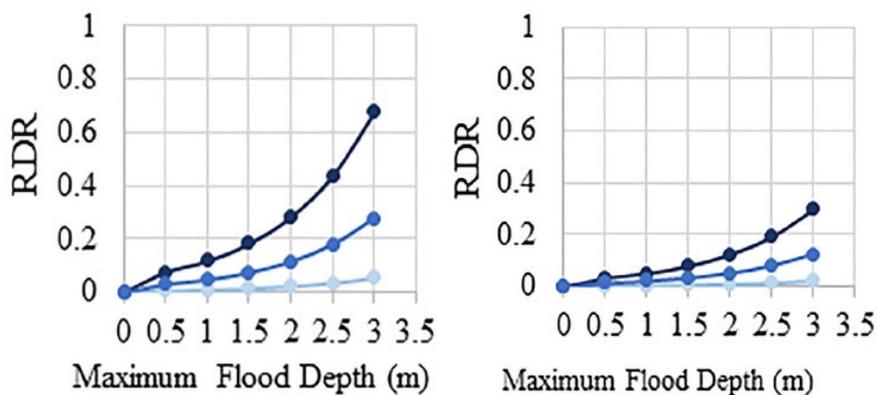


Figure 3-15: Road Damage Ratios for different flood depths for reference cases in Bangladesh, showing the difference between gravel/earth roads (left) and paved roads (rights) (Haque, Ikeuchi, Shrestha, Kawasaki, & Minamide, 2023).

Damage to bridges

Extreme river discharges can lead to higher scouring rates around the bridgehead or pillar foundations (USAID, 2015) (Nasr, et al., 2021). At the same time the bridge deck can get drowned and transported debris might result in damage to bridges (foundations, pillars and deck). Damages can range from inspections with minor repair works to a full bridge collapse and replacement in very extreme occasions. Design and maintenance state can make bridges more susceptible to these kinds of damages. Across the African continent, bridges are expected to have their structural safety and durability compromised, making them more susceptible to failure. Generally, bridges are designed based on historical or modelled flood levels at river crossings. Bridges are assumed to have been designed to withstand up to a T100 years event with no freeboard allowance. Bridges are thus assumed to get damaged if flood levels exceed the T100 design water level.

The vulnerability curve in Figure 3-16 shows the relation between H^{**} (flood level versus top bridge deck) and expected damage to the bridge. The vulnerability curve represents damages to a bridge due to scour and due to hydraulic forcing, for both arch- and beam bridges. The vulnerability curves are based on research from (Pucci A, 2023).

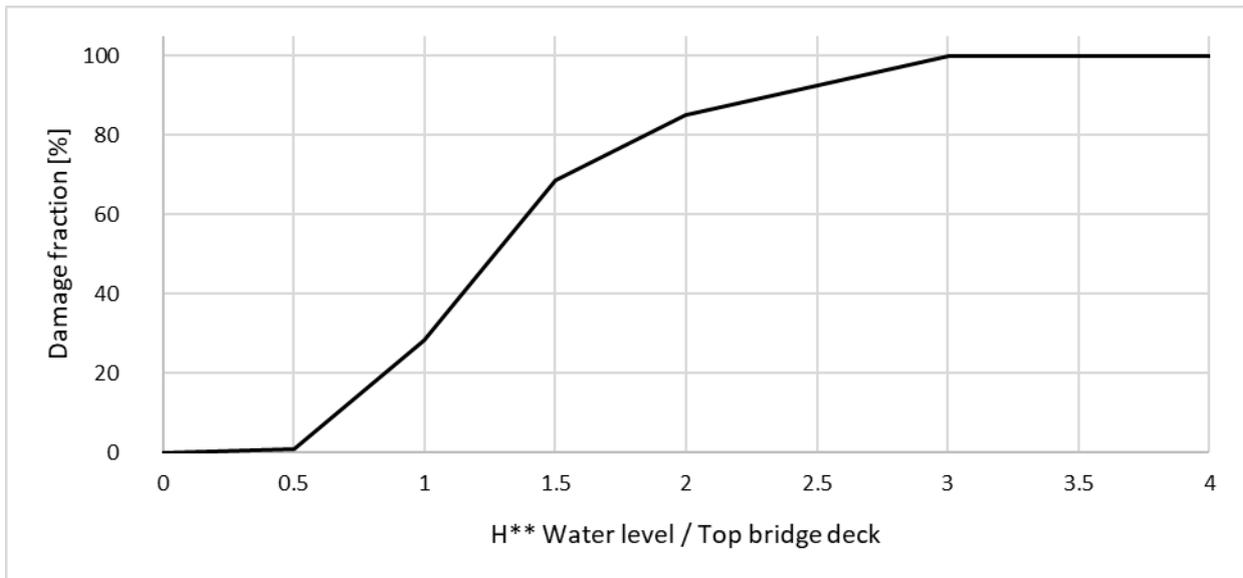


Figure 3-16: Vulnerability curves used for the relationship between bridge damage and flood depth (H** being the flood level versus top bridge deck).

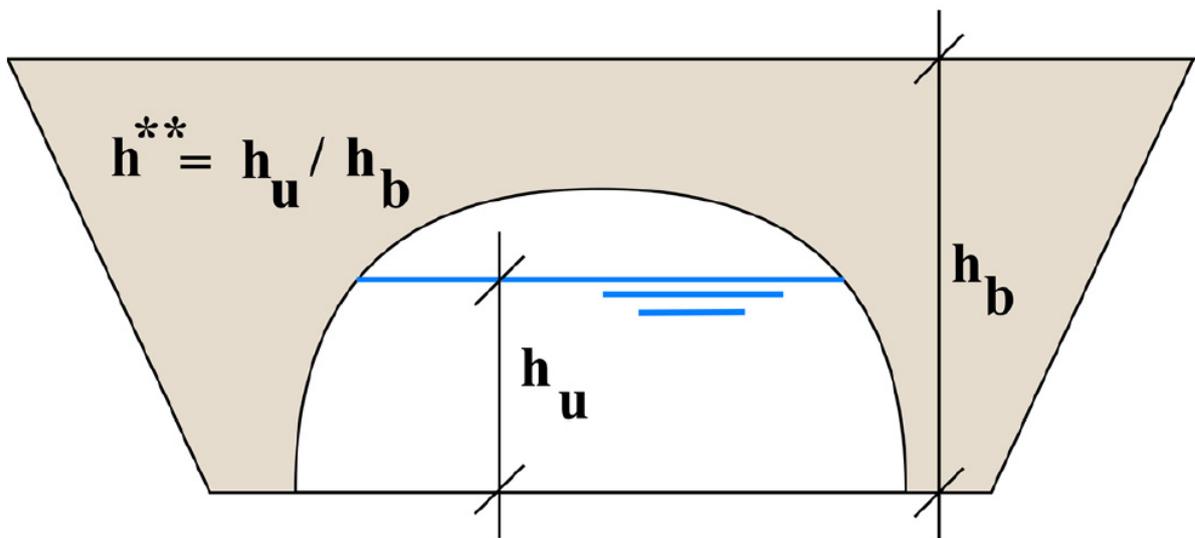


Figure 3-17: Graphical representation of H**, in this study h_b is considered as the T20 flood level + bridge deck of 0.5m, h_u is the flood level for the return period analysed.

4. CLIMATE RISKS TO THE GAMBIA'S TRANSPORT SYSTEMS – ROADS AND BRIDGES

This chapter presents the results of climate risk screening for roads and bridges in The Gambia's transport network, comprised of:

- **Direct risk** per climate hazard.
- **Socio-economic impacts**, including road frequency and population affected by connectivity disruptions to key facilities.
- **Combined risk score for roads** results, highlighting the highest-risk roads in The Gambia.

The risk score, based on the methodology in Chapter 0, provides a qualitative assessment of climate hazard risk, considering asset vulnerability and hazard intensity. This allows for risk score comparisons within The Gambia. The risk score aims to identify:

- At-risk transport assets.
- High-risk areas.
- Critical transport connections.

4.1 Direct risk

The direct risk is presented per climate hazard for the roads and bridges. The risk score, which considers asset vulnerability and hazard intensity/frequency, provides an objective risk assessment. The risk score enables prioritization of investments in high-risk roads and bridges.

The risk score is a combination of the average hazard intensity (e.g., flood depth) and the percentage of the road surface that is affected. So, a road segment that is completely flooded with an average depth of 4m or more would result in a risk score of 100. If only half of the road were flooded, or if the flood depth were 2.5m, it would result in a risk score of 50. For extreme temperatures a score of 0 means no risk of temperature related damages, a score of 100 means that every year the full top layer of asphalt is expected to be completely damaged by temperature related damages. This is directly related to the yearly number of days above 35°C and 40°C as this influences the heat stress exerted on the road segment.

For bridges, the risk score is based on the freeboard and how much the water level increases during extreme pluvial flood events. A bridge that has no freeboard left during an extreme flood gets a risk score of 25. When the water level is three times higher than the bridge deck (completely overflowing) during an extreme event, the bridge gets a risk score of 100.

The risk scores are made for the baseline (current day situation), the middle-of-the-road climate change scenario (SSP2-4.5), and the worst-case climate change scenario (SSP5-8.5) for the future horizon 2050. The climate risk is provided in tables, showing the road lengths and number of bridges with different risk scores. The risk scores vary from 0 (no risk) to 100 (extremely high risk).

4.1.1 Fluvial direct risk

Figure 4-1 shows the fluvial direct risk score for the baseline in The Gambia. Table 4-1 shows the road lengths and percentage of the total road network with a fluvial flood risk (risk score >0) in The Gambia. A large part of the roads in The Gambia (38%) have a risk score between 0-10. Furthermore, several roads show a significant risk of flooding (5% of the roads have a score of 10 or higher). These roads are mostly located near river crossings or near river bends (Figure 4-2). The flood risk is therefore high over a relatively short distance where the road traverses the flood extent of the river.

The direct risk scores are projected to increase for both scenarios, where the total length of roads that experience damage from fluvial flooding increases from 42.9% in the baseline to 44.6% under both scenarios by 2050. Furthermore, roads with a score of 10 or higher increase to 5.2% under SSP2-4.5 and 5.3% under SSP5-8.5 by 2050. Only small differences are observed between climate scenarios SSP2-4.5 and SSP5-8.5. This is due to relatively minor differences in long-duration rainfall estimates, which cause similar flood depths.

Table 4-1: Road lengths with fluvial flood risk scores for the baseline, SSP2-4.5, and SSP5-8.5 2050 scenarios.

Risk score	Baseline [km]		2050 SSP2-4.5		2050 SSP5-8.5	
	[km]	[%]	[km]	[%]	[km]	[%]
> 0-10	8,496	38.2%	8,733	39.3%	8,733	39.3%
10-20	516	2.3%	543	2.4%	541	2.4%
20-30	219	1.0%	252	1.1%	250	1.1%
30-40	104.3	0.5%	134.5	0.6%	139.7	0.6%
40-50	70.2	0.3%	78.7	0.4%	82.4	0.4%
50-60	43.8	0.2%	57.3	0.3%	58.0	0.3%
60-70	24.0	0.1%	31.7	0.1%	32.6	0.1%
70-80	28.1	0.1%	26.5	0.1%	26.1	0.1%
80-90	6.3	0.0%	20.6	0.1%	19.3	0.1%
90-100	18.5	0.1%	20.9	0.1%	22.9	0.1%
Total	9,526	42.9%	9,898	44.6%	9,905	44.6%

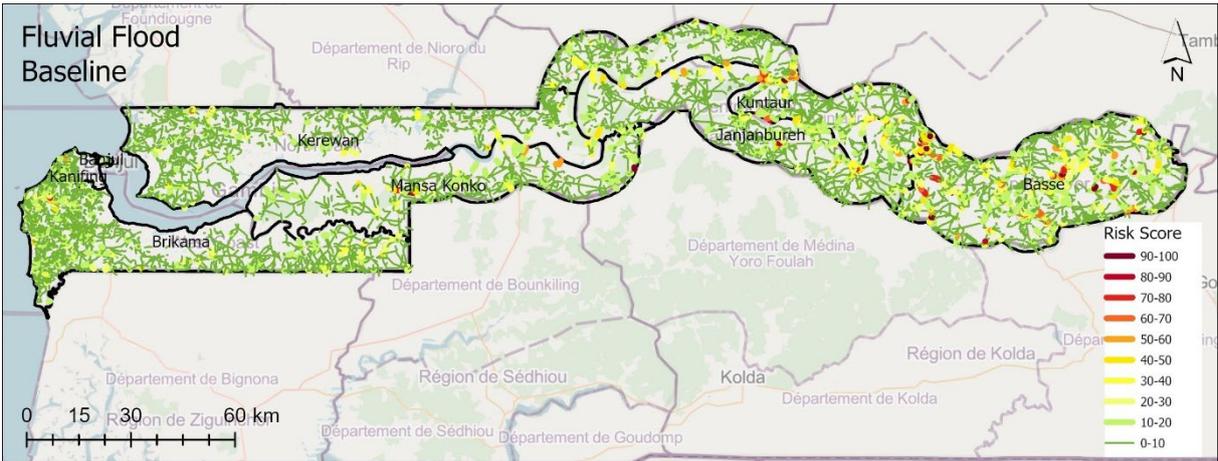


Figure 4-1: The fluvial direct risk score for roads in The Gambia – Baseline scenario.

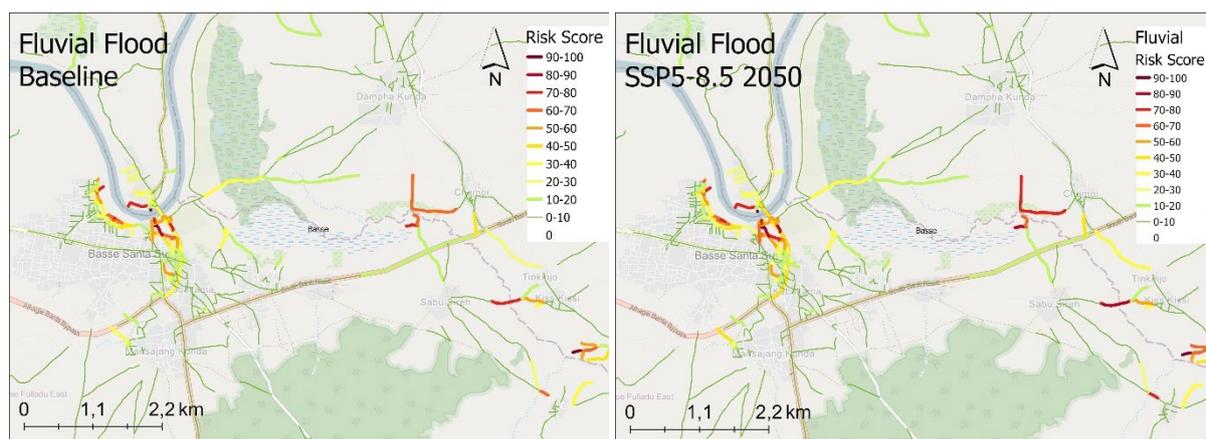


Figure 4-2: The fluvial direct risk score for roads for the town Basse – Baseline (left) and SSP5-8.5 2050 (right) scenarios as illustration.

4.1.2 Pluvial Flood Risk

Figure 4-3 shows the pluvial direct risk score for the baseline in The Gambia. Table 4-2 shows the road lengths and percentage of the total road network with a pluvial flood risk (risk score >0) in The Gambia. More than half of the roads in The Gambia (56%) have a risk score between 0-10, indicating the roads are damaged by mostly low water depths. Only a small percentage of roads (<1%) have a score of 10 or higher. These roads are mostly located near smaller streams which overflow during extreme rainfall events (Figure 4-4).

The risk scores are projected to increase for both scenarios, where the total length of roads that experience damage from pluvial flooding increases from 56.8% in the baseline to 60.9-62.1% under SSP2-4.5 and SSP5-8.5, respectively, by 2050, indicating road segments currently with no risk of flooding in the baseline are projected to become at risk by 2050. Furthermore, roads with a score of 10 or higher increase slightly from 0.7% to 1.1-1.3% by 2050.

Table 4-2: Road lengths with pluvial flood risk scores for the baseline, SSP2-4.5, and SSP5-8.5 2050 scenarios.

Risk score	Baseline [km]		2050 SSP2-4.5		2050 SSP5-8.5	
	[km]	[%]	[km]	[%]	[km]	[%]
>0-10	12,470	56.1%	13,272	59.7%	13,511	60.8%
10-20	127	0.6%	201	0.9%	230	1.0%
20-30	20	0.1%	34	0.2%	44	0.2%
30-40	2.3	0.0%	10.0	0.0%	11.7	0.1%
40-50	0.0	0.0%	0.7	0.0%	4.9	0.0%
50-60	1.0	0.0%	0.0	0.0%	0.0	0.0%
60-70	0.0	0.0%	1.0	0.0%	0.9	0.0%
70-80	0.0	0.0%	0.0	0.0%	0.2	0.0%
80-90	0.0	0.0%	0.0	0.0%	0.0	0.0%
90-100	0.0	0.0%	0.0	0.0%	0.0	0.0%
Total	12,621	56.8%	13,518	60.9%	13,803	62.1%

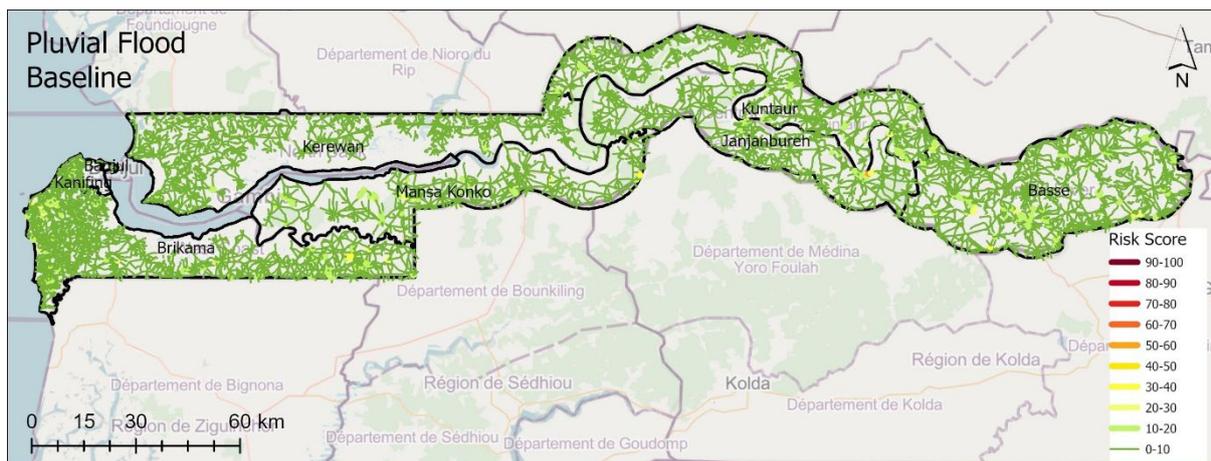


Figure 4-3: The pluvial direct risk score for roads in The Gambia – Baseline scenario.

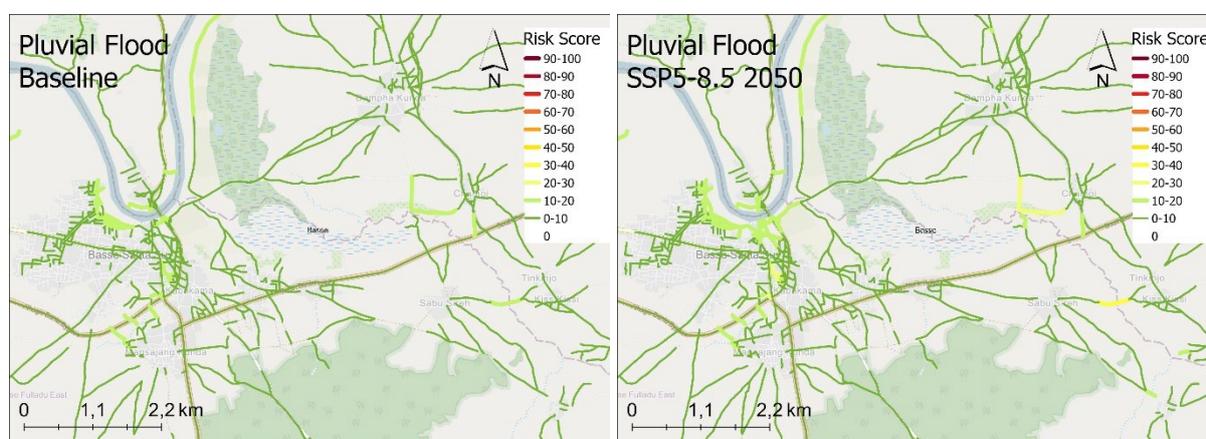


Figure 4-4: The Pluvial direct risk score for roads for the town Basse – Baseline (left) and SSP5-8.5 2050 (right) scenarios as illustration.

Figure 4-5 shows the pluvial direct risk score for bridges in the baseline in The Gambia. Table 4-3 shows the number of bridges and percentage of all bridges with a pluvial flood risk (risk score >0) in The Gambia. The flood risk to bridges is limited. A total of 122 bridges have a risk score between 0-10, which are located at crossing points of small streams and creeks. There are no bridges with a risk score higher than 10.

The number of bridges with a risk score between 0-10 is projected to increase from 122 in the baseline to 126 under both scenarios by 2050, indicating that a few bridges experience higher water levels, which put the bridges more at risk of flooding during extreme rainfall events.

Table 4-3: Number of bridges with pluvial flood risk scores for the baseline, SSP4-4.5, and SSP5-8.5 2050 scenarios.

Risk score	Baseline [km]		2050 SSP2-4.5		2050 SSP5-8.5	
	[#]	[%]	[#]	[%]	[#]	[%]
>0-10	122	78.2%	126	80.8%	126	80.8%
10-100	0	0.0%	0	0.0%	0	0.0%
Total	122	78.2%	126	80.8%	126	80.8%

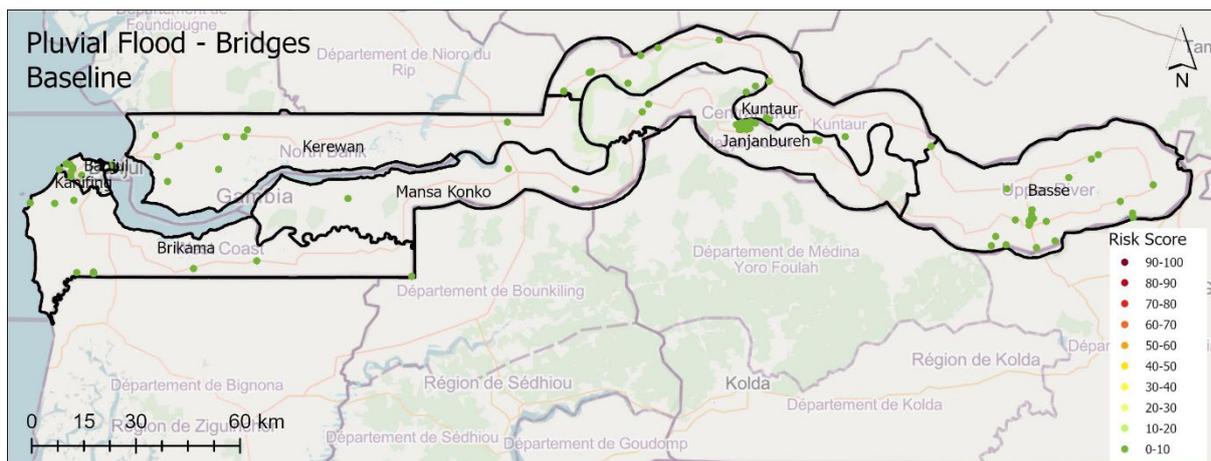


Figure 4-5: The pluvial direct risk score for bridges in The Gambia – Baseline scenario.

4.1.3 Coastal Flood Risk

Figure 4-6 shows the coastal direct risk score at the coast of Gambia for the baseline and under SSP5-8.5 by 2050.

Table 4-4 shows the road lengths and percentage of the total road network with a coastal flood risk (risk score >0) in The Gambia. A total of 91 km of roads are experiencing risk from coastal flooding. These roads are mostly located around the wetlands, with most roads located around the Tanbi Wetland in Banjul and a smaller part at the sea boundary of the Gambia River.

The risk scores are projected to increase for both scenarios, where the total length of roads that experience damage from coastal flooding increases from 91 km in the baseline to 135-141 km under SSP2-4.5 and SSP5-8.5, respectively, by 2050, indicating road segments currently with no risk of flooding in the baseline are projected to become at risk by 2050. Furthermore, roads with a score of 10 or higher increase slightly from 15 km to 30-31 km by 2050. Only small differences (a few centimetres) are observed between climate scenarios SSP2-4.5 and SSP5-8.5 for 2050. This is due to relatively minor differences in expected sea level rise estimates, which cause similar flood depths.

Table 4-4: Road lengths with coastal flood risk scores for the baseline, SSP2-4.5, and SSP5-8.5 2050 scenarios.

Risk score	Baseline [km]		2050 SSP2-4.5		2050 SSP5-8.5	
	[km]	[%]	[km]	[%]	[km]	[%]
>0-10	77	0.9%	106	1.2%	109	1.3%
10-20	11	0.1%	23	0.3%	23	0.3%
20-30	2	0.0%	6	0.1%	7	0.1%
30-40	2	0.0%	0	0.0%	0	0.0%
40-50	0	0.0%	0	0.0%	0	0.0%
50-60	0	0.0%	1	0.0%	1	0.0%
60-70	0	0.0%	0	0.0%	0	0.0%
70-80	0	0.0%	0	0.0%	0	0.0%
80-90	0	0.0%	0	0.0%	0	0.0%
90-100	0	0.0%	0	0.0%	0	0.0%
Total	91	1.1%	136	1.6%	141	1.6%

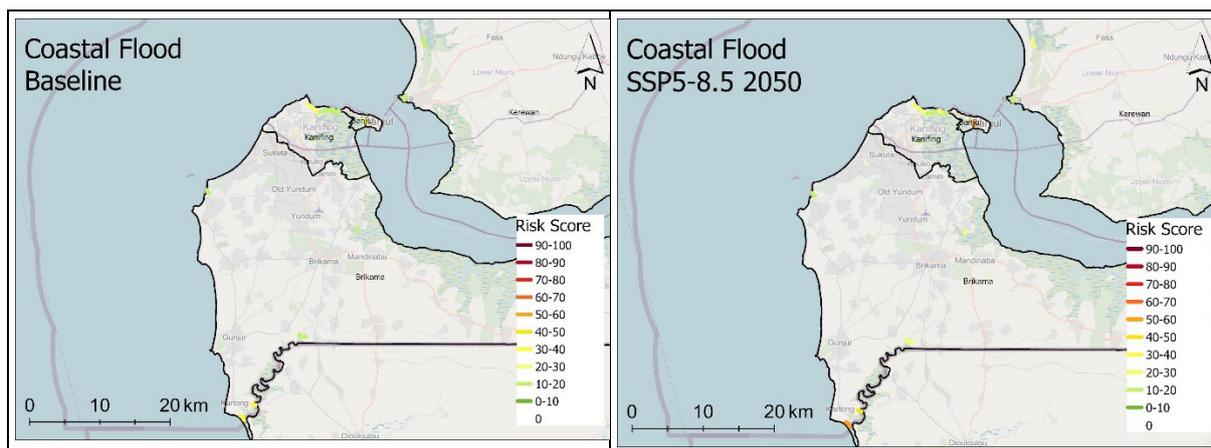


Figure 4-6: The coastal direct risk score for roads at the coast of Gambia – Baseline (left) and SSP5-8.5 2050 (right) scenarios.

4.1.4 Extreme Temperature Risk

Figure 4-7 shows the extreme temperature direct risk score for the baseline and under SSP5-8.5 by 2050 in The Gambia. Table 4-5 shows the road lengths and percentage of the total paved road network with an extreme temperature risk (risk score >0) in The Gambia. The entire paved road network receives a risk score in the baseline. The roads in the east of The Gambia experience greater heat stress than in western Gambia. In the eastern region, the risk scores vary from 60-80. The western regions are closer to the coast and therefore less exposed to extremely high temperatures than inland, resulting in lower risk scores that do not exceed 30.

The risk scores are projected to increase for both scenarios, where the total length of roads with a risk score above 60 increases from 44.8% in the baseline to 68.6% under SSP2-4.5 and 73.3% under SSP5-8.5 by 2050.

Table 4-5: Road lengths with temperature risk scores for the baseline, SSP5-8.5, and SSP5-8.5 2050 scenarios.

Risk score	Baseline [km]		2050 SSP2-4.5		2050 SSP5-8.5	
	[km]	[%]	[km]	[%]	[km]	[%]
>0-10	172	12.5%	0	0.0%	0	0.0%
10-20	193	14.0%	49	3.6%	0	0.0%
20-30	60	4.4%	125	9.1%	49	3.6%
30-40	70	5.0%	140	10.1%	125	9.1%
40-50	45	3.3%	54	3.9%	122	8.8%
50-60	222	16.0%	65	4.7%	72	5.2%
60-70	281	20.4%	61	4.5%	65	4.7%
70-80	338	24.5%	45	3.3%	61	4.5%
80-90	0	0.0%	244	17.6%	73	5.3%
90-100	0	0.0%	597	43.2%	813	58.8%
Total	1,381	100.0%	1,381	100.0%	1,381	100.0%

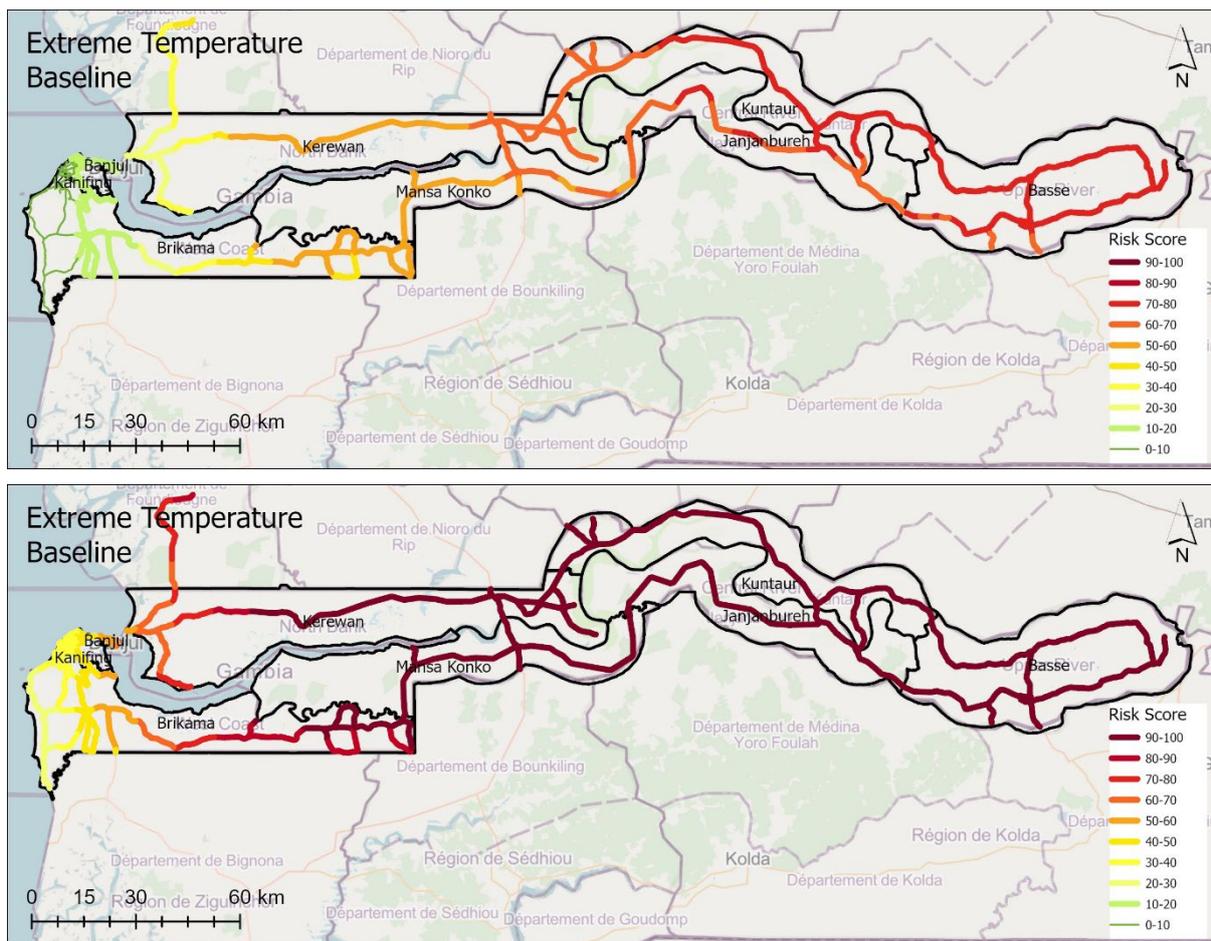


Figure 4-7: The extreme temperature direct risk score for roads in The Gambia – Baseline (upper) and SSP5-8.5 2050 (lower) scenarios.

4.2 Socio-economic impacts

The network analysis was performed for the origin-destination combinations listed in Table 3-4 and for one pluvial, fluvial, and coastal flood event as listed in Table 3-5. The network analysis output includes:

- **Road criticality**, indicating roads that are inaccessible (flood depth > 0.3m). This shows the frequency of road use under normal conditions to reach facilities, measured by the number population (social), markets (economic), or hotels (tourism).
- **Population affected**, showing the additional travel time during flood conditions compared to normal conditions, or communities which are completely cut-off from facilities during a flood event.

For road criticality, results were aggregated into single values for social, economic, and tourism impact by summing road frequencies across all origin-destination combinations and thereafter combining the flood events. These values were then categorized as low, medium, or high and a combined road criticality was generated based on the classification as shown in Table 4-6,

Table 4-6: Classification of road criticality into low, medium and high.

Road criticality	Social (# of population)	Economic (# of markets)	Tourism (# of hotels)	Combined
Low	< 1,000	< 3	< 3	One low
Medium	1,000 – 2,000	3 - 6	3 - 4	Low combined with one medium or multiple lows
High	> 2,000	> 6	> 4	Contains either a medium or high combined with a low/medium/high

Numerous communities were cut off due to flooding. To combine the results, we analysed if each community was isolated from any of the three social facilities (markets, schools, and hospitals) for the two flood events (pluvial and fluvial, excluding coastal as communities were not impacted by coastal flooding). The number of times a community was cut off across all events was then summed, resulting in a potential maximum of six cut-offs.

4.2.1 Road criticality

Table 4-7 shows the number and total length of flooded road segments (between nodes) due to flooding, which are used to access social, economic, or tourism facilities under normal conditions. The location of these roads is shown in Figure 4-8. A total length of 3,251 km has been identified as critical for these social facilities, where 279 km is classified as medium and only 41 km is classified as high. These roads are evenly spread across The Gambia, with most of the medium and high road criticality located in Brikama LGA.

Table 4-7: The number of roads and the total length classified as low, medium, and high criticality per LGA.

Road criticality	Low		Medium		High		Total	
	[#]	[km]	[#]	[km]	[#]	[km]	[#]	[km]
Banjul	0	0.0	0	0.0	0	0.0	0	0.0
Kuntaur	417	460.1	44	38.4	9	1.8	470	500.2
Janjanbureh	299	374.8	42	40.6	2	0.4	343	415.8
Kanifing	4	0.3	13	1.6	1	0.1	18	2.0
Mansa Konko	289	531.7	23	49.6	1	2.3	313	583.7
Kerewan	275	336.1	23	24.4	17	11.9	315	372.4
Basse	604	622.5	71	48.4	8	2.3	683	673.1
Brikama	747	606.0	200	76.2	65	22.3	1,012	704.5
Total	2,635	2,932	416	279	103	41	3,154	3,251.8

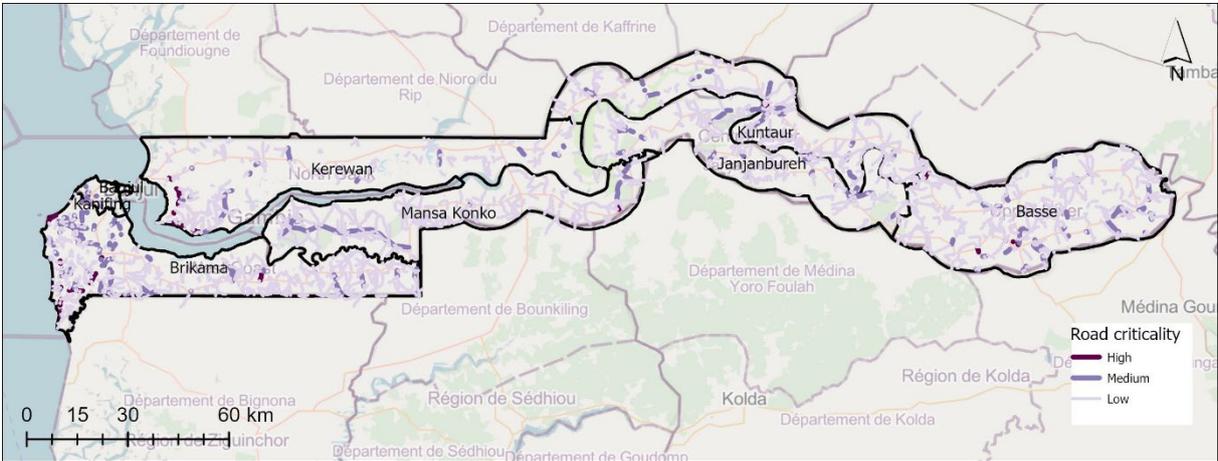


Figure 4-8: Roads with a low/medium/high criticality to access social, economic and tourism facilities in the Gambia.

4.2.2 Population impact

Table 4-8 and Table 4-9 shows the relative and total population cut-off from social facilities (markets, schools, and hospitals) and those with increased travel time due to flooding. It also shows the frequency of cut offs from any social facility resulting from the combined impact from pluvial and fluvial flood event, with a potential maximum of six cut-offs. The location of these communities is shown in Figure 4-9.

The following observations were made regarding the population impact of flooding:

- In The Gambia, 11% of the population is cut off from markets, 8% from schools, and 11% from hospitals during a flood event.
- A larger percentage of the population in The Gambia (11%) is completely cut off from social facilities during a flood event than experiences increased travel time via alternative routes (3%).
- The population is cut off from multiple social facilities (closest market, school, or hospital) simultaneously during a flood event.
- LGA Kuntaur, Mansa Konko, and Basse are the most significantly impacted, with 33%, 25%, and 26% of their respective populations cut off from any social facility.

As mentioned, 11% of the population is cut off from markets during a flood event. This equates to approximately 261,000 people (Table 4-9: The total population per LGA cut off from facilities and experiencing increased travel time during a flood event. Table 4-9), primarily located in the rural areas of The Gambia. These rural populations are highly dependent on markets for income and food. When flood events render markets inaccessible, it can be reasonably assumed that these 261,000 people in The Gambia will experience income loss annually.

Table 4-8: The relative population per LGA cut off from facilities and experiencing increased travel time during a flood event.

LGA	Population cut-off [%]			Number of times cut-off [%]							Increased travel time [%]		Total population [#]
	Markets	Schools	Hospital	1	2	3	4	5	6	Total	0.5-1 h	1h	
Banjul	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	29,838
Kuntaur	32%	33%	33%	0%	1%	21%	0%	0%	10%	33%	4%	2%	117,392
Janjanbureh	12%	11%	15%	0%	6%	7%	0%	0%	2%	15%	6%	3%	139,189
Kanifing	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	417,429
Mansa Konko	23%	23%	25%	0%	3%	8%	1%	3%	10%	25%	0%	1%	88,475
Kerewan	9%	7%	9%	0%	2%	7%	0%	0%	0%	9%	4%	5%	270,343
Basse	26%	22%	26%	0%	1%	12%	3%	0%	9%	26%	2%	5%	290,258
Brikama	8%	3%	8%	0%	4%	2%	0%	0%	1%	8%	1%	0%	1,070,176
Total	11%	8%	11%	0%	3%	5%	1%	0%	2%	11%	2%	1%	2,423,099

Table 4-9: The total population per LGA cut off from facilities and experiencing increased travel time during a flood event.

LGA	Population cut-off [%]			Number of times cut-off [%]							Increased travel time [%]		Total population [#]
	Markets	Schools	Hospital	1	2	3	4	5	6	Total	0.5-1 h	1h	
Banjul	0	0	0	0	0	0	0	0	0	0	0	0	29,838
Kuntaur	37,504	39,076	39,076	0	1,572	25,205	0	0	12,299	39,076	4,298	2,912	117,392
Janjanbureh	17,247	14,750	20,240	0	8,483	9,330	0	7	2,419	20,239	7,861	3,644	139,189
Kanifing	0	0	0	0	0	0	0	0	0	0	0	0	417,429
Mansa Konko	20,689	19,939	21,956	0	2,429	7,267	856	2,564	8,842	21,958	220	854	88,475
Kerewan	23,293	19,124	23,293	0	4,164	18,196	5	41	887	23,293	11,646	12,212	270,343
Basse	75,896	63,746	75,896	0	2,712	35,858	9,439	1,069	26,819	75,897	6,386	13,906	290,258
Brikama	86,347	36,168	82,684	3,664	41,955	24,571	4,560	3,571	8,027	86,348	15,207	1,345	1,070,176
Total	260,977	192,802	263,145	3,664	61,314	120,426	14,860	7,252	59,292	266,808	45,618	34,873	2,423,099

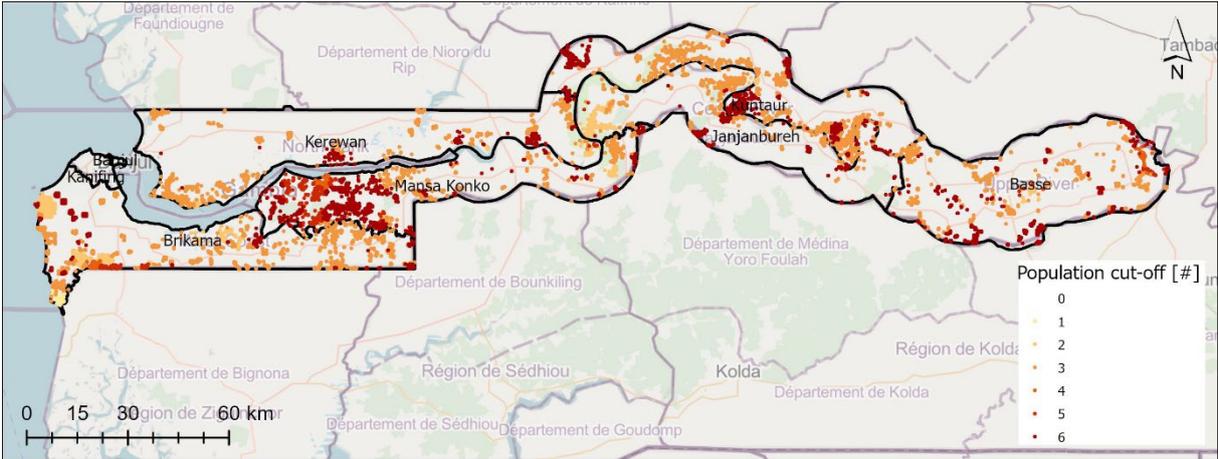


Figure 4-9: The number of times the population is cut off from social facilities (markets, schools, and hospitals) during a flood event (pluvial and fluvial).

4.3 Combined Risk Score for Roads

In general, many roads have a low direct risk score, as flood depths often remain below 0.5m, which indicates a damage fraction <0.1. However, this depth significantly impacts connectivity, as roads become inaccessible at a 0.3m threshold. To integrate direct risk and socio-economic impact results, critical roads (low, medium, or high criticality) with a direct risk score above 10 (expected physical damage from different flood events) were selected.

Table 4-10 shows the number and total length of road segments meeting both criteria and the location of these roads is shown in Figure 4-10. A total of 104 km of roads were identified with medium criticality and 8 km with high criticality. Brikama has the largest concentration of these roads, with 28.9 km of medium criticality and 4.3 km of high criticality.

Table 4-10: The number of road segments and the total length with a direct risk score above 10 and low/medium/high criticality per LGA.

Road criticality LGA	Low		Medium		High		Total	
	[#]	[km]	[#]	[km]	[#]	[km]	[#]	[km]
Banjul	0	0.0	0	0.0	0	0.0	0	0.0
Kuntaur	222	210.9	28	21.3	9	1.8	259	234.0
Janjanbureh	140	147.3	22	19.9	1	0.1	163	167.3
Kanifing	0	0.0	9	1.1	0	0.0	9	1.1
Mansa Konko	89	179.5	5	9.9	0	0.0	94	189.3
Kerewan	88	80.7	6	3.1	2	1.7	96	85.6
Basse	386	398.4	42	19.4	1	0.2	429	418.0
Brikama	236	133.2	100	28.9	17	4.3	353	166.5
Total	1,161	1,150	212	104	30	8	1,403	1,261.8

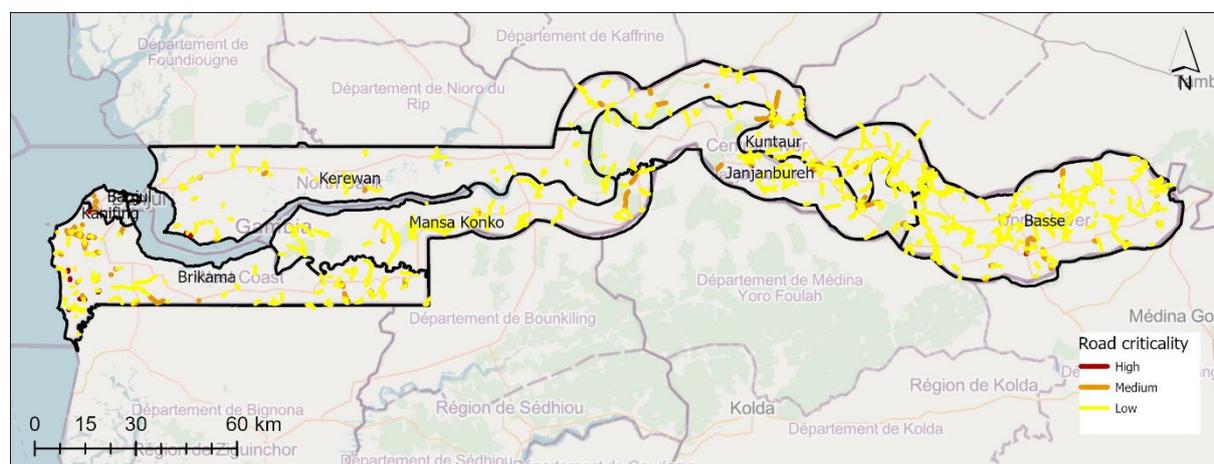


Figure 4-10: Roads with a direct risk score above 10 and low/medium/high criticality in the Gambia.

4.3.1 Results for Road Segments Selected for World Bank’s The Gambia Infrastructure Project

Table 4-11 shows the length of short-listed roads for investments by the WB and how much of the length of these roads overlaps with a direct risk score above 10 and low/medium/high criticality per LGA. In total, 61 road segments with a total length of 173.7 km has been short-listed for investments scattered across The Gambia. Out of these, 12 road segments with a total length of 36.4 km meet both criteria; these roads were assigned either a low (19.4 km) or medium (17.1 km) road criticality, as no roads were found to be highly critical (Figure 4-11).

Table 4-11: The total length of short-listed roads for investment with a direct risk score above 10 and low/medium/high criticality per LGA.

LGA	Short-list [km]	Road criticality [km]			
		Low	Medium	High	Total
Banjul	0.0	0.0	0.0	0.0	0.0
Kuntaur	0.0	0.0	0.0	0.0	0.0
Janjanbureh	31.9	1.2	0.0	0.0	1.2
Kanifing	24.0	0.0	0.3	0.0	0.3
Mansa Konko	14.2	0.0	14.2	0.0	14.2
Kerewan	20.0	0.8	0.0	0.0	0.8
Basse	55.7	13.2	2.5	0.0	15.7
Brikama	27.8	4.1	0.0	0.0	4.1
Total	173.7	19.4	17.1	0.0	36.4

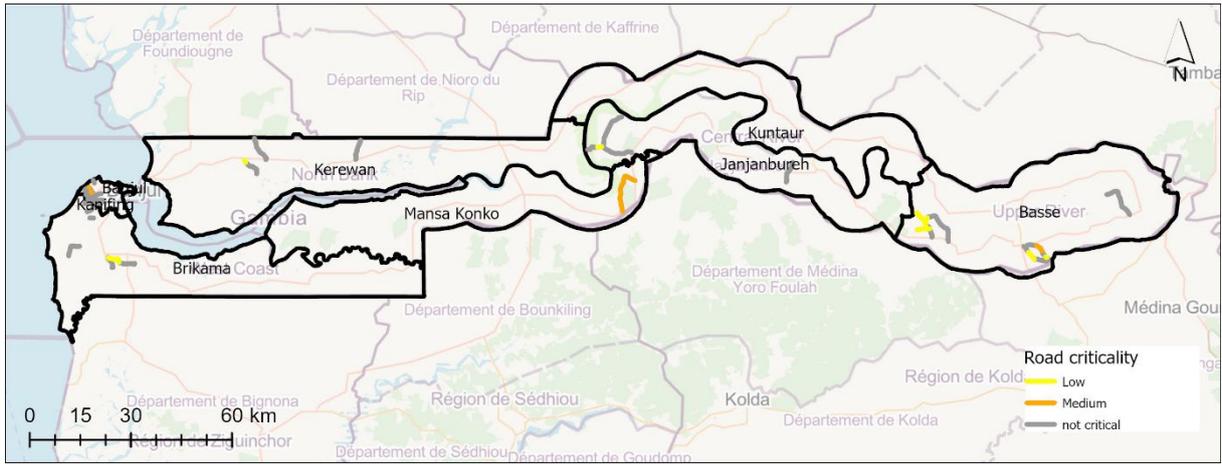


Figure 4-11: Short-listed roads for investment that overlap with a direct risk score above 10 and low/medium/high criticality in the Gambia.

5. CLIMATE RISKS TO THE GAMBIA'S TRANSPORT SYSTEMS – PORT AND FERRIES

This chapter considers the key climate risk associated with the Banjul Port and river jetties (refer initial climate risk screening in Table 3-7).

5.1 Port of Banjul

The Port of Banjul, as described in Chapter 3.2.4, has a key function in the transport system and broader economy of The Gambia.

Ships destined for the port currently experience idle time at anchorage due to the limited berth capacity of the port itself and putting additional costs on trade in The Gambia. To increase the cargo handling and storage capacity of the terminal to address the increasing demand on the port facility, together with current capacity and efficiency issues, the port was planned to be expanded and to be financed by AfDB and the European Investment Bank (EIB). As climate change is expected to exacerbate this problem of idle time as flooding is already experienced at the port. Therefore, for this expansion, a climate change risk assessment was undertaken in 2022 for the whole Port of Banjul (GCA, 2022).

In this assessment, a total of 33 different climate variables were analysed, from which extreme temperature, drought, and coastal flooding were identified as the key climate hazards considering the assets and operations of the port, and were further analysed. The following impacts due to climate hazards were estimated for the year 2050:

- Direct impact (physical damage):
 - **Extreme temperatures for access roads:** Material sensitivity to temperature causing damage to road surface and roads becoming unusable and/or delays in landside transport, resulting in 160,000 EU/year.
- Indirect impact (downtime of the port):
 - **Coastal flooding for landside operations:** Risk of port operations and transport temporarily being stopped due to flooding of the terminal site and/or the Bund Road, thereby limiting direct access to/from the port, resulting in an estimated downtime of 25 days/year.
 - **Extreme temperatures for marine operations:** Risk of reduced wellbeing and availability of staff due to exposure to extreme temperatures, resulting in staff shortages and reduced productivity with downtime estimation of 10 days/year.
 - **Extreme temperatures for landside operations:** Risk of reduced staff wellbeing (as above), higher electricity demand and risk of equipment damaged by high temperatures, resulting in replacement costs and downtime estimation of 10 days/year.
 - **Extreme precipitation for marine operations:** Risk of damage to bulk (non-containerized) goods and/or risk of dangerous working conditions when handling during extreme rainfall events, resulting in downtime estimation of 10 days/year.
 - **Extreme precipitation for landside operations:** Risk of temporary inundation of port area during extreme rainfall events, resulting in possible damage to cargo and downtime estimation of 10 days/year.

The majority of the impact of climate hazards is on port operations, causing downtime of the port. The direct impacts, physical damage to the assets of the port, are limited. In the current situation, it was estimated that the total annual climate risk is approximately 140,000 EUR/year in the baseline and increases to 160,000 EUR/year by 2050. Figure 5-2 shows the cumulative climate risk, indicating that the total climate risk can reach approximately 25 million EUR in 2050.

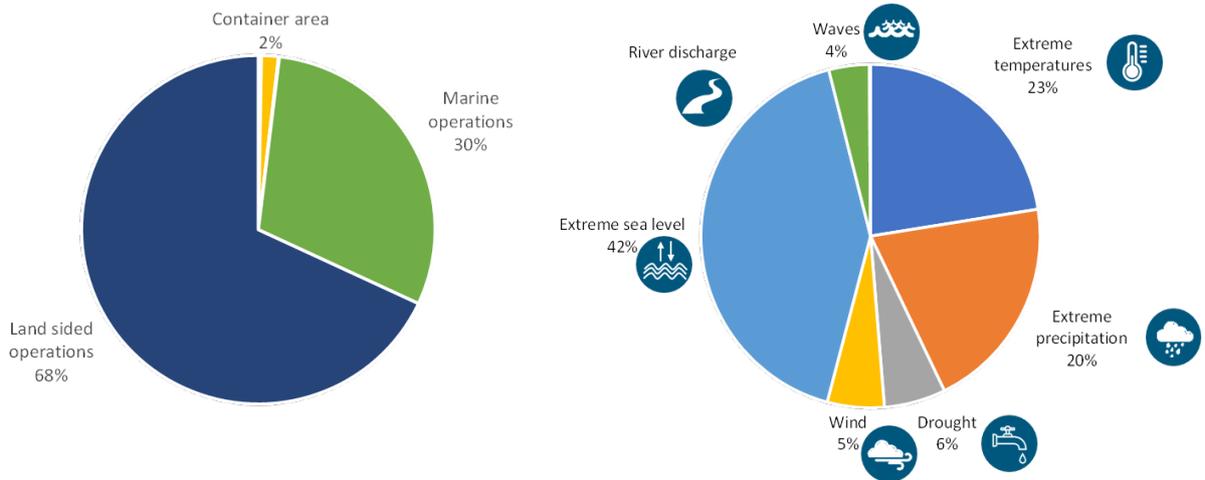


Figure 5-1: The relative contribution of the different assets/operations of the port (left) and of the different hazards (right) to the total risk to the port.

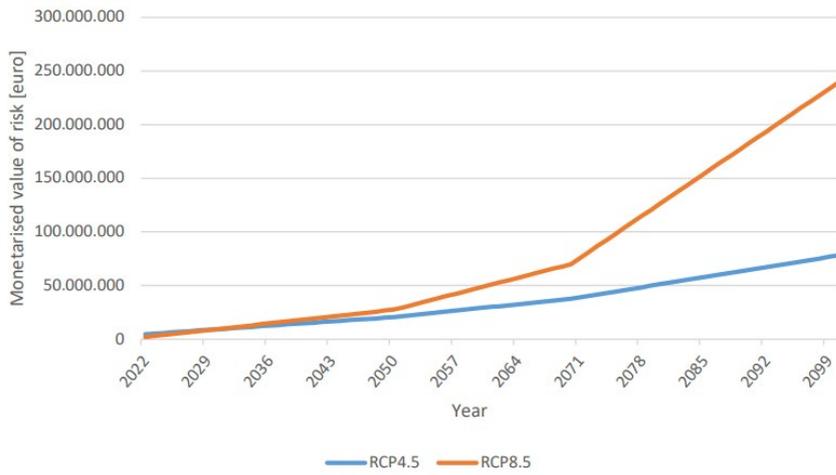


Figure 5-2: Cumulative climate risk over time for climate scenario RCP4.5 and RCP8.5.

5.2 River Jetties

River transport consists of ferry services at different river jetties. Currently, some river jetties are at risk of erosion and fluvial flooding. As described in the following narrative, climate change is expected to alter the river discharge of the Gambia River due to changes in precipitation patterns. These changes may have implications for water availability, flood risk, and navigation of the Gambia River.

An assessment of ten jetty locations, selected for their tourism potential and distributed along the Gambia River and a tributary near the southern Senegalese border, was conducted (GCA, 2022). This assessment estimated their current exposure to climate hazards through hydrodynamic and morphodynamic analyses. Figure 5-3 shows the locations of the jetties.

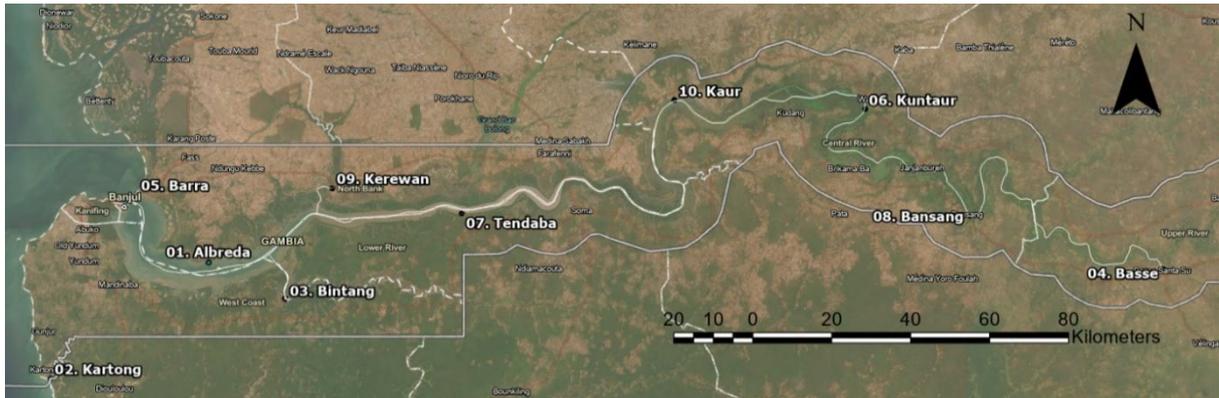


Figure 5-3: Overview of jetties spread along the Gambia River and Kartong at the southern border with Senegal.

The discharge of The Gambia River currently varies considerably with seasons, between approximately 100 m³/s in the dry season to approximately 1,000 m³/s during the rainy season. Figure 5-4 shows the projected changes in extreme river discharge values at the river mouth for different return periods under two climate scenarios (RCP4.5 and RCP8.5). The figure shows that the river discharge is likely to increase for all return periods under both scenarios, indicating a higher probability of flooding events. The increase is more pronounced for the higher return periods and the higher emission scenario, suggesting a greater risk of severe floods in the future. Currently, the jetties at Basse, Kuntaur, Tendaba, Bansang and Kaur are at a risk of fluvial flooding.

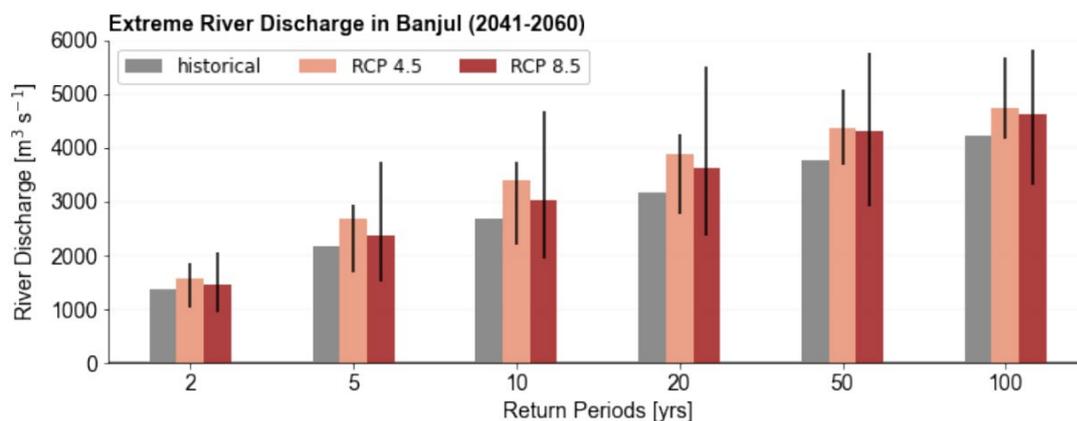


Figure 5-4: Comparison of projected extreme river discharge values at the Gambia river mouth for different return periods between 2 and 100 years. The values of the baseline period (grey) are compared against RCP4.5 and RCP8.5 by 2050 (GCA, 2022).

Climate change will also affect the sediment transport and the erosion and deposition patterns of the river, leading to changes in the river morphology, geometry, and stability of riverbanks. The jetty structures might marginally influence how the river responds to these changes and what adaptive measures are needed to mitigate the potential impacts of climate change on the river and the jetty structures. Currently, the jetties at Albreda, Barra, and Kuntaur are at risk of erosion.

6. PRELIMINARY ADAPTATION INVESTMENT OPTIONS

This chapter presents adaptation options that can be considered to address the climate risks identified in Chapters 4 and 5. A long-list of all potential adaptation solutions identified is provided, following which 12 adaptation projects are selected and further defined in Project Briefs.

6.1 Long-list of Measures

The objective of the long-list is to identify potential climate adaptation measures that may address the key climate risks identified for The Gambian national transport network.

This long-list considers a broad range of measures including both structural and non-structural measures. Structural measures may consist of hard engineering solutions ('grey infrastructure'), completely natural features ('green infrastructure') or a combination thereof ('Nature-based Solutions'). Figure 6-1 illustrates these concepts.

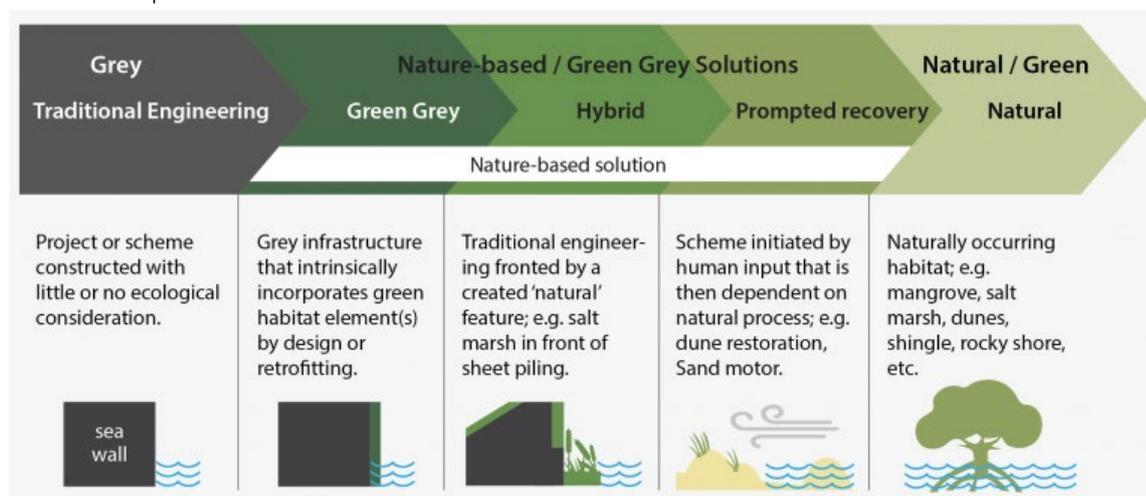


Figure 6-1: Approach to identification of adaptation measures -from grey to green solutions . [Copyright © 2017 The Authors – Naylor, L.A., Kippen, H., Coombes, M.A., et al. (2017)]

This approach provides a multi-layer safety to address climate risks and allows for the identification of measures that not only promote resilience to the assets, but that can provide benefits beyond the project area ('co-benefits'). For example, co-benefits can be to generate additional revenue streams for the asset operators or livelihood opportunities for the local communities that live in the surroundings of the road.

The starting point for the identification of adaptation measures was to determine types of measures that are the most relevant to address the key climate risks arising out of the climate risk assessment. The focus was on measures that could be adopted to improve standard designs for new/upgraded transport infrastructure, measures that can be 'bolted-on' to existing transport infrastructure, and operation and maintenance (O&M) interventions that can be implemented.

We have considered measures for the transport infrastructure (i.e., to address extreme heat and flooding) and operational measures and asset/disaster management systems (i.e., to reduce indirect impacts and prevent direct impacts). Moreover, to develop the long list of adaptation measures, the following elements for each potential measure were considered:

1. Identification of the key climate hazards.
2. Effect of the hazard on the environment.
3. Asset type affected by the risk.
4. Current impact on the asset type under prevailing climate conditions.
5. Potential impacts under more extreme climatic conditions.
6. Indication of either grey, green or Nature-based Solution (NbS) opportunity.
7. Type of measure – e.g. measure relates to design specifications, physical measures, operations & maintenance or institutional and social measures.

8. Category of measure.

With this structured process, adaptation measures could be identified and referenced to specific climate hazards, risks and/or assets they are targeted to. It also allowed to have an overview of how various measures could be interconnected between each other and guide the development of the short list in the next step of the prioritization of adaptation measures. **Annex 1** provides the full long list of adaptation measures identified. Note that this is still a preliminary long list and is still undergoing updates based on new insights and discussions with (local) experts.

Stakeholder engagement is fundamental to ensure that this long list of adaptation measures is appropriate for the context of The Gambia and, more specifically, to local conditions of the different infrastructural assets. Two *Multi Stakeholder Dialogues on Climate Risks* were held to identify and validate and expand on the long list of options with input from the key stakeholders, on 2-3 April 2025 and 19 June 2025. These consultations also provided important feedback from stakeholders for prioritizing adaptation measures.

6.2 Selection of preferred Adaptation Investment Options

Following completion of the long-list, a selection of preferred adaptation investment options was made. This selection was made qualitatively, with the objective of selecting 12 no. adaptation investment options that:

- Have a significant impact in addressing climate risks in the transport sector;
- Cover the range of major climate risks in the transport sector (coastal, fluvial and pluvial flooding; extreme temperature)
- Cover the range of infrastructure assets in the transport sector (roads, bridges, ports and river transport. The airport was excluded as climate risks there are comparatively less);
- Are viable to implement in the context of The Gambia;
- Are as far as possible location-specific.

To make the selection, professional judgement was applied making use of the inputs from the 2 no. *Multi Stakeholder Dialogues on Climate Risks* and insights from the local consultant team. In some cases, generic options from the long-list were made specific in the selection process (for instance in terms of location). The selection was validated with GCA.

Project Briefs were then prepared for these 12 no. adaptation investment options - refer Chapter 7.

7. ADAPTATION PROJECT BRIEFS

7.1 Introduction

The 12 adaptation options selected for which Project Briefs are presented are:

1. Nature-based sustainable land management practices
2. Nature-based urban drainage management
3. Road asset management system
4. Spot Improvement of rural roads
5. NRA maintenance support
6. Community-based road maintenance
7. Implement permeable paving technology
8. Upgrade drainage system in priority areas within the GBA
9. Upgrade of port access roads
10. Rehabilitation of non-operating river jetties
11. Bathymetric survey of Gambia River
12. Mangrove re-planting programmes

These Project Briefs were populated with details sourced through engagements with national stakeholders through the course of this assignment, using the template key on the following page.

For the majority of these Project Briefs, the National Roads Agency (NRA) is identified as the lead institution for implementation, therefore a specific validation meeting was held with NRA representatives on 22 September 2025 to validate the details presented in the Project Briefs. Feedback from this meeting was incorporated into the Project Briefs.

To provide further background to the funding and financing sources listed in the Project Briefs, reference tables are provided in **Annex 2**.

7.2 Adaptation Project Briefs

Template Key:

Name of the Project
Climate risk context
Describe background context of Project. This includes the describing the climate risk that should be addressed, what climate hazard/s underpin this risk, and what the impacts of this climate risk are on assets and services. (max 100 words).
Adaptation project description
Describe the proposed adaptation Project. Can be described in multiple (generally sequenced) actions. Define what infrastructure, natural asset or service is targeted for adaptation. E.g. rural roads; port; river transport. Confirm spatial extent of project. i.e. name a specific location, or a particular region, or nationally applicable over the entire country.
Expected outputs and impacts
Describe the adaptation rationale- i.e. what the reduction in climate risk is due to the adaptation Project.
Gender considerations
Does this Project have gender-differentiated impacts or benefits? How can this Project best ensure that gender considerations are accounted for?
Enabling environment
Consider alignment with sectoral policies – i.e. what existing policies and/or plans support this Project? Are there any prerequisites in the enabling environment for this Project to be executed?
<i>{Insert image of option}</i>
Project category
Select whether Project is: Physical – structural ‘bricks-and-mortar’ infrastructural actions whereby physical changes are made ‘on-the-ground’; Social / Behavioural – actions focussed on people, typically relating to awareness or training, changes in operations and the like; or Institutional / Governance – actions that focus on institutional organisation or governance systems (policy, regulation, etc) that enable the environment for adaptation. For Physical projects, further sub-categorise by: NbS – Nature-based Solutions, being actions that incorporate naturally occurring habitat into transport solutions (also referred to as ‘green infrastructure’); Grey – project constructed with little or no ecological elements; or Hybrid – solutions that combines elements of green (NbS) and grey infrastructure to perform desired function

For Physical projects, further sub-categorise by:
Capital – major projects or upgrades that improve or extend the life, value, or functionality of an asset; or
Maintenance - routine or minor works aimed at keeping an asset in its current condition or restoring it to working order.

Climate hazard/s addressed

Denote by symbol/s which hazards are addressed by the Project.



- coastal flooding



- extreme temperature



- extreme precipitation



- drought



- fluvial / pluvial flooding



- extreme wind



- wildfires

Implementation considerations

What institution could lead implementation, and who supports and/or executes?

- Lead implementing institution: xx
- Supporting institution/s: xx

Potential funding and financing sources

List what options may be viable for funding and financing of the Project:

- Typical sources
- Specific Climate Funds
- Any particular financing/funding mechanisms or other sources that may be appropriate.

Refer to Annex 2 for definitions and further information on funding and financing sources

Co-benefits

List what co-benefits may be realised through implementation of the adaptation Project.

Capital / upfront costs

<\$10m; \$10m - \$100m; >\$100m



Operational costs

Per year: <\$100k; \$100k - \$1m; >\$1m



Implementation time

<3yr; 3-5yr; >5yr



1. NATURE-BASED SUSTAINABLE LAND MANAGEMENT PRACTICES

Climate risk context

The Gambia faces escalating climate threats—extreme heat, drought, floods, saline intrusion, and erosion. Floods in particular can cause damage and unavailability of roads and bridges, especially in low-lying zones like Banjul, CRR, and North Bank. Flooding accounts for over 90% of direct road risk. Particularly when floods follow droughts, sediment runoff can block road drainage systems, increasing maintenance costs and exacerbating flood damage. Nature-based solutions related to land management practices can curb floods, stabilize soils, and protect transport corridors, strengthening resilience and supporting climate adaptation.

Adaptation project description

Implement nature-based sustainable land management practices in rural catchments, such as wetland restoration, reforestation, and sustainable grazing of livestock. Implemented actions in two phases:
Phase 1: Baseline studies to identify priority areas/watersheds and size of interventions.

- These studies (Climate risk assessments, hydrological modelling) will identify the scope and nature of interventions for sustainable land management (SLM) investments at the watershed level. They will identify sites and activities for interventions in the priority areas.

Phase 2: Implementation

- **Integrated Watershed and Wetland Restoration**
 Rehabilitate degraded wetlands, restore riparian vegetation, and implement buffer zones to reduce runoff and sedimentation. This could be explored along Central River Region (CRR) and North Bank Region, where rice fields and transport corridors are vulnerable.
- **SLM for Roadside Corridors**
 Apply agroforestry, contour planting, and vegetative cover along transport routes to reduce erosion and dust. This could be applied along the Upper River Region (URR) and Lower River Region (LRR), where drought and erosion are prevalent.

Expected outputs and impacts

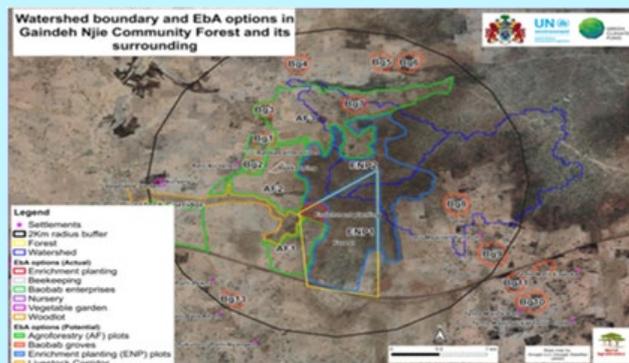
- Large-scale application of these measures could result in:
- 40–60% fewer road closures during floods.
 - 20–30% lower rural road maintenance costs.
 - Improved ecosystem services (flood control, biodiversity).
 - Stronger community resilience and green jobs through NbS

Gender considerations

- As women are the primary users of wetlands and formerly land, train women on para-extension farming
- Promote gender-sensitive land tenure reforms and secure land tenure for women.

Enabling environment

- Alignment with the National Land Policy –ensure that priority areas identified and nature of management practices proposed are supported by the NLP.
- Alignment with the National Agricultural Investment Plan (GNAIP) and climate-smart agriculture policies.
- Climate-resilient land use mapping, management and planning tools to guide infrastructure siting and ecosystem protection such as LDSF, DATAR and WOCAT-LADA
- Geospatial information systems (GIS) for real-time monitoring, risk assessment, and decision-making support.
- Stakeholder awareness of sustainable agricultural practices.



Project category

Institutional + Physical - NbS (Capital + Maintenance)

Climate hazard/s addressed:



Implementation considerations

Lead: National Environment Agency (NEA)

Supporting:

- Ministry of Agriculture
- Department of Water Resources (DWR)
- National Roads Agency (NRA)
- City or area councils, farmer cooperatives, etc.

Potential funding and financing sources

- Typical sources: National and foreign governments, multilateral development banks, bilateral development organizations, private sector and development funds.
- Specific Climate Funds: Green Climate Fund (GCF), Adaptation Fund, GEF Trust Fund, SCCF (via GEF), InfraCo Africa (PIDG), IFC InfraVentures.
- UN & Global Programs: FAO Green Climate Facility, UNCCD Land Degradation Neutrality Fund

Co-benefits

- Enhanced food security
- Enhanced biodiversity and ecosystem services
- Rice farming resilience

Capital / upfront costs



Operational costs



Implementation time



2. NATURE-BASED URBAN DRAINAGE MANAGEMENT

Climate risk context

The Greater Banjul Area's (GBA) flat, low-lying terrain and poorly maintained drainage make it highly vulnerable to flooding. With few formal drains beyond Kotu Stream and Tanji River, roads often act as natural channels, causing street floods that last for days during the rainy season. These events disrupt mobility and damage infrastructure. Communities in Banjul, Kanifing, Brikama, and Tanji are particularly affected. Within the GBA, 69km of roads which are considered critical for reaching social facilities flood regularly.

Adaptation project description

Implement nature-based solutions to urban drainage challenges, in a way that local drainage issues are addressed without compromising groundwater recharge or moving the problem downstream.

Primary measure:

- **Implement Bioswales:** Construction of longitudinal road-side bioswales should include vegetation that is suitable for the dry climate of the GBA. These bioswales should be deployed in flood-prone urban zones (e.g., Old Jeshwang, Fajikunda, Ebo Town) based on flood and incident mapping. This approach has already proven successful with the implementation of a bioswale, containing both shrubs and trees, along the Banjul Highway.

Supplementary measures: Additional measures that can supplement the effectiveness of bioswales could include:

- **Implement Permeable Pavements.** Both for road surfaces and for ancillary infrastructure such as pedestrian sidewalks, parking areas and the like, such that more rainfall infiltration takes place and less runoff.
- **Add Detention/Retention Elements & Desilting Regimes.** Install offline basins, retention ponds, and expanded outfalls where space allows; implement regular desilting upstream of hotspots.
- **Integrate Measures with Urban Planning, Zoning and Building Regulations.** Mandate green infrastructure in zoning codes for new developments and retrofits, including green building requirements that reduce peak rainfall runoff.

Expected outputs and impacts

- Reduced urban flooding and road closures, improving mobility and safety.
- Lower road repair and maintenance costs through improved stormwater management.

Gender considerations

- Reduce extent of flooding through these measures, to enable safe mobility on foot for women through public spaces and frequently-used roads, both during and after flood events.
- Address disproportionate impacts on women and children by promoting their active participation and leadership in NbS initiatives, both during planning, implementation, and monitoring stages.

Enabling environment

- Integration with municipal authority plans, budgets (especially O&M), and operational capacity, to ensure sustainability of the measures.
- Adequate space for green infrastructure must be ensured through enforced spatial planning.
- Strengthen urban planning frameworks under the Ministry of Lands and Regional Government.
- Adopt municipal bylaws supporting green infrastructure integration.



Bioswale at Banjul Highway

Project category

Physical - Hybrid (Capital)

Climate hazard/s addressed:



Implementation considerations

Lead: National Roads Authority (NRA)

Supporting:

- MECCNAR – Climate policy and coordination,
- NEA – Environmental regulation and wetland protection,
- Municipal Councils (KMC, BCC, BAC) – Local implementation and O&M.
- Ministry of Lands & Physical Planning – Urban planning and zoning
- Department of Water Resources (DWR) – Drainage and stormwater management
- Community Groups – Local stewardship and maintenance

Potential funding and financing sources

- Typical sources: National and foreign governments, multilateral development banks, bilateral development organizations, private sector and development funds.
- Specific Climate Funds: Green Climate Fund (GCF)
- UN Agencies: UN-Habitat.

Co-benefits

- Greater rainwater infiltration resulting in increased groundwater recharge.
- More urban green spaces for resilience and liveability.
- Urban heat reduction and sustainable cooling
- Job creation

Capital / upfront costs 

Operational costs 

Implementation time 

3. ROAD ASSET MANAGEMENT SYSTEM

Climate risk context

The Trans-Gambia highway and urban roads receive regular maintenance, but low-traffic roads are often neglected due to budget cuts and a focus on high-traffic routes, leading to their faster deterioration. Climate hazards, especially flooding and extreme heat, worsen the damage by cracking pavements, causing erosion, and shortening road lifespan. Currently 87% of rural roads are in poor condition. The establishment of a sustainable Road Asset Management System (RAMS) is critical to address this vulnerability, as the lack of maintenance undermines connectivity, economic activity, and resilience in rural areas where reliable transport is vital for livelihoods and essential services.

Adaptation project description

Re-establishment of a RAMS (a RAMS was previously piloted but use was discontinued) to effectively track where climate risks materialize for informed decision-making regarding required maintenance. Currently, asset data is stored in QGIS, but not all assets are mapped. The following steps are envisioned:

- **Set up a data visualization and management system:** Implement a road asset management system with a suitable subscription or non-subscription model that the NRA can maintain long-term. This can build upon the RAMS pilot set up using QGIS between 2019–2021.
- **Establish a low-cost, sustainable data collection method:** Develop a technology-based data collection method to supplement the current manual and resource-intensive approaches such as visual assessment, subsurface investigations, and coring. This technology-based data collection method is envisaged to enable data collection by community stakeholders, especially in rural areas – such as use of a smartphone app to record maintenance needs (such as potholes or surface erosion). And could be supplemented by use of drone photogrammetry.

Expected outputs and impacts

- More effective rehabilitation and maintenance activities, leading to cost-effective improvements in road connectivity, especially in rural areas.

Gender considerations

- Conduct a gender assessment to identify women-specific transportation needs, their vulnerabilities, and associated roads in need of maintenance.
- Prioritize women's participation in decision-making and consultations.
- For road maintenance activities, apply a minimum woman employment quota (aiming for 20-30% representation).

Enabling environment

- Ensure consistent and sufficient funding mechanism for operating the RAMS itself over a long time period – at least the next 10 years to ensure the benefit is realised.
- Strengthen institutional capacity to maintain the RAMS within NRA.



Project category

Institutional

Climate hazard/s addressed:



Implementation considerations

Lead: National Roads Agency (NRA)

Supporting:

- Ministry of Transport Works and Infrastructure (MOTWI)

Potential funding and financing sources

- Typical sources: National and foreign governments, multilateral development banks, bilateral development organizations, private sector and development funds.
- Specific Climate Funds: Adaptation Fund, GEF Trust Fund, GEF Small Grants Programme (SGP), IFC InfraVentures
- After initial injection of funding to support re-establishment, the RAMS should be supported by ringfenced funding for the next 10 years to ensure its funding is not re-allocated to other needs.

Co-benefits

- Reduced maintenance costs
- Increased rural income generation
- Enhanced economic opportunities through reduced travel time and transportation
- Improved rural accessibility and connectivity to essential services

Capital / upfront costs



Operational costs



Implementation time



4. SPOT IMPROVEMENT OF RURAL ROADS

Climate risk context

Rural accessibility in The Gambia is frequently compromised not by issues over the entire length of rural roads, but by specific 'weak spots' along that length such as low-lying sections or poorly drained areas. With climate change, rainfall intensity and severity of flood events are expected to increase, leading to more erosion, washouts, and road closures. These disruptions isolate rural communities from markets, schools, and health services, especially during the rainy season.

Adaptation project description

This project adopts a phased spot improvement approach by targeting only the most vulnerable road sections. According to SSATP, in many cases only ~10% of road length requires intervention to restore all-season functionality, with costs 50-90% lower than full upgrades (Lebo, 2001). Spot improvements can be executed in three phases:

- **Phase 1: Rapid Spot Improvements:** This consists of low-cost, immediate interventions at critical bottlenecks. Rehabilitation includes spot re-graveling, basic drainage, erosion control, and raising the roads.
- **Phase 2: Replace or Add Culverts:** At locations where road culverts are not functioning at the required capacity (due to climate change, under-design or other factors), replace existing culverts with larger capacity culverts or add additional culverts, whichever is most economical in the circumstances.
- **Phase 3: Replace Fords with Climate-Resilient Upgrades:** This is primarily applicable to well-used roads that were constructed decades ago. The improvement consists of replacing fords with culverts/bridges on high socio-economic value rural roads. Such works would be fully engineered, including access road works, drainage, and scour protection.

Expected outputs and impacts

- Improved access to health facilities, schools, and markets; reduced transport disruptions; enhanced agricultural trade and food security; and reduced long-term maintenance costs.
- Specific to Phase 1: Quick and affordable restoration of access, resulting in immediate improvement in rural accessibility, reducing rainy-season isolation.
- Specific to Phases 2 & 3: Ensures long-term resilience and reliable year-round access on critical road sections.

Gender considerations

- Conduct a gender assessment to identify women-specific transportation needs, their vulnerabilities, and associated roads in need of maintenance.
- Prioritize women's participation in decision-making and consultations.
- For road maintenance activities, apply a minimum woman employment quota (aiming for 20-30% representation).
- Ensure the collection of sex-aggregated data.

Enabling environment

- Establish a RAMS to identify hotspots where most issues occur, allowing for the selection of intervention locations by applying prioritization criteria that combine climate vulnerability and socio-economic value.



Project category

Physical – Grey (Capital)

Climate hazard/s addressed:



Implementation considerations

Lead implementing agency: National Roads Agency (NRA)
Supporting:

- Ministry of Transport Works and Infrastructure (MOTWI)
- Ministry of Agriculture (MOA)
- Local Government

Potential funding and financing sources

- Typical sources: National and foreign governments, multilateral development banks, bilateral development organizations, private sector and development funds.
- Specific Climate Funds: Green Climate Fund (GCF), Adaptation Fund, GEF Trust Fund, SCCF (via GEF), InfraCo Africa (PIDG), IFC InfraVentures
- Community-led contributions (labor for minor works)

Co-benefits

- Reduced maintenance costs.
- Increased market access and rural income generation.
- Strengthened disaster preparedness and community ownership.

Capital / upfront costs



Operational costs



Implementation time



5. NRA MAINTENANCE SUPPORT

Climate risk context

The Trans-Gambia highway and urban roads receive regular maintenance, but low-traffic roads are often neglected due to budget cuts and a focus on high-traffic routes, leading to their faster deterioration. Climate hazards, especially flooding and extreme heat, exacerbate damage by cracking pavements, causing erosion, and shortening road lifespan. Currently 87% of rural roads are in poor condition. This lack of maintenance undermines connectivity, economic activity, and resilience in rural areas where reliable transport is vital for livelihoods and essential services.

Adaptation project description

Technical assistance to NRA to expand road maintenance planning capacity. Specifically to:

- Assist in developing more robust maintenance plans that could support the assignment of increased maintenance budget (primarily to purchase and operate more road maintenance equipment).
- Assist in developing, procuring and monitoring Output and Performance-based Road Maintenance Contracts to leverage private sector capacity and efficiency.

It is critical for the success of the project that such technical assistance is long-term, preferably at least over a five-year term and renewable thereafter, to ensure that the knowledge gained can be effectively applied in practice. Such a long-term commitment would support the institutionalization and thus sustainability of new approaches.

Expected outputs and impacts

- Capacitated NRA (staff, systems and road maintenance equipment)
- Subsequently, improved condition of roads, resulting in improvements in urban and rural road connectivity.

Gender considerations

- Conduct a gender assessment to identify women-specific transportation needs, their vulnerabilities, and associated roads in need of maintenance.
- Prioritize women's participation in decision-making and consultations.
- For road maintenance activities, apply a minimum woman employment quota (aiming for 20-30% representation).
- Provide sexual and gender-based violence (SGBV) training when women are employed.

Enabling environment

- Ensure consistent and sufficient funding mechanisms over a long time period (both for the technical assistance and for the maintenance activities themselves).
- Base level of institutional capacity for maintenance planning and performance-based contracting.



Project category

Institutional

Climate hazard/s addressed:



Implementation considerations

Lead: Ministry of Transport, Works and Infrastructure (MOTWI) and/or National Roads Agency (NRA)

Potential funding and financing sources

- Typical sources: National and foreign governments, multilateral development banks, bilateral development organizations, private sector and development funds.
- Specific Climate Funds: Green Climate Fund (GCF), Adaptation Fund, GEF Trust Fund, SCCF (via GEF), InfraCo Africa (PIDG), and IFC InfraVentures.

Co-benefits

- Reduced maintenance costs.
- Work opportunities and skills development of rural people through increased road maintenance activities, leading to increased rural income generation.
- Enhanced economic opportunities through reduced travel time and transportation.
- Improved rural accessibility and connectivity to essential services.

Capital / upfront costs



Operational costs



Implementation time



6. COMMUNITY-BASED ROAD MAINTENANCE

Climate risk context

In rural Gambia, feeder roads connect communities to the primary road network, providing essential connectivity. Most of these feeder roads are of earth construction that can erode from flooding during the rainy season and may thereby become inaccessible or hazardous for vehicles until maintenance is undertaken. Improving and maintaining rural roads is expensive (per capita) due to the low population density. Currently 87% of rural roads are in poor condition. Roads in poor condition undermine connectivity, economic activity, and resilience in rural areas where reliable transport is vital for livelihoods and essential services.

Adaptation project description

Implement community-based road maintenance and monitoring to undertake small-scale upkeep in rural areas and inform the NRA about the requirement for other maintenance. This project is focused on maintenance, rather than labor-based road rehabilitation that utilizes local communities which was trialled in The Gambia with limited success, due mainly to technical challenges and health implications. The proposed approach for maintenance is as follows:

- Use existing community-based organizational structures such as Village Development Councils (VDCs), which can direct work to the appropriate Kafo (community group) to undertake small-scale maintenance of rural feeder roads. This includes providing the community with necessary materials and training.
- Maintenance activities could range from localized re-leveling of the road surface, maintaining functionality of longitudinal earthen drainage channels, keeping any culverts clear of siltation and debris, or even grading the road surface if larger machinery is available.
- A road monitoring function (ideally integrated into a RAMS) could also be invested in the community organizational structure, to identify and communicate needs for larger-scale maintenance and rehabilitation activities beyond the means of the community structure, for which NRA would be responsible.

Expected outputs and impacts

- Reduced flooding damage to unpaved roads due to increased level of maintenance.
- Improved rural road condition and availability due to more rapid maintenance response post flooding events.

Gender considerations

- Conduct a gender assessment to identify women-specific transportation vulnerabilities and needs, and associated road maintenance needs such as access to markets and health facilities.
- For road maintenance activities, apply a minimum woman employment quota (aiming for 20-30% representation).
- Provide SGBV training when women are employed.

Enabling environment

To enable such community-based road maintenance, an underlying institutional, contract and funding structure would need to be set up and trialled, that accounts for:

- Proper identification and engagement of the relevant community stakeholders who could participate and benefit from road maintenance.
- A sustainable funding mechanism.
- Inclusive and participatory decision-making processes involving community stakeholders as well as road owners.
- Development of the technical and institutional capacity of local communities to take part in road maintenance.



Project category

Physical – Grey (Maintenance)

Climate hazard/s addressed:



Implementation considerations

Lead: National Roads Agency (NRA)

- **Implementation:** Community-based structures
- **Support:** Ministry of Transport, Works and Infrastructure (MOTWI)

Potential funding and financing sources

- Typical sources: National and foreign governments, multilateral development banks, bilateral development organizations, private sector and development funds.
- Specific Climate Funds: no direct match.
- Set-up and pilot of approach requires initial funding external to Gambian Government; ongoing funding should come from government revenue.

Co-benefits

- Reduced maintenance costs (~15% through the use of community-based resources).
- Increased rural income generation.
- Enhanced economic and social opportunities through improved rural accessibility.

Capital / upfront costs



Operational costs



Implementation time



7. IMPLEMENT PERMEABLE PAVING TECHNOLOGY

Climate risk context

In The Gambia, roads are often crucial for connecting communities to essential services. Many of these are earth roads that erode from flooding during the rainy season, making them impassable for days at a time. Since it is not cost-effective to asphalt low-traffic roads, they are not prioritized for surfacing improvement. In The Gambia a total of 2,810 km earth roads floods regularly, impeding critical access to social facilities. As a result, the poor condition of these roads undermines connectivity, economic activity, and resilience in areas where reliable transport is vital for livelihoods and essential services.

Adaptation project description

On low-traffic roads that experience heavy erosion due to flooding, particularly on slopes or on the road shoulders, and that have critical importance for maintaining connectivity (such as approach roads to culverts, bridges, essential service routes, roads to agriculture, and feeder roads):

- Implement a specifically designed permeable paving technology. This can be in the form of interlocking concrete permeable pavers (PICP) strategically placed only in the wheel tracks of the road, or across the whole road surface, or as sidewalks. Applying permeable paving only at the road shoulders as edge restraint would also be a practical solution, as these are often the areas most damaged by flood erosion. Hollow gaps within the paving blocks are filled with loose earth, and where feasible seeded with grass

An example of permeable paving of road shoulders within The Gambia is in Basse, where it was applied on a busy road and remains intact after many years of use. This successful installation could serve as a model for future designs.

Rural areas where heavy agricultural machinery utilise roads are locations that could particularly benefit from permeable paving solutions.

Parking or waiting areas for trucks on the primary road network are also locations that could benefit from permeable paving, such as at either end of the Transgambia Bridge.

Expected outputs and impacts

- Reduce rainfall run-off from road by 30-90%
- Road functionality retained after flooding events (no erosion of rideable pavement)

Gender considerations

- Conduct a gender assessment to identify women-specific transportation needs, their vulnerabilities, and associated roads in need of improvement.
- Prioritize women's participation in decision-making and consultations.
- For construction activities, apply a minimum woman employment quota (aiming for 20-30% representation).

Enabling environment

- Inclusive and participatory planning processes involving multiple stakeholders such as local communities, environmental authorities, road managers, and adjacent landowners.
- Adequate technical expertise and capacity to design, manufacture, construct and maintain permeable paving systems.



Project category

Physical – NbS (Capital)

Climate hazard/s addressed:



Implementation considerations

Lead: National Roads Agency (NRA)

Support:

- Ministry of Transport, Works and Infrastructure (MOTWI)
- Ministry of Agriculture (MOA)
- Local Councils

Potential funding and financing sources

- Typical sources: National and foreign governments, multilateral development banks, bilateral development organizations, private sector and development funds.
- Specific Climate Funds: Green Climate Fund (GCF), Adaptation Fund, GEF Trust Fund, SCCF (via GEF), InfraCo Africa (PIDG), IFC InfraVentures.

Co-benefits

- Reduced rainwater runoff and consequent downstream erosion (permeable pavement is a multi-purpose solution, which can serve as pavement for pedestrians and vehicles and address storm water management simultaneously).
- Groundwater recharge.
- Reduced maintenance costs.
- Pre-cast concrete manufacturing capacity.
- Enhanced economic opportunities through reduced travel time and transportation.
- Improved accessibility and connectivity to essential services.

Capital / upfront costs



Operational costs



Implementation time



8. UPGRADE DRAINAGE SYSTEM IN PRIORITY AREAS WITHIN THE GBA

Climate risk context

The Greater Banjul Area (GBA) is a low-lying coastal region with flat topography that makes it highly vulnerable to flooding. Heavy rainfall regularly overwhelms undersized and poorly maintained drainage networks, while sea-level rise and storm surges compound risks in coastal and riverfront zones. Climate change is projected to increase rainfall intensity and frequency of extreme events, resulting in prolonged waterlogging, road closures, property damage and heightened health risks from waterborne diseases. Illegal dumping in drains and weak maintenance further exacerbate flooding impacts. In line with the *Greater Banjul Area 2040 Development Plan* priority hotspots include: Bakau, Brikama City, Bijilo-Brusubi-Brufut-Ghana Town corridor.

Adaptation project description

Bakau – as part of Kotu Stream Basin (USD 3.2m)

- Construct climate-resilient culverts and secondary drains.
- Restore wetlands and integrate swales to absorb runoff.
- Install waste/debris traps to keep drains functional

Brikama City (USD 1m)

- Expand and formalise the stormwater network in central and peri-urban areas.
- Integrate drainage into new growth hubs and local plans.
- Combine grey drains with green corridors for water retention.

Bijilo-Brusubi-Brufut-Ghana Town corridor (USD 1m)

- Install culverts and roadside drains along urbanising corridors.
- Apply permeable paving and swales in new housing estates.
- Link drainage works with transport corridor upgrades.

Lamin

- Construct climate-resilient culverts and secondary drains

Expected outputs and impacts

The improvement of drainage is crucial for preventing the spread of diseases in the GBA. The costs of flooding to residents, including damage property, adverse impacts on health and wellbeing, and quality of life caused by flood would all be relieved through improved drainage. Estimated metrics related to outputs and impacts are:

- Protect a population projected to grow from 1.4m (2020) to 2.6m (2040) and households from 224k to 479k.
- Support compact growth by enabling urban density to rise from 2,858 to 5,256 people/km².
- Ensure industrial/logistics land grows from 146 to 1,137 ha without flood risk.

Gender considerations

- For construction activities, apply a minimum woman employment quota (aiming for 20-30% representation).
- Set up drainage committees with representation of women.
- Prioritize women's participation in decision-making and consultations.

Enabling environment

- Grounded in the GBA 2040 Development Plan policies on drainage, sanitation, and land use.
- Requires coordination between MECCNAR, NRA, Banjul City Council, Kanifing Municipal Council, Brikama Area Council, NAWEC, and NEA.
- Linked to targets for land use, housing, infrastructure, and environmental protection in national and local planning.
- Supports creation of a long-term drainage masterplan and integration with local development plans.



Source: WACA Project

Project category

Physical – Grey & NbS (Capital)

Climate hazard/s addressed:



Implementation considerations

Lead: National Roads Agency (NRA)

Support:

- Ministry of Environment, Climate Change and Natural Resources (MECCNAR)
- Kanifing Municipal Council and/or Brikama Area Council

Potential funding and financing sources

- Typical sources: National and foreign governments, multilateral development banks, bilateral development organizations, private sector and development funds.
- Specific Climate Funds: no direct match.

Co-benefits

- Health: Less stagnant water, fewer vector-borne diseases.
- Mobility: Reliable roads and reduced flood-related closures.
- Economy: Protected port, trade hubs, and growth corridors.
- Environment: Green corridors for water retention, biodiversity, and cooling.
- Social inclusion: Community participation, with roles for women and youth in upkeep.

Capital / upfront costs



Operational costs



Implementation time



9. UPGRADE OF PORT ACCESS ROADS

Climate risk context

The Port of Banjul's operations are likely to be more frequently disrupted by climate hazards as climate change occurs, leading to increased costs and logistical challenges. A climate risk assessment concluded that the primary cause of the Port of Banjul climate-related disruption is expected to be due to temporary closures of the Bund Road, the only connection between the port and the hinterland, because of extreme temperatures, heavy rainfall, and rising sea levels. Operation of the planned Sanyang Deep-Sea Port is similarly reliant on functional access roads, which while not studied as yet, are also likely to experience similar issues as the Bund Road, making it crucial to ensure that its access roads are also climate resilient.

As both ports are likely to remain operational into the future, climate resilience of their access roads is critical to the national economy.

Adaptation project description

Climate-related improvements for access roads to both ports entail:

- Climate resilient paving, i.e. when re-surfaced, the road surfacing design should take account of future extreme temperatures in combination with heavy rains and truck loads.
- Prevent truck overloading with weighbridges.
- Climate-based road maintenance consisting of a weather based preventive and corrective maintenance and repair program, whereby inspections and small repairs are intensified during the hot and rainy season when more damage is expected.

Specific to the Bund Road:

- Implement a mangrove restoration programme to reduce wave action on road shoulders.

(note: a project for upgrades to the Bund Road is underway, implemented by GPA and supported by the AfDB)

Expected outputs and impacts

- Reduced road deterioration increasing the lifetime of the road.
- Protection of the access roads from flooding damage, reducing temporal closures and disruptions of port access.

Gender considerations

- Prioritize women's participation in decision-making and consultations.
- For construction activities, apply a minimum woman employment quota (aiming for 20-30% representation).

Enabling environment

- Inclusive and participatory planning processes involving the different stakeholders who have an interest in the road, including trucking companies and road police.



Project category

Physical – Grey & NbS (Capital & Maintenance)

Climate hazard/s addressed:



Implementation considerations

Lead: National Roads Agency (NRA)

Supporting:

- Banjul City Council (BCC)
- Brikama Area Council (BAC)
- Gambia Ports Authority (GPA)
- Alport Banjul (PPP private party)

Potential funding and financing sources

- Typical sources: National and foreign governments, multilateral development banks, bilateral development organizations, private sector and development funds.
- Specific Climate Funds: No direct match.
- Extension of the scope of the Port Operation PPP currently in place, to include for access road upgrades, could be considered as a means to provide capital financing.

Co-benefits

- Safety improvements of the road
- Improved regional connectivity for trade and passenger transport.
- Improvement of woman-owned businesses at the ports.

Capital / upfront costs



Operational costs



Implementation time



10. REHABILITATION OF NON-OPERATING RIVER JETTIES

Climate risk context

The *Greater Banjul Area 2040 Development Plan* recognizes river transport as a key priority for The Gambia as a whole. Restoring jetties will provide reliable routes for both freight and passengers, linking the GBA with the wider country and region. With congested roads and the growing impacts of climate change, river transport offers a vital alternative.

However, many jetties are now non-operational, weakened by sedimentation, flooding, riverbank erosion, and fluctuating water levels. These hazards, combined with lack of maintenance, have reduced connectivity and increased dependence on vulnerable road networks.

Adaptation project description

This project entails actions to restore jetties to operational condition and ensuring that operational jetties/terminals are sufficiently robust to be resilient to current and future climate hazards. Key actions are:

- **Restore inland non-operating jetties on strategic lines** (e.g. Kartong, Bintang, Basse, Kuntaur, Kerewan and/or Tendaba. Ballingo), reinforcing connectivity between the GBA and upriver communities and commercial operations.
- **Stabilize riverbanks and manage sedimentation at operating river jetties** (e.g. Kaur, Janjanbureh and/or Bansang) with nature-based solutions such as mangrove restoration to prolong service life.

This project will build on the lessons learned from the Tourism Diversification & Resilience in The Gambia Project (TDRGP) for priority non-operational jetties.

Expected outputs and impacts

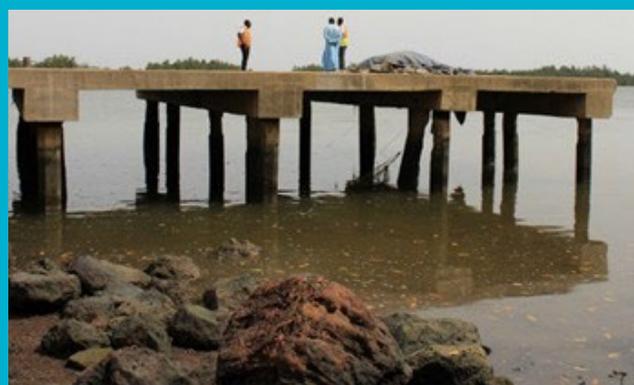
- Operational jetties restored along critical up- and down-river lines, reducing road dependency.
- Reliable river crossings for passengers, traders, and commuters.
- Reduced disruption from climate-related flooding and erosion at jetty sites.

Gender considerations

- Ensure that the river transport services and their sanitation facilities are gender-friendly and accessible to women and people with disabilities.

Enabling environment

- Operation of river transport services and the jetty infrastructure that support it, requires coordination between Ministry of Transport, Works and Infrastructure (MOTWI), Gambia Port Authority (GPA), and Local Councils, as there is no single authority responsible for the whole river transport sector.
- To ensure operation and maintenance funding continues to be directed towards these facilities rather than other port priorities, consideration could be given to creating a separate river transport authority.
- Feasibility studies and costing are needed.



Project category

Physical – Grey and Hybrid

Climate hazard/s addressed:



Implementation considerations

Lead: Ministry of Transport, Works and Infrastructure (MOTWI)
Support:

- Ministry of Tourism & Culture (MOTC)
- Gambia Ports Authority (GPA)
- Local Councils

Potential funding and financing sources

- Typical sources: National and foreign governments, multilateral development banks, bilateral development organizations, private sector and development funds.
- Specific Climate Funds: Green Climate Fund (GCF)
- TDRGP follow-up financing (World Bank)
- Public-private partnerships in eco-tourism and river transport can be considered as financing mechanisms.

Co-benefits

- Inclusive mobility: More connection between south and north bank, providing safer and more predictable crossings improve access to schools, health care, and markets.
- Economic benefits: Lower costs and improved reliability for small traders and riverine communities, resulting in increased trade flows.
- Reduced road maintenance costs: Reduced truck traffic significantly reduces damage to roads which primarily arises from heavy vehicles.
- Climate change mitigation: Reduced truck traffic lowers greenhouse gas emissions.
- Tourism opportunities: Revived river lines and jetties enhance eco- and cultural tourism potential upriver.

Capital / upfront costs



Operational costs



Implementation time



11. BATHYMETRIC SURVEY OF GAMBIA RIVER

Climate risk context

The Gambia River is the country's backbone, providing potential for resilient transport, trade, and tourism. However, reliable data on the river's depth, sedimentation, and hydrological dynamics is lacking. This knowledge gap undermines the planning of navigation routes for larger ships, river jetty rehabilitation, flood protection, and ecosystem management. Climate change is expected to alter rainfall, river discharge, and sedimentation patterns, further complicating river management. Without current bathymetric data, infrastructure investments risk being poorly designed, underutilized, or maladapted.

Adaptation project description

This option focuses on conducting a comprehensive bathymetric survey of the Gambia River, covering priority stretches from Banjul to the inland regions. Key actions include:

- Conduct modern hydrographic and bathymetric surveys to map river depths, sediment loads, and morphology.
- Establish a river monitoring system with regular updates on depth erosion, and sedimentation.
- Integrate data into national planning, supporting climate-resilient river transport, jetty rehabilitation, and flood risk management.
- Train national institutions in survey techniques and data interpretation.
- Create an open-access geospatial database for planners, engineers, and investors.

Expected outputs and impacts

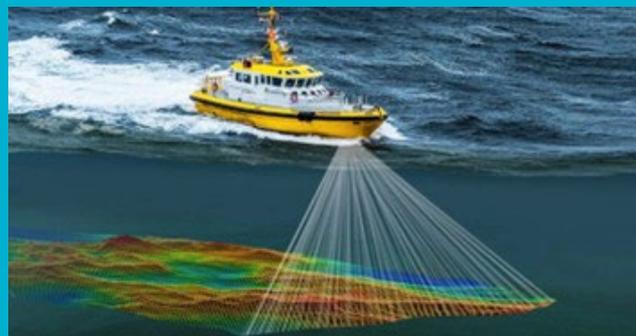
- Reliable and up-to-date bathymetric maps of the Gambia River.
- Stronger evidence base for rehabilitating jetties and re-establishing inland water transport.
- Enhanced ability to design flood risk management measures and climate adaptation infrastructure.
- Improved investor confidence through availability of robust river data.
- Long-term monitoring capacity for adaptive management of river systems.

Gender considerations

- Prioritize women's participation in decision-making, consultations, and road maintenance employment.
- Reliable flood risk information reduces household vulnerability, especially for women as primary caregivers during disaster recovery.
- Inclusion of women in survey training and data management and promote gender-balanced participation in technical fields.

Enabling environment

- Requires collaboration with hydrological and environmental monitoring agencies under MECCNAR.
- Potential to link with regional initiatives on inland waterways.
- Supports inland navigation goals of MOTWI and GPA.



Project category

Institutional

Climate hazard/s addressed:



Implementation considerations

Lead: Ministry of Transport, Works and Infrastructure (MOTWI)

Support:

- Ministry of Environment, Climate Change and Natural Resources (MECCNAR)
- Gambia Ports Authority (GPA)

Potential funding and financing sources

- Typical sources: National and foreign governments, multilateral development banks, bilateral development organizations, private sector and development funds.
- Specific Climate Funds: Green Climate Fund (GCF), Adaptation Fund, GEF Trust Fund, SCCF (via GEF), InfraCo Africa (PIDG), IFC InfraVentures.
- If regional objectives can be met through the survey, then ECOWAS may be able to facilitate funding.

Co-benefits

- Improved planning for inland transport and trade.
- Enhanced flood early-warning and risk management.
- Strengthened tourism and eco-tourism opportunities along the river.
- Increased investor confidence through data transparency.

Capital / upfront costs 

Operational costs 

Implementation time 

12. MANGROVE RE-PLANTING PROGRAMMES

Climate risk context

The Gambia faces major climate threats - sea level rise, coastal flooding, erosion, and saltwater intrusion - impacting roads, bridges, rice fields, and riverine settlements. Mangroves, covering 581 km², reduce these risks by stabilizing shorelines and protecting infrastructure. Found from Banjul to Tendaba, 7 mangrove species thrive. These ecosystems lower transport maintenance costs and support connectivity. However, drought, salinization, oyster harvesting, and land conversion threaten them. Restoration is vital for climate resilience, food security, and safeguarding key transport corridors along the Gambia River.

Adaptation project description

Develop Technical Design and Implementation Guidelines

- Standardize mangrove restoration protocols, including species selection, planting density, hydrological techniques, and community engagement.

Map Priority Restoration Zones

- Identify primary and secondary restoration areas by overlaying climate risk zones with infrastructure and economic hotspots.

Restoration Projects in High-Impact Areas

- Implement restoration, monitor ecological and carbon outcomes, and build local capacity. The following are potential high-impact areas:
 - Transgambia Bridge and Bintang Bolong (Lower River Region)
 - Tendaba and Elephant Island (Central River Region)
 - North Bank Region
 - Banjul and Kombo (West Coast Region)

Expected outputs and impacts

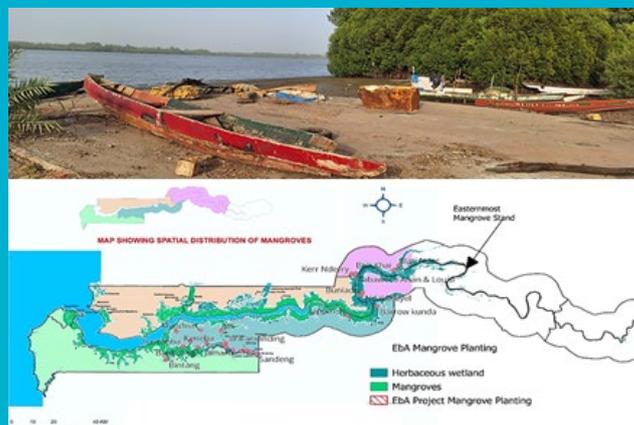
- Infrastructure Resilience: Restoration near roads, bridges, and settlements protects transport and economic assets from erosion and inundation.
- Coastal Protection: Mangroves buffer against sea level rise, storm surges, and tidal flooding by stabilizing shorelines and reducing wave energy.
- Reduces saltwater intrusion, preserving freshwater and farmland and mitigating damage to transport infrastructure.

Gender considerations

- Ensure safe working conditions for woman in mangrove re-planting programmes.
- Inclusive training in nursery management and monitoring.
- Promote equitable access to resources and ecosystem service benefits (e.g. fish, shellfish, firewood, beehives), noting that most mangrove re-planting programmes take place in areas where previously women grew rice before saltification rendered these paddies unproductive.
- Collaborate with other service (e.g. fish, shellfish, firewood, beehives) stakeholders.

Enabling environment

- Reduced Pressure on Mangroves: Promotion of alternative energy, grazing practices, and technologies to limit firewood use and land degradation.
- Policy Support: Development of natural resource and environmental conservation policies to guide sustainable management of the new resources arising from the mangrove.
- Sustainable Livelihoods: Support for eco-friendly aquaculture and oyster harvesting techniques to balance conservation with income generation.



Project category

Institutional + Physical - Green (Capital + Maintenance)

Climate hazard/s addressed:



Implementation considerations

Lead (oversight): Ministry of Environment, Climate Change and Natural Resources (MECCNAR), supported by National Environment Agency (NEA)

Implementing Partners: Dep of Forestry, Dep of Fisheries or Dep of Parks and Wildlife.

Local Execution: Village and Ward Development Committees (VDCs/WDCs) and Community-Based Organizations (CBOs) lead on-the-ground activities.

Policy & Technical Support: Centre for Innovation in Climate Adaptation & Resilience Building (CICARB) in The Gambia offer capacity building and technical guidance (also other NGOs and CBOs e.g. BirdLife, WABSA)

Monitoring & Knowledge Sharing: Research institutions, such as the University of The Gambia's National Climate Action Center.

- Sites best selected by MECCNAR and CICARB.

Potential funding and financing sources

- Typical sources: National and foreign governments, multilateral development banks, bilateral development organizations, private sector and development funds.
- Specific Climate Funds: Green Climate Fund (GCF)
- Conservation NGOs: e.g., Wetlands International and similar organizations.

Co-benefits

- Empowers communities through ecotourism, local engagement, and capacity building.
- Enhances environmental resilience by restoring ecosystems, boosting biodiversity, and supporting carbon storage.
- Improves livelihoods via strengthened food and water security and climate mitigation.
- Safeguards access to resources

Capital / upfront costs



Operational costs



Implementation time



8. CONCLUSIONS

8.1 Climate Risk

The climate risk screening described the impacts and qualitatively assessed the risk to the transport network due to current and future projected climate hazards. This allows to identify the key climate hazards and most vulnerable infrastructure assets, providing an identification of the most at-risk transport assets, the high-risk areas within The Gambia and the critical transport connections within the infrastructure network.

The climate risk screening evaluates the following impacts on The Gambia's transport network:

1. **Direct risk**, or the physical damage.
2. **Socio-economic impacts**, or the disruptive impacts to key facilities for the population, economics and tourism.

The direct risk assessment revealed that a significant portion of roads in The Gambia are exposed to flooding. For fluvial flooding, 38% of roads and for pluvial flooding, 56% of roads have a low direct risk score (between 0-10). A smaller percentage of roads have a risk score of 10 or higher (5% for fluvial and <1% for pluvial). This suggests that most exposed roads experience shallow flooding during high-frequency events. The direct risk assessment showed that for extreme temperature, the entire paved road network in The Gambia is at direct risk, with risk scores ranging from 60-80 inland and not exceeding 30 along the coast.

Climate change projections indicate an increase in direct risk scores for both flooding and extreme temperatures. The increase in risk score for flooding showed that certain roads currently at no flood risk expected to become exposed to flooding by 2050. For fluvial flooding, this is an increase from 43% to 45% of all roads in The Gambia from the baseline to 2050. For pluvial flooding, the increase is from 57% to 61%, and for coastal flooding, it's from 1.1% to 1.6%. The risk scores for extreme temperatures, which are already high, are projected to further increase throughout The Gambia by 2050.

Although many roads in The Gambia have a low direct risk score for flooding, due to flood depths often remaining below 0.5m during high-frequency events, accessibility is significantly impacted as roads become inaccessible at a 0.3m threshold. Of the 3,251 km identified as critical for accessing social facilities, 279 km are classified as medium risk and only 41 km as high risk. When these roads become inaccessible during a flood event, 11% of the population is cut off from markets, 8% from schools, and 11% from hospitals.

To integrate direct risk and socio-economic impact results, critical roads (low, medium, or high criticality) with a direct risk score above 10 were selected. A total of 104 km of roads were identified with medium criticality and 8 km with high criticality.

8.2 Preliminary Adaptation Options

A long-list of potential climate adaptation measures that may address the key climate risks identified for The Gambian national transport network was made that comprises 35 adaptation options as listed in **Annex 1**.

A short-list of 12 adaptation options were selected that:

- Have a significant impact in addressing climate risks in the transport sector;
- Cover the range of major climate risks in the transport sector (coastal, fluvial and pluvial flooding; extreme temperature)
- Cover the range of infrastructure assets in the transport sector (roads, bridges, ports and river transport);
- Are viable to implement in the context of The Gambia;
- Are as far as possible location-specific.

These adaptation options were described in **1-page Project Briefs** using details sourced through engagements with national stakeholders through the course of this assignment.

8.3 Way Forward

The insights and results arising from this Report can be used to support:

- the prioritization of road segments for inclusion in the World Bank's The Gambia Infrastructure Project;
- the development of the World Bank's Country Climate Strategy; and
- the Government of The Gambia (Ministry of Finance and Ministry of Transport, Works and Infrastructure) in integrating priority adaptation and resilience interventions, including Nature-Based Solutions (NBS), into the new Transport Masterplan for the roads and fluvial transport system network.
- the sourcing of funding and financing for the selected adaptation options described in the Project Briefs.

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Annexes

ANNEX 1. LONGLIST OF ADAPTATION OPTIONS

#	Climate Hazard	Effect on the environment	Asset Type Affected	Current Impact on the road/assets	Potential impacts with extremes	Grey and Green Opportunities	Type of Measure	Category of Measure
1	Extreme (High) Temperatures	Extreme dry conditions: (1) warmer air & soil, (2) more evaporation --> drier soil -->impact on the vegetation	Pavement: (Surface dressing AC Surfacing DBM Base Cemented SB) (Paved Shoulders)	Rutting, flushing, and bleeding of the asphalt and single seal	Increased rate and severity of bleeding and permanent deformation under the slow-moving wheel loads	Design/use more heat/oxidant resistant asphalt / binder	Design Specifications	Modify bitumen binder and use appropriate aggregate gradings.
2	Extreme (High) Temperatures	Extreme dry conditions: (1) warmer air & soil, (2) more evaporation -> drier soil -->impact on the vegetation	Pavement: (Surface dressing AC Surfacing DBM Base Cemented SB) (Paved Shoulders)	Rutting, flushing, and bleeding of the asphalt and single seal	Increased rate and severity of bleeding and permanent deformation under the slow-moving wheel loads	Select concrete pavement	Design Specifications	Select and design a concrete pavement.
3	Extreme (High) Temperatures	Extreme dry conditions: (1) warmer air & soil, (2) more evaporation -> drier soil -->impact on the vegetation	Pavement: (Surface dressing AC Surfacing DBM Base Cemented SB) (Paved Shoulders)	Rutting, flushing, and bleeding of the asphalt and single seal	Increased rate and severity of bleeding and permanent deformation under the slow-moving wheel loads	Planting Shade trees on road edges: Use of the indigenous vegetation to provide shade to the road.	Physical Measures	Low-cost method of reducing the pavement temperature and defect recurrence period. Creates co-benefits with neighbouring communities.
4	Extreme (High) Temperatures	Extreme dry conditions: (1) warmer air & soil, (2) more evaporation -> drier soil -->impact on the vegetation	Bridges, Major Culverts	The bridge expansion joints movements beyond its design capacity.	The concrete interphases will get crushed resulting in spalling off of the concrete.	Enlarge the expansion joints if they exist.	Physical Measures	Design deck expansion joints and movement joint in the parapets for latest temperature ranges.
5	Extreme (High) Temperatures	Extreme dry conditions: (1) warmer air & soil, (2) more evaporation -> drier soil -->impact on the vegetation	Bridges, Major Culverts	The bridge expansion joints movements beyond its design capacity.	The concrete interphases will get crushed resulting in spalling off of the concrete.	For new structures design to the latest temperature ranges.	Design Specifications	Design deck expansion joints and movement joint in the parapets for latest temperature ranges.
6	Extreme (High) Temperatures	Extreme dry conditions: (1) warmer air & soil, (2) more evaporation -> drier soil	Bridges, Major Culverts	The bridge bearing movements beyond its design capacity.	The bearing might fail or the load transfer from the deck to the bearing seating might be in a position that is not	For existing situations, replace the bearings with ones that can accommodate the larger movements.	Physical Measures	Design bearings for latest temperature ranges.

#	Climate Hazard	Effect on the environment	Asset Type Affected	Current Impact on the road/assets	Potential impacts with extremes	Grey and Green Opportunities	Type of Measure	Category of Measure
		-->impact on the vegetation			designed for it, causing the concrete to burst and spall.			
7	Extreme (High) Temperatures	Extreme dry conditions: (1) warmer air & soil, (2) more evaporation -> drier soil -->impact on the vegetation	Bridges, Major Culverts	The bridge bearing movements beyond its design capacity.	The bearing might fail or the load transfer from the deck to the bearing seating might be in a position that is not designed for it, causing the concrete to burst and spall.	For new bearings design for the latest temperature ranges.	Design Specifications	Design bearings for latest temperature ranges.
8	Extreme (High) Temperatures	Extreme dry conditions: (1) warmer air & soil, (2) more evaporation -> drier soil -->impact on the vegetation	Bridges, Major Culverts	Restraint cracking, bursting, and spalling of concrete due to the excessive expansion and contraction of the structure.	Cracking and spalling of concrete which can lead to corrosion of the steel reinforcing.	Identify restraints in existing structures and release them.	Operations & Maintenance	Design the structure such that it can accommodate latest temperature ranges and where restraints are induced that can resist it.
9	Extreme (High) Temperatures	Extreme dry conditions: (1) warmer air & soil, (2) more evaporation -> drier soil -->impact on the vegetation	Bridges, Major Culverts	Restraint cracking, bursting, and spalling of concrete due to the excessive expansion and contraction of the structure.	Cracking and spalling of concrete which can lead to corrosion of the steel reinforcing.	For new structures, design for these restraints.	Design Specifications	Design the structure such that it can accommodate latest temperature ranges and where restraints are induced that can resist it.
10	Extreme (High) Temperatures	Extreme dry conditions: (1) warmer air & soil, (2) more evaporation -> drier soil -->impact on the vegetation	Stormwater and Drainage Structures	Reduced functions of the vegetation to: (1) intercept and retain rainfall, (2) stabilize slopes and (3) provide shade	Increased runoff downstream during high intensity rainfall and higher probability for erosion	Design underground drainage along slopes with alternative water sources for irrigation. Take measures to retain and infiltrate water and store it for the dry period. Irrigate trees to maintain their function (e.g., by reusing treated stormwater)	Design Specifications	Increase evaporation to cool the air
11	Extreme (High) Temperatures	Extreme dry conditions: (1) warmer air & soil, (2) more evaporation -> drier soil -->impact on the vegetation	Road	Wildfire risks- potential removal of vegetation along the upstream slopes	Increased frequency and intensity	Application of strategic thinning practices (replicating how nature reduces shrubs and understory trees) to promote healthier and more resilient forests which are less vulnerable to large-scale wildfires. Restore natural herbivore populations to keep the understory more open.	Institutional & Social Measures	Strategic Thinning, select proper tree species, use wild herbivores or cattle to remove excess understory vegetation

#	Climate Hazard	Effect on the environment	Asset Type Affected	Current Impact on the road/assets	Potential impacts with extremes	Grey and Green Opportunities	Type of Measure	Category of Measure
12	Fluvial and Pluvial Flooding	Large discharge volumes and water levels along rivers and channels and high moisture content in pavement layers	Bridges, Major Culverts	Erosion of foundations (Spread footings or piles).	Pose danger to structural integrity and can result in a total collapse.	Found the structure on solid rock. Provide erosion protection when and where required. Shape the support footing/pile cap and stem to encourage free flow of the water.	Design Specifications	Design the structure such that it is founded on solid rock and if erosion is anticipated, then design it such that it can accommodate this anticipated erosion. Provide erosion protection to existing structures where there is evidence of erosion.
13	Fluvial and Pluvial Flooding	Large discharge volumes and water levels along rivers and channels and high moisture content in pavement layers	Bridges, Major Culverts	Siltation on the riverbed.	Reducing the hydraulic opening size, which can lead to overtopping of the structure during flooding.	Regular maintenance to clear the siltation. Design the hydraulic opening such that it can accommodate predicted future siltation.	Operations & Maintenance	Maintenance Planning and Design Specifications
14	Fluvial and Pluvial Flooding	Large discharge volumes and water levels along rivers and channels and high moisture content in pavement layers	Bridges, Major Culverts	Overtopping or washing away of the superstructure.	Pose danger to structural integrity and can result in a total collapse.	Design the hydraulic opening for a flood and freeboard with an appropriate return period. Tie the deck into the sub-structure. For beam and slab decks, provide breather holes in the beams. Design the longitudinal road alignment such that the low point is at one of the bridge approaches.	Design Specifications	Design the hydraulic opening to accommodate the design flood. Design the structure to withstand the associated flood forces.
15	Fluvial and Pluvial Flooding	Large discharge volumes and water levels along rivers and channels and high moisture content in pavement layers	Pavement: (Surface dressing AC Surfacing DBM Base Cemented SB) (Paved Shoulders)	Cracking, ponding, and progressive erosion of the pavement material	Increased surface disintegration, potholes and deformations under the heavy vehicle loading	Excavate to the surface (& base) layers and reconstruct damaged sections	Operations & Maintenance	Repair damaged base layer
16	Fluvial and Pluvial Flooding	Large discharge volumes and water levels along rivers and channels and high moisture content in pavement layers	Pavement: (Surface dressing AC Surfacing DBM Base Cemented SB) (Paved Shoulders)	Cracking, ponding, and progressive erosion of the pavement material	Increased surface disintegration, potholes and deformations under the heavy vehicle loading	Excavate to the surface (& base) layers and reconstruct damaged sections	Operations & Maintenance	Repair damaged base layer
17	Fluvial and Pluvial Flooding	Large discharge volumes and water levels along rivers and channels and high moisture content in pavement layers	Pavement: (Surface dressing AC Surfacing DBM Base Cemented SB) (Paved Shoulders)	Cracking, ponding, and progressive erosion of the pavement material	Increased surface disintegration, potholes and deformations under the heavy vehicle loading	Modify designs	Design Specifications	Modify designs to: 1. Reduce moisture susceptibility. 2. Make allowance for poor

#	Climate Hazard	Effect on the environment	Asset Type Affected	Current Impact on the road/assets	Potential impacts with extremes	Grey and Green Opportunities	Type of Measure	Category of Measure
								subgrade support when soaked.
18	Fluvial and Pluvial Flooding	Large discharge volumes and water levels along rivers and channels and high moisture content in pavement layers	Pavement: (Surface dressing AC Surfacing DBM Base Cemented SB) (Paved Shoulders)	Erosion and/or softening of shoulder material if not surfaced	Extended periods of and more severe erosion and/or softening of unpaved shoulder material	Improve moisture sensitivity of gravel shoulder material	Design Specifications	Modify designs to reduce moisture susceptibility
19	Fluvial and Pluvial Flooding	Increased free fall of water along the road shoulders and reserve	Road	Erosion of the reserve and the shoulders, initiating with cracks which transform into potholes.	More severe erosion of reserve and shoulders	Reinforce kerb wall between the road edge and the drain/shoulder with geotextile.	Physical Measures	Shoulder strengthening
20	Fluvial and Pluvial Flooding	Increased free fall of water along the road shoulders and reserve	Road	Erosion of the reserve and the shoulders, initiating with cracks which transform into potholes.	More severe erosion of reserve and shoulders	Provide surface protection and strengthen shoulders	Physical Measures	Modify gravel shoulder material with bitumen emulsion. Cover shoulders with surfacing seal or asphalt
21	Fluvial and Pluvial Flooding	Increased free fall of water along the road shoulders and reserve	Road	Erosion of the reserve and the shoulders, initiating with cracks which transform into potholes.	Exposed base layers of the road	Repair damage to shoulder and base layers.	Operations & Maintenance	Modify material with cement and bitumen emulsion
22	Fluvial and Pluvial Flooding	Increased free fall of water along the road shoulders and reserve	Road	Erosion of the reserve and the shoulders, initiating with cracks which transform into potholes.	Exposed base layers of the road	Bio-designed slopes	Physical Measures	Reduce run-off effects
23	Fluvial and Pluvial Flooding	Increased free fall of water along the road shoulders and reserve	Road	Erosion of the reserve and the shoulders, initiating with cracks which transform into potholes.	Erosion of the shoulders and road reserve	Introduction of surface protection to the road reserve can protect the road prism.	Physical Measures	Geocells, reno mattresses, etc.
24	Fluvial and Pluvial Flooding	Increased free fall of water along the road shoulders and reserve	Road	Erosion of the reserve and the shoulders, initiating with cracks which transform into potholes.	Larger craters	Vegetation can be used to stabilize the soil. Reinforced curb wall between the road edge and the drain/shoulder with geotextile	Physical Measures	Reduce run-off effects

#	Climate Hazard	Effect on the environment	Asset Type Affected	Current Impact on the road/assets	Potential impacts with extremes	Grey and Green Opportunities	Type of Measure	Category of Measure
25	Fluvial and Pluvial Flooding	Increased free fall of water along the road shoulders and reserve	Bridges, Major Culverts	Erosion behind the wingwalls of bridge structures	This may compromise the structural integrity of the structure.	Geotextile fabric between the soil and the base of the structure to limit sediment runoff. Routine Maintenance.	Physical Measures	Increase water retention & infiltration
26	Fluvial and Pluvial Flooding	Increase in susceptibility to landslides due to extreme rainfall	Road	Soil, slope instability and poor pavement layer performance	Damage to assets and road closure (partial/total)	Implement Retaining Walls / Gabion Walls / Geocells / Reno mattresses to reduce risk of increased moisture and provide dewatering solutions	Physical Measures	Improve drainage during extreme events
27	Fluvial and Pluvial Flooding	Increase runoff into water bodies	Stormwater and Drainage Structures	Carrying debris and sediments to the road assets	Risks to the safety and livelihood of residents on the road edge	Clearing of debris build-up	Operations & Maintenance	Local clearing team
28	Fluvial and Pluvial Flooding	Increase runoff into water bodies	Stormwater and Drainage Structures	Carrying debris and sediments to the road assets	Intensification of erosion and landslide events, as well as damage to vegetation and road assets	Integrated water catchment management solution	Institutional & Social Measures	integrated water resources management
29	Fluvial and Pluvial Flooding	Increased discharge and runoff	Roads	Limited guidelines and enforcement resulting in a lack of drainage infrastructure	Flooded roads and houses	Design guidelines and enforcement for proper drainage systems.	Grey – green – Institutional	Drainage guidelines and enforcement
30	Wildfires	Wildfires reducing vegetation and spreading to built-up areas	Roads, conductors, isolators	Damage to roads and equipment	Defect equipment and severely damaged roads	Fireproofing / fire fighting infrastructure / response system	Grey – Green – Institutional	Increase fire protection
31	Multi-hazard		Road	Any risk		Early Warning Systems and Disaster Risk Management	Institutional & Social Measures	Technology
32	Multi-hazard		Road	Any risk	As listed above	Early Warning Systems and Disaster Risk Management	Institutional & Social Measures	Community Involvement
33	Multi-hazard		Road	Any risk		Climate-Resilient Asset Management System	Institutional & Social Measures	Technology
34	Droughts	Less precipitation	Bridges, Major Culverts, Stormwater	Soils drier --> impact on vegetation	Reduced functions of the vegetation to: (1) intercept and retain rainfall, (2) stabilize slopes and (3) provide shade	Plant species that are drought resistant e.g., because of deeper roots or water storage in tissues.	Physical Measures	Increase water retention & infiltration
35	Droughts	Less precipitation increased dust forming	Bridges, Major Culverts, Stormwater	Soils drier --> increased dust	Reduced functions of the vegetation to: (1) intercept and retain dust	Plant barriers that capture dust alongside roads	Green - Physical Measures	Increase dust interception

ANNEX 2. PROJECT FUNDING AND FINANCING SOURCES

Table 9-1: Typical Funding Institutions

Institution	Description	Instruments	Examples
National government	Direct contribution from national budget	Payment of contractors, transfers to implementing agencies and local authorities (which use the funds to pay contractors)	Government of The Gambia
Foreign governments	Contributions from foreign governments, mostly through bilateral development agencies	Grants and (concessional) loans	Agence Française de Développement (AFD), Banque Ouest Africaine de Developpemen (BOAD), China International Development Cooperation Agency (CIDCA), ECOWAS Bank for Investment and Development (EBID), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), International Finance Corporation (IFC), Japan International Cooperation Agency (JICA), Private Infrastructure Development Group (PIDG), Swedish International Development Cooperation Agency (SIDA).
Multilateral development banks	Supranational institution created by a group of countries that provides financial and technical assistance to developing nations	Grants and (concessional) loans	World Bank, African Development Bank, BOAD, EBID
Bilateral and multilateral development banks - private sector window	Department or subsidiary of bilateral or multilateral development bank that provides financing to the private sector (companies and commercial banks)	Loans and equity. This source of funds can also contribute to public infrastructure projects through the financing of public-private partnerships.	Invest International (Netherlands), Proparco (France), IFC (World Bank Group), PIDG (six national governments), ...
Private sector	Commercial banks and equity investors	Sovereign loans to governments; loans and equity to projects (project finance)	
Development funds	Capital pools established by several national and or international institutions to finance a specific category of projects. The establishment of a fund allows to bundle capital and investment management skills,	Grants and (concessional) loans	Climate funds presented in following table

	adapted to the projects financed by the fund.		
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Table 9-2: Specific Climate Funds

No.	Fund / Programme	Manager	Donors / Capital Sources	Thematic focus	Geographic focus	Funding type(s)	Min / Max funding	Eligibility / key conditions
1	Green Climate Fund (GCF)	GCF Secretariat / Board	Countries, co-finance	Climate mitigation & adaptation	Developing countries (esp. LDCs, SIDS, Africa)	Grants, concessional loans, equity, guarantees	Millions to 100s of millions USD	Via Accredited Entities; align with GCF criteria
2	Adaptation Fund	Adaptation Fund Board / Adaptation Fund Board Secretariat (hosted by GEF)	Contributions from developed countries, CER proceeds (Kyoto Protocol)	Adaptation to climate change; resilience in vulnerable communities	Developing countries, particularly vulnerable (LDCs, SIDS, Africa focus)	Grants (direct access modality through national implementing entities)	Typically US\$1m–10m per project; up to US\$10m per country cap	Eligible developing countries under Kyoto Protocol; access via accredited implementing entities
3	Climate Investment Funds (CIF)	CIF Administrative Unit (World Bank as Trustee)	Donor countries (multilateral trust funds; \$11bn pledged)	Climate mitigation, adaptation, renewable energy, clean tech, forestry, resilience	Over 70 developing countries globally	Concessional loans, grants, risk mitigation instruments, equity (through MDBs)	Project sizes vary; programs often \$10m–100m+	Countries must be CIF pilot participants; projects implemented through MDBs (World Bank, AfDB, ADB, EBRD, IDB)
4	Climate Investment Funds (CIF)-Pilot Programme for Climate Resilience (PPCR)							Priority is given to highly vulnerable least developed countries eligible for concessional funds from MDBs
5	InfraCo Africa – Sub-Sahara Infrastructure Fund	InfraCo Africa (PIDG)	PIDG donors (UK, NL, CH)	Infrastructure (energy, transport, water)	Sub-Saharan Africa	Equity, quasi-equity, risk capital	US\$1–10m typical; target fund US\$300m	Catalytic risk capital, SSA focus
6	NEPAD Climate Change Fund	AUDA-NEPAD	Germany	Adaptation mainstreaming, NAPs, biodiversity	African Union Member States	Grants	Up to €200,000	African govts/RECs/CSOs via calls
7	Special Climate Change Fund (SCCF)	GEF	Donor contributions via GEF	Adaptation, tech transfer, capacity building	Developing countries (priority vulnerable)	Grants	Varies per project	Via GEF Agencies; UNFCCC guidance
8	Islamic Development Bank – LLF	IsDB	BMGF, ISFD, ADFD, KSRelief, QFFD	Health, agri, basic infrastructure	33 IsDB member countries (low income)	Concessional loans blended with grants	Portfolio US\$2.5bn; project size varies	Sovereign projects in eligible countries
9	Global Innovation Lab for Climate Finance	Climate Policy Initiative	Govts (e.g. Germany IKI), philanthropies	Innovative finance instruments for climate	Global (developing countries)	Grants/TA for pilots	Up to US\$250k per instrument	Annual Call for Ideas; competitive selection

No.	Fund / Programme	Manager	Donors / Capital Sources	Thematic focus	Geographic focus	Funding type(s)	Min / Max funding	Eligibility / key conditions
10	GEF Trust Fund	GEF Secretariat / World Bank trustee	Donor replenishments	Biodiversity, climate, land, oceans, chemicals	Global (developing countries)	Grants (sometimes concessional/blended)	Small grants to large multi-country programs	Must align with GEF focal areas; via GEF Agencies
11	Danish Climate Investment Fund (DCIF)	IFU (Denmark's DFI)	Govt of Denmark, IFU, institutional investors	Low-carbon projects, RE, efficiency	Developing countries	Equity, quasi-equity	Varies, fund several bn DKK	Commercial sustainable projects; co-financing
12	Africa50 Infrastructure Acceleration Fund (IAF)	Africa50	DFIs, institutional investors (e.g. IFC)	Infrastructure (energy, transport, digital)	Africa	Equity (PE fund)	Target US\$500m fund	Commercial African infrastructure projects
13	DBSA Project Preparation Fund	DBSA	DBSA, SA Govt/Infrastructure SA	Feasibility, structuring, technical prep	South Africa / SADC	Grants, TA	Project-specific (no fixed cap)	Must align with national infra priorities
14	GEF Small Grants Programme (SGP)	UNDP (for GEF)	GEF core resources	Community-level env./climate action	144 countries	Small grants	Up to US\$75,000	NGOs/CBOs; local SGP procedures
15	African Infrastructure Investment (AIIM/AIIF)	AIIM (Old Mutual group)	DFIs, institutional LPs (EIB, BII)	Energy, logistics, digital infra	Africa (SSA focus)	Equity (PE funds)	US\$50–100m typical tickets; fund ~US\$500m	Commercial infra assets; PE strategy
16	Emerging Africa Infrastructure Fund (EAIF)	Ninety One (for PIDG)	PIDG donors, private capital	Private infra (multi-sector)	Africa (expanded to Asia)	Long-term debt	US\$10–65m; up to 15–20y tenor	Private borrowers; bankable infra projects
17	IFC InfraVentures	IFC (World Bank Group)	IFC capital	Early-stage project development	Developing countries	Risk capital for dev. costs; convertible to equity	Up to US\$8m/project; US\$150m facility	Private projects meeting IFC criteria

Table 9-3: Sample of funding mechanisms

No.	Name	Institution	Description	Instruments
1	Public-private partnership (PPP)	Private developers and investors	A PPP is a long-term contractual agreement between a public authority and a private partner under which the latter is entrusted with the design, construction, financing, operation or management of an asset of public interest (e.g. transport or energy production infrastructure). The private partner is remunerated either by availability or service fees paid by the contracting authority, or by the private users of the infrastructure (e.g. tolls in the case of a motorway PPP). A PPP is an instrument for mobilising private capital (equity and loans) to finance public infrastructure.	Equity and loans
2	Semi-public company	Private developers and investors + public entities	A semi-public company (SEM) is a variant of a PPP in which the public sector also invests equity alongside the private partner. An SEM is a public limited company in which one or more public entities (often local authorities) and one or more private companies participate, with the latter also providing the necessary technical expertise. The purpose of the SEM is to build and operate the project.	Equity and loans
3	Environmental taxes	National and sub-national governments	An environmental tax is a tax on an activity that has a negative impact on the environment. The tax base is a physical entity, such as air pollution emissions, industrial effluents, fossil fuel consumption, drinking water consumption, etc. The revenue from the tax can then be used to finance measures to prevent or mitigate environmental impacts.	Revenue
4	Development levy	National and sub-national governments	A one-time levy imposed on property and asset owners in an area where development work is undertaken to improve public services. In the case of coastal resilience projects, governments may levy a one-time fee when undertaking investments that benefit property and asset owners in a given area.	Revenue
5	Carbon credits	Carbon markets, brokers and buyers of carbon credits (see, for example, https://carbonwise.co/directory/ and https://www.climateactionreserve.org/how/carbon-market-directory/)	Carbon credits are generated by projects that have avoided or removed greenhouse gas emissions. Each credit represents one tonne less of carbon dioxide, or another greenhouse gas equivalent (CO ₂ e), in the atmosphere. Carbon credits are sold on carbon markets. The revenue from the sale of carbon credits provides additional financial resources to the project that can be used to cover operating costs or debt servicing. There are two types of carbon markets. Credits sold on voluntary carbon markets are purchased by companies that voluntarily choose to invest in carbon reduction projects, for example to offset their own emissions, or as part of a CSR initiative. Compliance markets are created as a result of national and/or international regulatory requirements capping emissions. In certain sectors and countries, regulations allow a percentage of the reduction to be achieved through the purchase of carbon credits.	Revenue