Adapting Together, Thriving Tomorrow

Summary For Decision Makers

Climate Projections and Climate Risks for Ghana

GREEN CLIMATE FUND

UN environment programme

CONTENTS

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We hope this summary report will be useful to support adaptation decisions at different levels.

ABBREVIATIONS

CMIP	Climate Model Intercomparison Project
CORDEX	Coordinated Global Downscaling Experiment
CRU TS	Climatic Research Unit Timeseries
CSA	Climate-Smart Agriculture
EbA	Ecosystems-based adaptation
ERA	ECMWF ReAnalysis
ERA5	ECMWF global reanalysis
GCF	Green Climate Fund
GCM	Global Climate Model
GHG	Greenhouse Gases
GPCC	Global Precipitation Climatology Centre
I&APs	Interested and Affected Parties
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
LE	Lower extreme
MA	Metropolitan Assembly
MAP	Mean Annual Precipitation
MMDAs	Metropolitan, Municipal and District Assemblies
NAP	National Adaptation Plan
RCM	Regional Climate Model
RCP	Relative Concentration Pathway
SOM	Self-Organising Map
SRES	Special Report on Emissions Scenarios
SSP	Shared Socioeconomic Pathway
SSPs	Shared Socioeconomic Pathways
STMA	Sekondi-Takoradi Metropolitan Assembly
SU30	Maximum temperature exceeding 30°C
UE	Upper extreme
WSC	Water sensitive cities

Key Messages

Ghana stands at a decisive moment in its climate journey. The analysis presented in this Summary for Decision Makers shows a compelling narrative of the challenges and opportunities that lie ahead.

In general, there is strong confidence in the projection of increased air temperature across all future climate scenarios and throughout the country over the four identified climate zones, but particularly under a future high-emission scenario and in the Central and Northern regions of the country.

By the end of the century, it is anticipated that **temperatures** will increase by between **0.5 and 4.5°C** depending on the global state of GHG emissions, with a significant **increase in very hot days**.

Future climate projections, however, suggest only weak **changes in average annual rainfall** with a range of only +/- 5% in the ensemble mean and for the identified joint climate change scenarios.

Overall, there is a greater probability of **wetting** for Ghana but interspersed with some very dry years. This, combined with increased temperature, could still result in an increasing frequency of droughts.

The latest CMIP6 climate models hint at a heightened sensitivity in rainfall, potentially indicating an even greater increase in "wetness", with very significant increases in wetting in the Northern Climate Zone. However, this is only reflected in a handful of the global models and remains uncertain.

Historical data points to an increasing frequency and magnitude of extreme events, particularly flooding. The trend of increasing number of very hot days and maximum daily rainfall, which leads to increased flood risk, is expected to persist and intensify into the future, especially under the higher global emission scenarios. There may also be seasonal shifts in rainfall for Ghana.

Increasing sea level rise and **more intense storms** threaten coastal infrastructure and communities, including transport infrastructure, power stations and cultural sites critical to the tourism economy.

It is crucial to understand that Ghana's vulnerability to these climatic changes is also the result of socio-economic dynamics including rapid population growth and environmental degradation. These magnify the country's risk profile and the current capacity to deal with these risks is very low.

The future, however, is not entirely bleak. Amidst the challenges, adaptation is possible. By embracing best practices, Ghana can fortify its climate resilience through the provision of essential services and meeting the Sustainable Development Goals (SDG), championing Climate Smart Agriculture (CSA), enhancing Integrated Water Resources Management (IWRM) including with upstream countries in the Volta Basin, preventing environmental degradation, strengthening coastal defences, supporting more diverse and climate resilient livelihoods, early warning systems, etc.

Adapting to the impacts of climate change requires a coordinated response and prioritising the most vulnerable communities. The results presented here for both the national-level climate projections and the two sub-national level climate change risk assessments will help achieve these aims.

1 INTRODUCTION

An analysis of historical temperature and precipitation records, combined with recent weather events in Ghana, it is evident that the pace of climate change is rapidly changing. This realisation underscores the urgent need for proactive measures, as Ghana will continue to experience the significant impacts of climate change in the years to come.

The purpose of this document is to highlight key climate change risks and scenarios to support the Government of Ghana to address climate change impacts from a more integrated, coordinated and sustainable manner .

This report provides a summary of:
- National Climate Change Risk Projections and Scenarios
- Tamale Metropolitan Assembly Climate Change Risk Assessment
- Sekondi-Takoradi Metropolitan Assembly Climate Change Risk Assessment

Tamale and Sekondi-Takoradi were selected as priority Municipal and Metropolitan District Assemblies (MMDAs) for more detailed sub-national climate change risk assessment as they represent two of the main ecological regions in Ghana, namely the Guinea Savannah and the Coastal region.

CREATING CONTEXT

The National Adaptation Plan (NAP) process was established under the Cancun Adaptation Framework (CAF). It enables States to formulate and implement NAPs as a means of identifying medium and long-term adaptation needs and developing and implementing strategies and programmes to address those needs. It is a continuous, progressive and iterative process which follows a country-driven, gender-sensitive, participatory and fully transparent approach.

The Paris Agreement (2015) in its global goal on adaptation (Article 7) brought new elements and dimensions to climate change adaptation. Namely, enhancing adaptive capacity, strengthening resilience and reducing vulnerability to medium and long-term climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the global temperature limit of less than 2°C.

The NAP process in Ghana is being coordinated by the Environmental Protection Agency (EPA) on behalf of the Ministry of Environment, Science, Technology, and Innovation (MESTI). The EPA is currently implementing the Green Climate Fund (GCF) NAP Readiness Project with the UNEP as a delivery partner.

The project governance structure is anchored on the technical guidance of a Cross-Sectoral Policy Groups (CSPGs) to facilitate knowledge co-creation and for institutional buy-in for effective implementation once the plans are developed.

There are five (5) CSPGs focusing on thematic areas including Agriculture and Forestry, Health, Infrastructure (energy, water and transport), Private Sector as well as Disaster Risks and Cities. The CSPG members are from different stakeholder institutions including public, private, CSOs including youth and women groups, academia and research, etc.

The findings, risks and scenarios captured in this document creates an understanding of the past and current climate impacts, the potential impact of future climate, with and without climate change and the disaggregation of other changes that are occurring in the area covered by the risk assessment, so that the impact of climate change can be isolated, analysed and presented in the form of a robust and clear climate risk narrative for Ghana and the way forward.

The blocks to the right provide an overall summary of a Climate Change Risk and a Climate Change Scenario ensuring that the same understanding is used throughout the document.

CLIMATE CHANGE RISK

The possibility of negative impacts on human or ecological systems due to climate-related changes. **Climate change risk** is derived from a combination of **Hazard, Exposure, Sensitivity and Adaptive Capacity**. Sensitivity and Adaptive Capacity determined overall **Vulnerability.**

RISK=HAZARD+EXPOSURE+VULNERABILITY

CLIMATE CHANGE SCENARIOS

Hypothetical narratives that outline different possible **future conditions** of the climate, based on factors including greenhouse gas emissions, technological developments, and policy decisions. These are referred to as either **Relative Concentration Pathway** (RCPs) or **Shared Socioeconomic Pathways** (SSPs).

2 SOCIO-ECONOMIC DEVELOPMENT PATHWAYS OF GHANA

The creation of local level socioeconomic development scenarios scenarios can assist with evaluating the potential for future climate change risk and vulnerability. These national and local level socio-economic development scenarios were developed out on four of the global Shared Socioeconomic Pathways (SSPs) used by the Intergovernmental Panel on Climate Change (IPCC).

The four selected SSPs are summarised below:

	SUSTAINABILITY: Taking the Green Road	This pathway is characterised by more inclusive global development and improved management of global commons, low global population growth and slower economic development, leading to relatively low resource and energy demand. Environmental technologies are favoured. Global, national, and regional institutions are strong and flexible, and human well-being has improved.
	FOSSIL-FUELED DEVELOPMENT: Taking the Highway	This SSP is characterised by competitive markets, innovation and participatory societies that produce rapid technological progress and development of human capital as a way to achieve sustainable development. It is a world of intensive fossil fuel development, high energy demand and rapid technological progress, but also characterised by a focus on health, education and institutions to enhance human and social capital.
	INEQUALITY: A Road Divided	This SSP is characterised by increasing inequalities both between and within countries, concentration of power within a small elite, and moderate economic growth in the industrialised world with a large, vulnerable population on the rest of the planet. Technological development is uneven and global markets volatile due to prevailing political uncertainties.
	REGIONAL RIVALRY: A Rocky Road	This SSP is characterised by resurgent nationalism, competitiveness and security, along with weak global institutions. Other features are trade barriers, authoritarian governments and highly regulated economies. Economic development is slow but material consumption intensive.

Table 1: Summary of Shared Socioeconomic Pathways (SSPs).

The key drivers of change used to define the SSPs are shown in the figure and consist of the following: (1) demography and settlement patterns, (2) consumption and rate of economic growth, (3) direction and rate of technology change, (4) nature of governance, and (5) social and political values. The potential implication of these alternative socio-economic development scenarios needs to be determined for Ghana at the national and sub-national level which can then be aligned with the sub-national level risk assessments

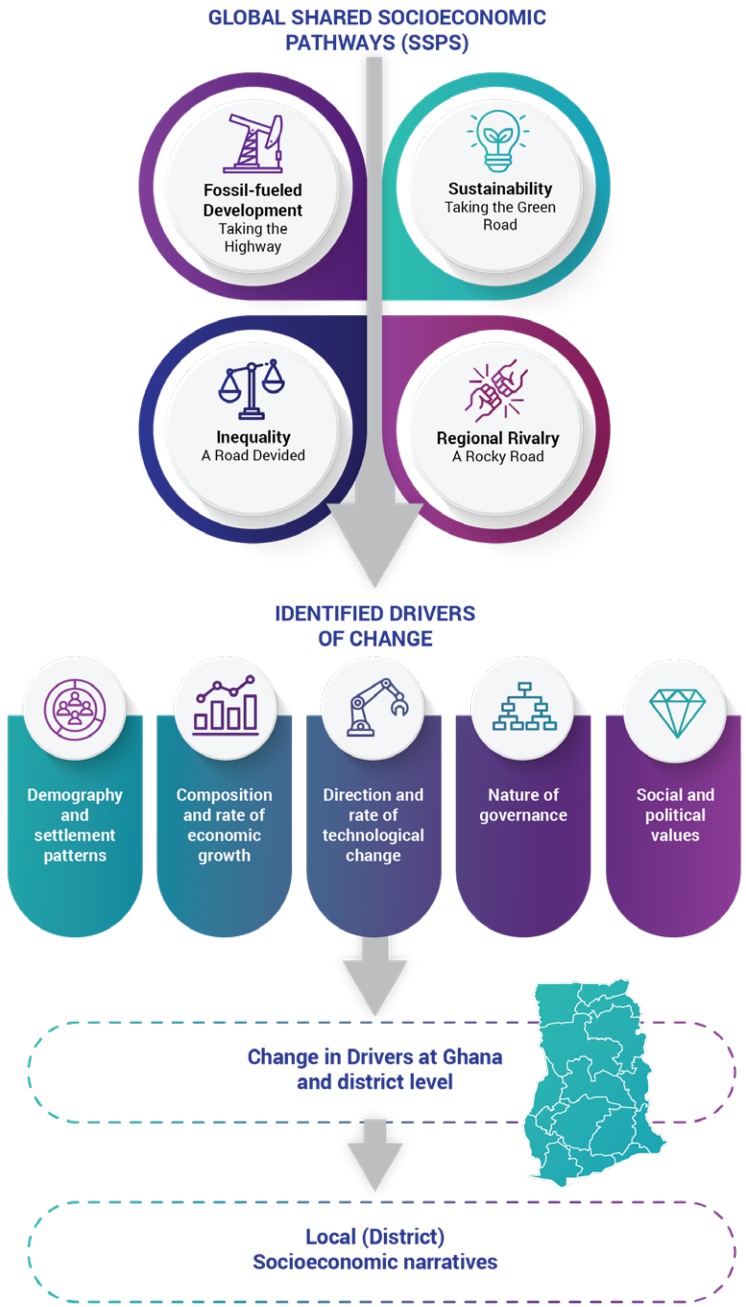


Figure 1: Adapted approach to develop local socioeconomic narratives.

3 VULNERABILITY AND ADAPTIVE CAPACITY

Vulnerability to climate change in Ghana is most pronounced for those who rely heavily on natural resources and have limited capacity to cope with these changes, especially those dependent on climate-sensitive livelihoods like agriculture. Smallholder farmers, particularly female-headed households, are highly exposed to the impacts of climate change and variability. Women constitute 52% of the agricultural labour force in Ghana and produce 70% of subsistence crops. They also rely on water and crops for their household responsibilities. However, their adaptive capacity to climate change is constrained by factors such as limited access to financial resources, insufficient information and technology, and unfavourable land tenure systems.

Ghana's high vulnerability score and low readiness score places it in the upper-left quadrant of the ND-GAIN Matrix, indicating both a great need for investment and innovation to improve readiness and an urgency for action. Ranked as the 64th most vulnerable and the 124th most ready country in the world, specific adaptation strategies need to be implemented to ensure that Ghana is ready for future climate changes.

Ghana's heightened vulnerability can be attributed to factors such as:	**Ghana's low readiness score emphasises the challenges Ghana faces in:**
1. Reliance on agriculture 2. Exposure to extreme weather events 3. Consequences of potential climate change on water resources, health, infrastructure, and ecosystems.	1. Resource mobilisation 2. Effective governance, and 3. Promoting social preparedness for climate adaptation.

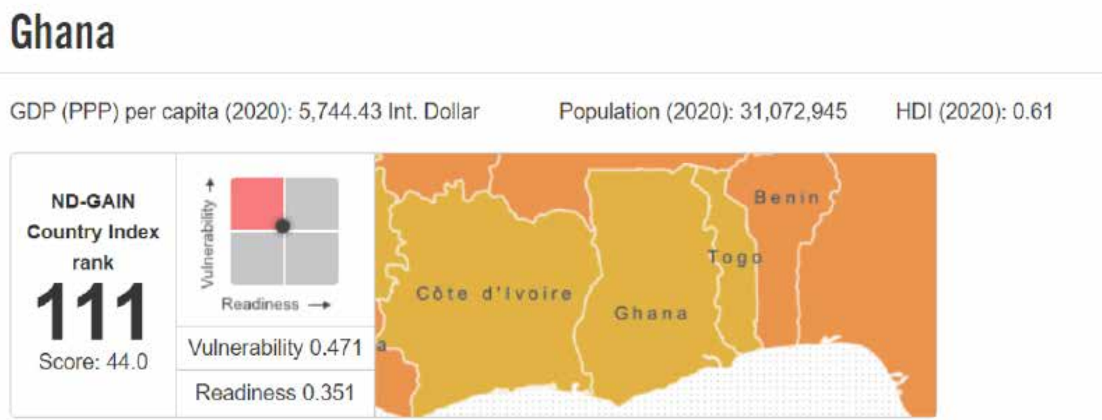


Figure 2: The ND-GAIN Country Matrix for Ghana.

4 THE NATIONAL CLIMATE CHANGE RISK PROJECTIONS AND SCENARIOS

Ghana's climate is strongly influenced by the West African monsoon winds, which varies slightly along with the country's varied topography and from south to north moving inland from the coast. With most of the rain falling in intense storms of short duration, the country is vulnerable to extreme events such as heavy rainfall (with on average 44mm per day) resulting in heavy run-off and erosion, especially at the beginning of the rainy season. At the same time, prolonged dry seasons in the north has led to serious droughts in the region.

Ghana's high degree of vulnerability to climate change poses a threat to growth and development.

The information below captures some of the observed climate trends for Ghana:

TEMPERATURE

The mean annual **temperature has increased** by 1.0°C since 1960.	The rate of increase has been more rapid in the **north** of Ghana.	**'Hot' days have increased by 13%** in all seasons.	**'Hot' nights have increased by 20%** in all seasons.	**'Cold' days and 'cold' nights have decreased by 3.3% and 5.1%** respectively.

RAINFALL

Ghana's **rainfall varies** significantly from year to year, making it difficult to identify long term trends.	No evidence of a trend in the proportion of rainfall that falls in 'heavy' events between 1960 and 2006.	Rainfall saw a well-defined cumulative reduction of 2.4% per decade since 1960, but a recently increasing trend.	No clear trend observed in the intensity and frequency of extreme rainfall events, but this is **likely to increase**.

NATURAL HAZARDS AND EXTREME EVENTS

In the past 50 years, 22 major **hydrometeorological event** took place.	The recurrence of both **floods and droughts** in the Northern Savanna region of Ghana is becoming a common phenomenon.	**24-hour maximum rainfall events** appear to have increased resulting in an increased risk of urban flooding.	The 2007 catastrophic floods in northern Ghana occurred immediately after a period of drought.

Rising sea levels, drought, higher temperatures, and erratic rainfall negatively impacts infrastructure, hydropower production, food security and coastal and agricultural livelihoods.

THE FUTURE CLIMATE OF GHANA

For this study, Ghana was separated into four homogenous climate zones (north, central, south-west and coastal) based on an analysis of current rainfall patterns and expected changes, with each zone having a common rainfall climatology. Furthermore, these climatic zones were compared with the identified ecological regions for Ghana.

Figure 3: Ghana's ecological regions

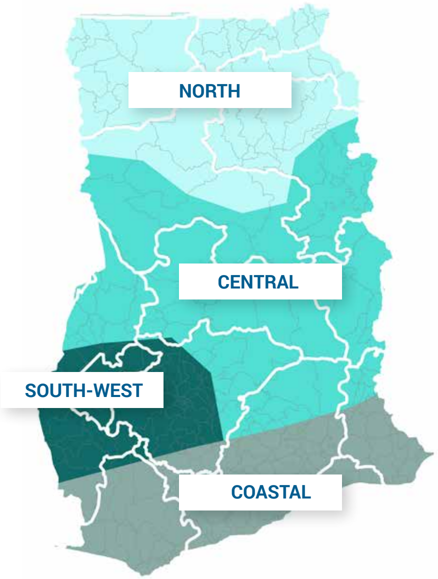


Figure 4: Ghana's four homogenous climate zones

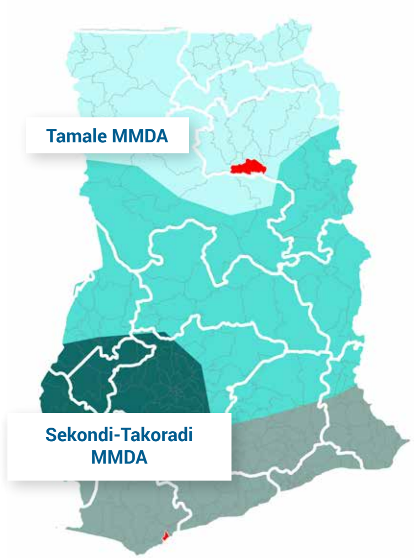


Figure 5: Primary MMDAs used for the Climate Change Risk Assessments

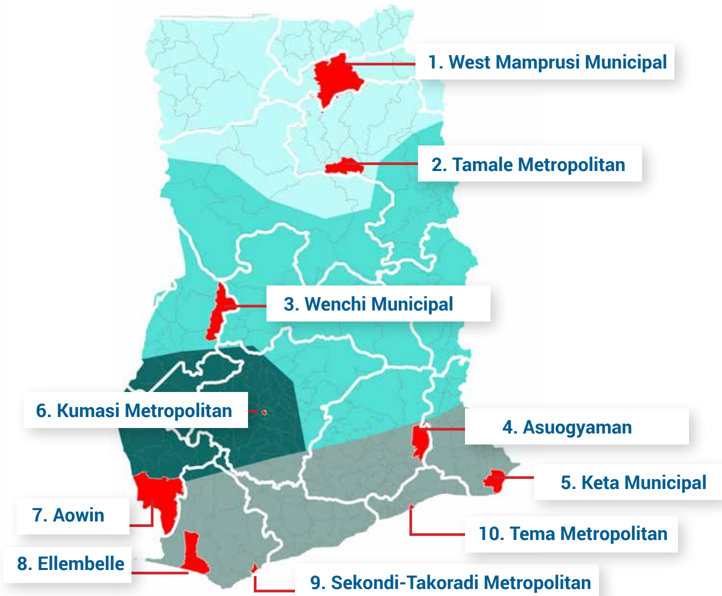
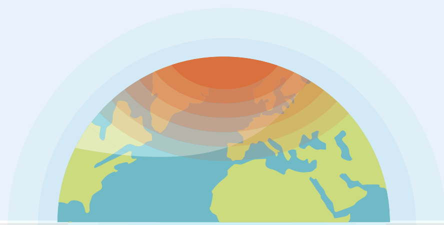


Figure 6: Downscaled climate change scenarios were produced for a total of 10 identified MMDAs

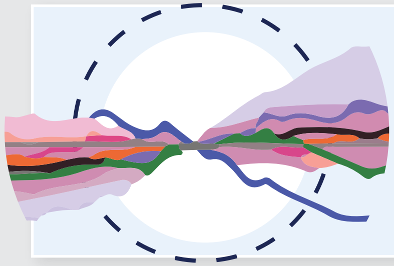
For the climate risk assessments, Tamale and Sekondi-Takoradi Metropolitan (shown in red in the maps above) were chosen as the priority MMDAs. However, downscaled climate change scenarios were produced for a total of 10 identified MMDAs in order to support undertaking of climate change risk assessments for these additional MMDAs under the NAP program.



Analysis of Climate Change Scenarios for Ghana

Understanding the uncertainty in future climate change projections, under different global emission scenarios is critical to supporting decision-making.

For the analysis of future climate change scenarios in Ghana, two different but complementary approaches were used to explore the range of possible scenarios and the associated levels of uncertainty. The results were presented for the four homogenous climate zones and the ten priority Metropolitan, Municipal and District Assemblies (MMDAs).



One of the critical aspects of this study was the variety of approaches that were used for the analysis for future climate change projections using Self Organising Maps (SOMs) and Plume Plots. This ensures that a range of climate uncertainties are assessed and considered, to ensure relevant adaptation solutions can be put in place in support of Climate Resilient Development.

DID YOU KNOW?

Relative Concentration Pathways (RCP) are a set of scenarios used by climate scientists to model and project future greenhouse gas emissions and their impact on the Earth's climate system. These RCP scenarios are essential for climate research because they provide a range of potential futures that can be used to study the possible consequences of different levels of greenhouse gas emissions on global temperature, sea level rise, extreme weather events, and other aspects of the Earth's climate system.

Three RCPs were used to create realistic projections for this report:

RCP 2.6

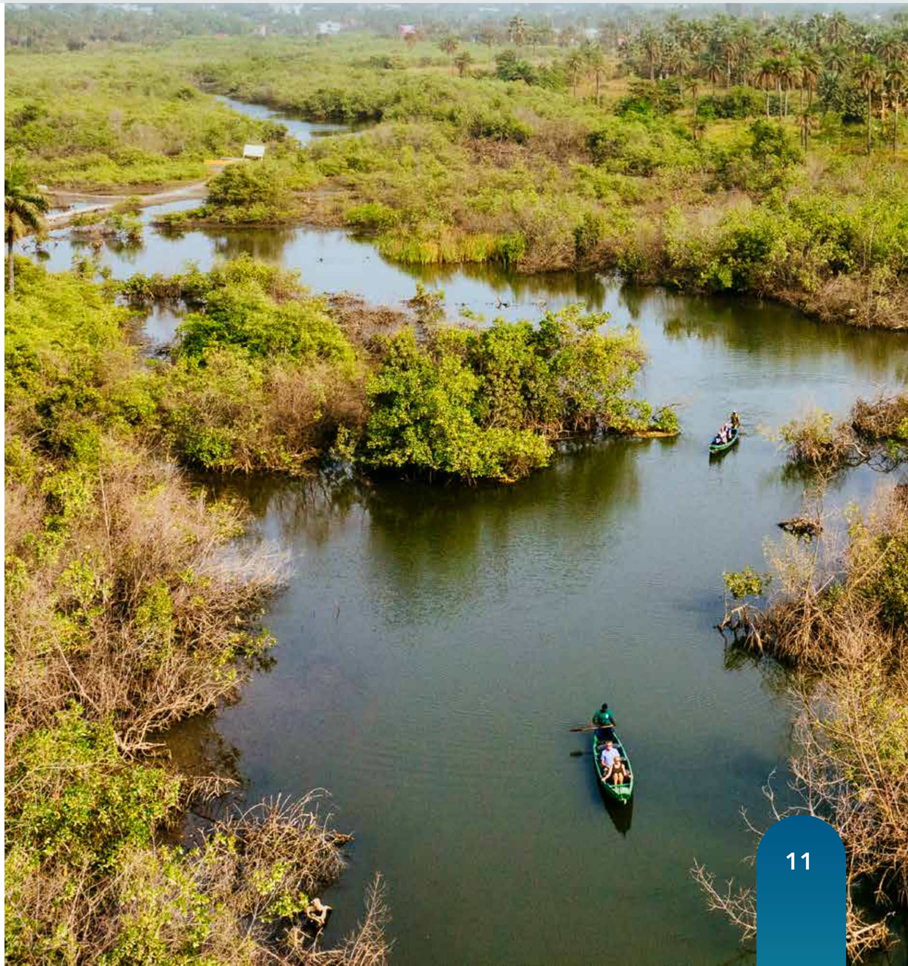
Represents a scenario in which strong mitigation efforts are implemented to limit global warming to 2 degrees Celsius above pre-industrial levels by the end of the century.

RCP 4.5

Represents a scenario in which greenhouse gas emissions are stabilised at a moderate level, resulting in a more restrained increase in radiative forcing compared to higher emission scenarios. It reflects a future where some actions are taken to reduce emissions but not as aggressively as in the RCP 2.6 scenario.

RCP 8.5

Represents a scenario of high greenhouse gas emissions and limited mitigation efforts, leading to a much higher level of warming and more severe climate impacts.



Overall Summary of Climate Change Scenario Results and Potential Impact

Based on the analysis of the available climate change model projections for Ghana, the following can be summarised:

Overall Summary of Climate Change Scenario Results

Higher annual average temperature values occur, as expected, with **increasing emissions.**

For the North Zone, the 100-year return value under RCP8.5 increases by approaching 6°C.

Weak changes in the overall "wetness" of the climate without a clearly defined direction of future changes in total annual rainfall.

Latest CMIP6 model results, however, suggest the potential for **more significant "wetting"**, particularly over the Northern region of Ghana which requires further investigation, bias correction and downscaling.

Strong **increases in air temperatures** manifested in all scenarios and all zones.

These increases amount to on average 0.5 - 1.5 °C, 1.5 - 2.5 °C and 2.5 - 4.5 °C for the RCPs.

Due to unclear precipitation trends, limited change in drought occurrences and magnitudes.

However, when combined with an increasing trend in average annual temperatures, could result in an increasing risk of drought.

These two points are interconnected, emphasising the potential variations in future scenarios, especially concerning overall wetness, when comparing the older CMIP5 climate models to the more recent CMIP6.

Greater increases in temperatures expected over the northern region and a greater potential for wetting in the coastal zone for CMIP5

Possible trend towards **increased return values for the wettest years,** perhaps indicating the prospects of increased flooding.

By 2035, an expected increase in the maximum one-day rainfall across all regions of around 25%, increasing to 42% by 2085 under RCP4.5 and 66% under RCP 8.5.

Trends in temperature and rainfall

The table shows how the climate is expected to change for the remainder of the century in each of the four climate zones and under the three global emission scenarios. It lists how much the average temperature will increase on average per decade (in °C) and how much rainfall will change (as a percentage).

Climate Zones	Temperature °C per decade			Rainfall % change per decade		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
North	**+0.09**	**+0.24**	**+0.57**	−0.1	+0.1	+0.6
Central	**+0.08**	**+0.23**	**+0.55**	−0.0	+0.0	+0.6
Southwest	**+0.08**	**+0.23**	**+0.52**	+0.1	+0.1	+0.6
Coastal	**+0.08**	**+0.22**	**+0.50**	−0.1	+0.3	+0.8
	Interpretation			**Interpretation**		
	• Changes in all four zones are similar, with most trends, other than RCP2.6, statistically significant (shown in bold) • Under RCP2.6 the increases tend to plateau after mid-century; there is also some plateauing in the final two or so decades under RCP4.5. • Temperatures increase throughout the century under RCP8.5, reaching an average rise of almost 4°C by 2100. • Projected temperature trends are strongest in the North Zone, but only significantly under RCP 8.5.			• Non-significant trends in rainfall are present for most zones under RCP2.6 and RCP4.5, with statistically significant positive trends under RCP8.5 across all four zones. • The strongest trends in rainfall are for the Coastal Zone which is significant under RCP 4.5 and RCP 8.5. • However, it's important to note that this analysis doesn't take into account potential changes in rainfall patterns throughout the year or the effects of rising temperatures. These factors are likely to result in drier conditions across all zones, increasing the risk and severity of droughts. Additionally, there may be delays in early-season rainfall.		

Table 2: Overall trends in climate for the remainder of the century in °C/decade and %/decade. Statistically significant trends are indicated in bold and are shaded.

Temperature trends in long-term (multiple years) extreme weather events:

Based on our research under RCP 8.5, by **mid-century**, Ghana is almost certain (100%) to face two back-to-back years with temperatures rising beyond the usual range. Soon after, a similar trend is expected for three consecutive years. In essence, this suggests that Ghana will experience several years where average temperatures rank among the hottest of recorded years.

Under RCP4.5, similar results are seen, but two back-to-back years with temperatures rising will only be reached by the **century's end.**

Under RCP2.6, chances of reaching two back-to-back years of rising temperatures are **50% by mid-century** and then decrease slightly afterwards as the benefits of global mitigation are realised.

In summary, we can be confident that we will experience two-to-three year periods with temperatures much higher than what we currently encounter, especially if emissions continue to rise.

Rainfall trends in long-term (multiple years) extreme weather events:

There are clear and significant increases in extended dry periods. This means longer stretches of dry weather, even though overall drought risk hasn't significantly increased based solely on changes in average annual rainfall.Noticeable positive trends in overall wetter periods have also been observed.

Noticeable positive trends in overall wetter periods have also been observed.

All trends are **most prominent under RCP8.5** and in the Southwest and Coastal Zones. **This indicates that yearly rainfall amounts might increase with climate change, leaning towards more wetter years,** but interspersed with very **dry years.**

Joint Scenario Climate Change Pathways and Likelihood

To help Ghana's decision-makers prepare for climate changes in the next 50 years, a range of possible future climate outcomes were determined in the form of joint climate change scenario pathways. By using over 30 climate models, each associated with one of the three emissions scenarios (RCP 2.6, RCP 4.5, and RCP 8.5), we can estimate the likelihood of temperature and rainfall changes using Self Organising Maps (SOMs). Notably, when multiple models agree and make similar predictions, their collective likelihood increases. This valuable information empowers policymakers to make informed and proactive decisions.

- For each RCP, four joint scenarios were identified by examining common temperature and rainfall changes in each of the three emission scenarios. Two additional scenarios representing an upper and lower extreme scenario were also identified.
- The joint scenario pathways were identified using the full complement of downscaled climate change scenarios from the CORDEX and for each of the three global emission scenarios; RCP 2.6, RCP 4.5 and RCP 8.5. The joint scenario pathways are named as A26, B26, C26, D26. The likelihood of each scenarios is determined based on the number of climate models in each cluster of results.

The following sections provide a summary of the joint scenarios for each of the four climate zone as well as a summary of the Plume plots for temperature and rainfall up to the end of the century.

Joint Climate Change Scenarios Pathways and Likelihood

DID YOU KNOW THAT PREDICTING FUTURE CLIMATE CHANGES IS AN INTRICATE TASK?

It involves considering a multitude of interconnected factors, from population growth and land-use changes to the unpredictability of greenhouse gas emissions. These multifaceted variables make it challenging to provide precise forecasts for the years to come, therefore, various models are used to make assumptions and analyses about the future that can be used for policy changes and decision making.

SUMMARY FOR THE NORTHERN CLIMATE ZONE

Joint Climate Change Scenarios Pathways and Likelihood

The SOMs (Self Organising Maps) analysis was used to identify a set of four joint scenario pathways representing the expected change in temperature and rainfall in each of the four climate zones and under the three emission scenarios RCP 2,6, RCP 4.5, and RCP 8.5. Two additional scenarios, representing an upper extreme (UE) and a lower extreme (LE) scenario where also identified. The resulting probability of each of these scenarios and the expected impact over the future time periods are shown in the table below.

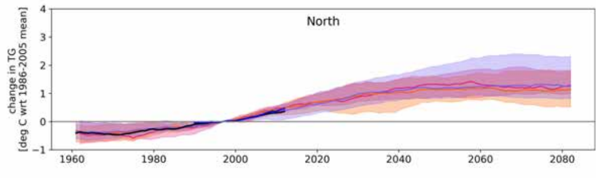
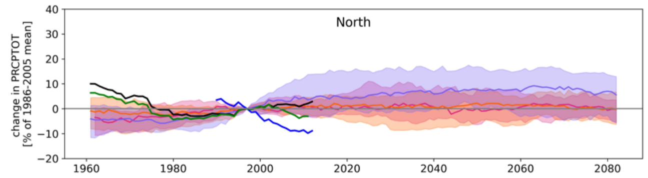
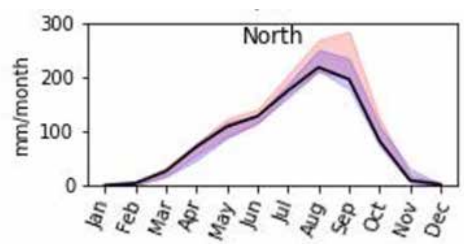
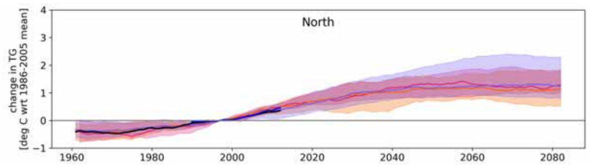
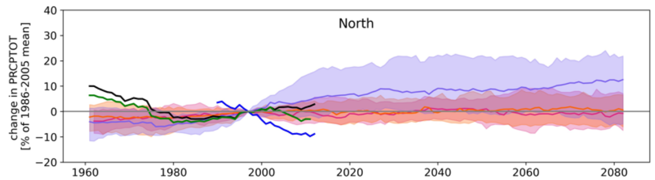
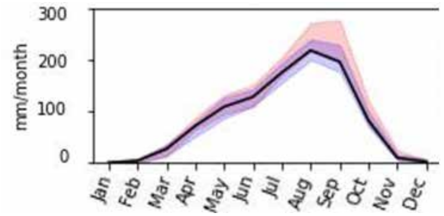
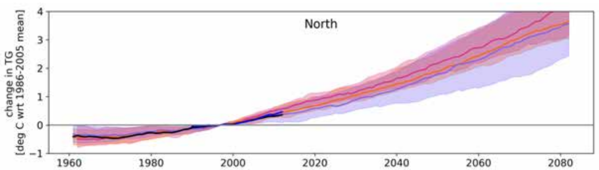
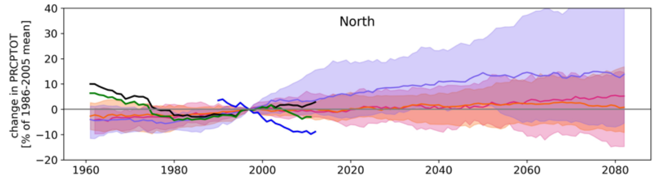
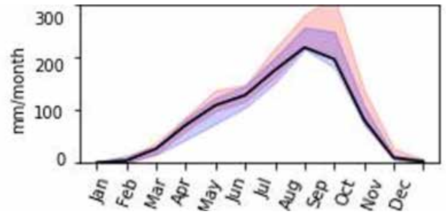
	Scenario	Likelihood of Scenario	**Expected Temperature (°C) and Rainfall (%) Impacts** Relative change from base year.					
			2035		**2060**		**2080**	
			Temp	**Rainfall**	**Temp**	**Rainfall**	**Temp**	**Rainfall**
RCP 2.6: Strong mitigation efforts are implemented	**A26**	**35%**	↑ 0.5°C	↑ 5%	↑ 0.5°C	↑ 5%	↑ 0.5°C	↑ 5%
	B26	**25%**	↑↑ 1.5°C	↑ 5%	↑↑ 1.5°C	↑ 5%	↑↑ 2°C	↑ 5%
	C26	**25%**	↑ 1°C	No change	↑ 1°C	No change	↑ 1°C	No change
	D26	**15%**	↑ 1°C	↓ 5%	↑↑ 1.5°C	↓ 5%	↑ 1°C	↓ 5%
	UE	-	↑ 0.5°C	↑↑↑ 15%	↑ 1°C	↑↑↑ 15%	↑↑ 1.5°C	↑↑ 10%
	LE	-	↑ 1°C	↓ 5%	↑ 1°C	↓ 5%	↑↑ 1.5°C	↓↓ 10%
RCP 4.5: Greenhouse gas emissions are stabilised at a moderate level	**A45**	**50%**	↑ 1°C	No change	↑↑ 1.5°C	No change	↑↑↑ 2.5°C	No change
	B45	N/A	-	-	-	-	-	-
	C45	**40$**	↑ 1°C	↓ 5%	↑↑ 1.5°C	↓ 5%	↑↑ 2°C	↓↓ 10%
	D45	**10%**	↑ 1°C	↑↑ 10%	↑↑ 1.5°C	↑↑ 10%	↑↑ 1.5°C	↑↑ 10%
	UE	-	↑ 1°C	↑↑↑ 15%	↑ 1°C	↑↑↑ 15%	↑↑ 2°C	↑↑↑ 15%
	LE	-	↑ 1°C	↓↓ 10%	↑↑ 2°C	↓↓ 10%	↑↑ 1.5°C	↓↓↓ 15%
RCP 8.5: High greenhouse gas emissions and limited mitigation efforts	**A85**	**40%**	↑ 1°C	↑ 5%	↑↑ 2°C	↑ 5%	↑↑↑ 3.5°C	↑ 5%
	B85	**35%**	↑↑ 1.5°C	↓ 5%	↑↑↑ 2.5°C	↓ 5%	↑↑↑↑ 4.5°C	↓↓ 10%
	C85	N/A	-	-	-	-	-	-
	D85	**25%**	↑↑ 1.5°C	↑↑ 10%	↑↑ 2°C	↑↑ 10%	↑↑↑ 3.5°C	↑↑↑ 15%
	UE	-	↑ 1°C	↑↑ 10%	↑↑ 2°C	↑↑↑ 15%	↑↑↑ 3.5°C	↑↑↑↑ 20%
	LE	-	↑ 1°C	↓↓ 10%	↑↑↑ 3.5°C	↓↓ 10%	↑↑↑↑↑ 5°C	↓↓↓ 15%

SUMMARY FOR THE NORTHERN CLIMATE ZONE

Future Climate Change Scenarios (Comparison of CORDEX, CMIP5 and CMIP6 climate model ensembles)

The below graphs show how each of the three emission scenarios evolves over time. As can be seen under the temperature trends, there is an expected increase under RCP2.6 and RCP4.5, but plateauing after about 2050, with a significant increase under RCP 8.5 continuing to the end of the century. The median values for temperature are relatively consistent between CMIP 5, CORDEX and CMIP 6 and match well to the observed temperature trend. For rainfall there is very little change expected under CMIP 5 and CORDEX, with small increase in the mean annual rainfall under RCP 8.5 by the end of the century. The latest scenarios from the IPCC, i.e. CMIP6 tend to show a greater likelihood of a significant increase in mean annual rainfall, particularly under RCP 8.5, although there is still considerable uncertainty in these rainfall scenarios.

The seasonal plots shows the greatest increase in rainfall during August and September.

	Change in Average Annual Temperature	Changes in Mean Annual Rainfall	Seasonal changes in rainfall (2035-2065)
RCP 2.6			
RCP 4.5			
RCP 8.5			

CORDEX ensemble median
CMIP5 ensemble median
CMIP6 ensemble median
CRU TS 4.05
ERA5
GPCC
CORDEX 23 member ensemble
CMIP5 31 member ensemble
CMIP6 32 member ensemble

historical 1981-2010 (CRU)
CMIP6 2035-2065
CORDEX 2035-2065

SUMMARY FOR THE CENTRAL CLIMATE ZONE

Joint Climate Change Scenarios Pathways and Likelihood

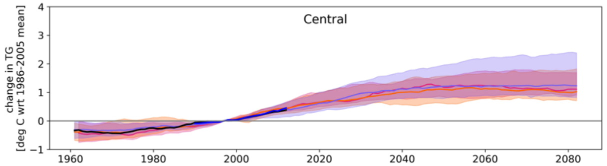
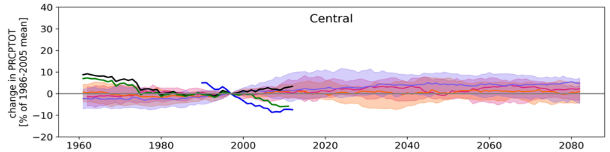
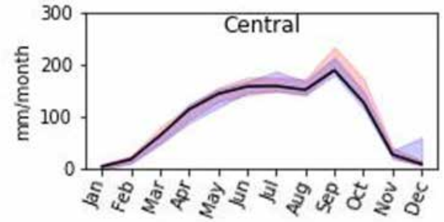
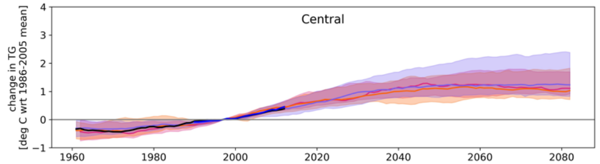
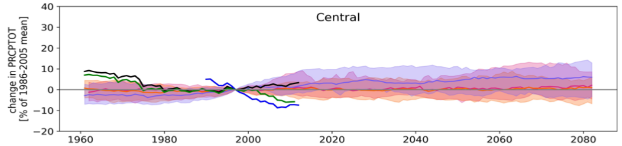
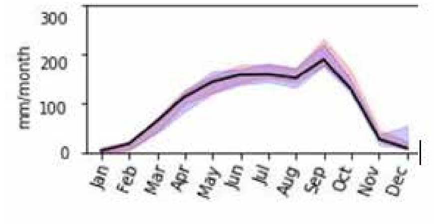
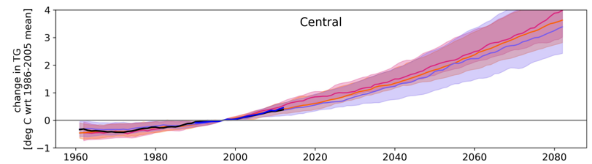
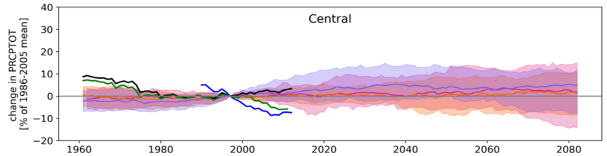
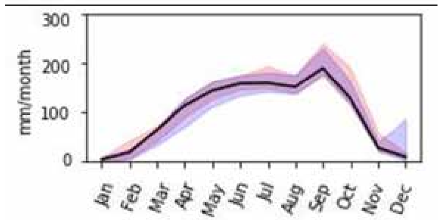
The below table shows the most likely scenario pathways for each of the three emissions scenarios.

	Scenario	Likelihood of Scenario	**Expected Temperature (°C) and Rainfall (%) Impacts** Relative change from base year.					
			2035		**2060**		**2080**	
			Temp	**Rainfall**	**Temp**	**Rainfall**	**Temp**	**Rainfall**
RCP 2.6: Strong mitigation efforts are implemented	**A26**	**30%**	↑ 0.5°C	↑ 5%	↑ 0.5°C	↑ 5%	↑ 0.5°C	↑ 5%
	B26	**25%**	↑↑ 1.5°C	↑ 5%	↑↑ 1.5°C	↑ 5%	↑↑ 2°C	↑ 5%
	C26	**30%**	↑ 1°C	No change	↑ 1°C	No change	↑ 1°C	No change
	D26	**15%**	↑ 1°C	↓ 5%	↑↑ 1.5°C	↓ 5%	↑ 1°C	↓ 5%
	UE*	**-**	↑ 0.5°C	↑↑↑ 15%	↑ 1°C	↑↑↑ 15%	↑↑ 1.5°C	↑↑ 5%
	LE	**-**	↑ 1°C	↓ 5%	↑ 1°C	↓ 5%	↑↑ 1.5°C	↓↓ 10%
RCP 4.5: Greenhouse gas emissions are stabilised at a moderate level	**A45**	**50%**	↑ 1°C	No change	↑↑ 1.5°C	No change	↑↑↑ 2.5°C	No change
	B45	N/A	-	-	-	-	-	-
	C45	30%	↑ 1°C	↓ 5%	↑↑ 1.5°C	↓ 5%	↑↑ 2°C	↓↓ 10%
	D45	**20%**	↑ 1°C	↑↑ 10%	↑↑ 1.5°C	↑↑ 10%	↑↑ 1.5°C	↑↑ 10%
	UE	**-**	↑ 1°C	↑↑↑ 15%	↑ 1°C	↑↑↑ 15%	↑↑ 2°C	↑↑↑ 15%
	LE	**-**	↑ 1°C	↓↓ 10%	↑↑ 2°C	↓↓ 10%	↑↑ 1.5°C	↓↓↓ 15%
RCP 8.5: High greenhouse gas emissions and limited mitigation efforts	**A85**	**40%**	↑ 1°C	↑ 5%	↑↑ 2°C	↑ 5%	↑↑↑ 3.5°C	↑ 5%
	B85	**10%**	↑↑ 1.5°C	↓ 5%	↑↑↑ 2.5°C	↓ 5%	↑↑↑↑ 4.5°C	↓↓ 10%
	C85	**50%**	↑↑ 1.5°C	No change	↑↑↑ 2.5°C	No change	↑↑↑ 3.5°C	No change
	D85	**N/A**	-	-	-	-	-	-
	UE	**-**	↑ 1°C	↑↑ 10%	↑↑ 2°C	↑↑↑ 15%	↑↑↑ 3.5°C	↑↑↑↑ 20%
	LE	**-**	↑ 1°C	↓↓ 10%	↑↑↑ 3.5°C	↓↓ 10%	↑↑↑↑↑ 5°C	↓↓↓ 15%

SUMMARY FOR THE CENTRAL CLIMATE ZONE

Future Climate Change Scenarios (Comparison of CORDEX, CMIP5 and CMIP6 climate model ensembles)

The below graphs show how the temperature trends in the Central Climate Zone is expected to increase under RCP2.6 and RCP4.5, with a significant increase under RCP8.5. Regarding the rainfall trends for the Central Climate Zone, it shows very little change in the ensemble mean for all three climate projections, but with a maximum.

	Temperature trends	Rainfall trends	Seasonal changes in rainfall (2035-2065)
RCP 2.6			
RCP 4.5			
RCP 8.5			

CORDEX ensemble median
CMIP5 ensemble median
CMIP6 ensemble median
CRU TS 4.05
ERA5
GPCC
CORDEX 23 member ensemble
CMIP5 31 member ensemble
CMIP6 32 member ensemble

historical 1981-2010 (CRU)
CMIP6 2035-2065
CORDEX 2035-2065

SUMMARY FOR THE SOUTHWESTERN CLIMATE ZONE

Joint Climate Change Scenarios Pathways and Likelihood

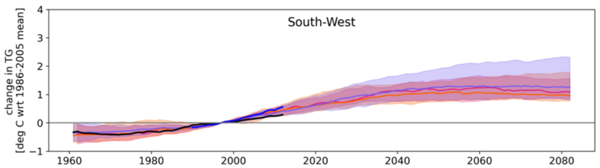
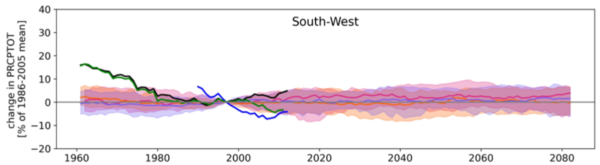
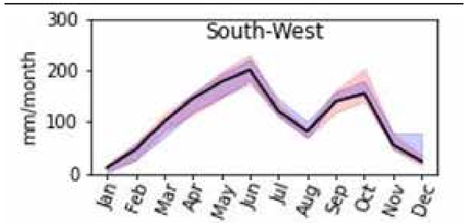
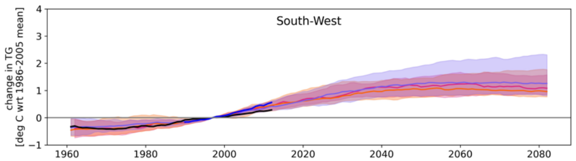
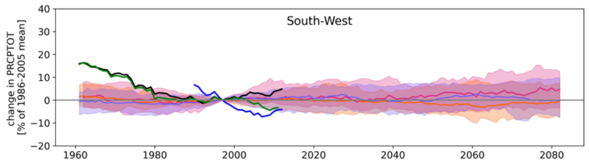
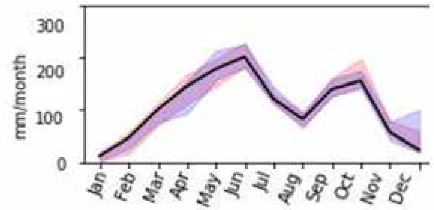
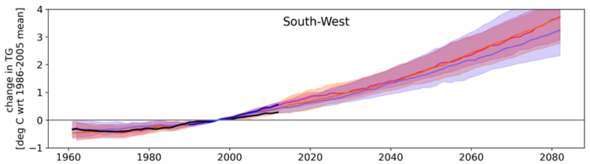
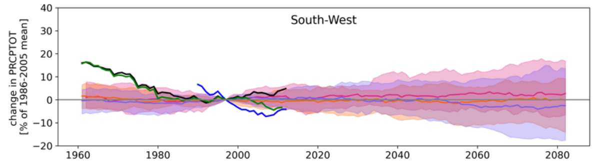
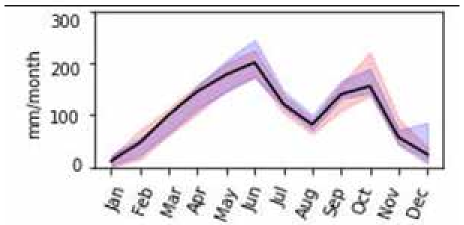
The below table shows the most likely scenario pathways for each of the three emissions scenarios.

	Scenario	Likelihood of Scenario	Expected Temperature (°C) and Rainfall (%) Impacts Relative change from base year.					
			2035		2060		2080	
			Temp	Rainfall	Temp	Rainfall	Temp	Rainfall
RCP 2.6: Strong mitigation efforts are implemented	**A26**	**30%**	↑ 0.5°C	↑ 5%	↑ 0.5°C	↑ 5%	↑ 0.5°C	↑ 5%
	B26	**20%**	↑↑ 1.5°C	↑ 5%	↑↑ 1.5°C	↑ 5%	↑↑ 2°C	↑ 5%
	C26	**40%**	↑ 1°C	No change	↑ 1°C	No change	↑ 1°C	No change
	D26	**10%**	↑ 1°C	↓ 5%	↑↑ 1.5°C	↓ 5%	↑ 1°C	↓ 5%
	UE*	-	↑ 1°C	↑↑ 10%	↑↑ 1.5°C	↑↑ 10%	↑↑ 1.5°C	↑ 5%
	LE	-	↑ 1°C	↓ 5%	↑ 1°C	↓ 5%	↑↑ 1.5°C	↓↓ 10%
RCP 4.5: Greenhouse gas emissions are stabilised at a moderate level	**A45**	**40%**	↑ 1°C	No change	↑↑ 1.5°C	No change	↑↑↑ 2.5°C	No change
	B45	N/A	-	-	-	-	-	-
	C45	45%	↑ 1°C	↓ 5%	↑↑ 1.5°C	↓ 5%	↑↑ 2°C	↓↓ 10%
	D45	**15%**	↑ 1°C	↑↑ 10%	↑↑ 1.5°C	↑↑ 10%	↑↑ 1.5°C	↑↑ 10%
	UE	-	↑ 1°C	↑↑↑ 15%	↑ 1°C	↑↑↑ 15%	↑↑ 2°C	↑↑↑ 15%
	LE	-	↑ 1°C	↓↓ 10%	↑↑ 2°C	↓↓ 10%	↑↑ 1.5°C	↓↓↓ 15%
RCP 8.5: High greenhouse gas emissions and limited mitigation efforts	**A85**	**30%**	↑ 1°C	↑ 5%	↑↑ 2°C	↑ 5%	↑↑↑ 3.5°C	↑ 5%
	B85	**25%**	↑↑ 1.5°C	↓ 5%	↑↑↑ 2.5°C	↓ 5%	↑↑↑↑ 4.5°C	↓↓ 10%
	C85	**15%**	↑↑ 1.5°C	No change	↑↑↑ 2.5°C	No change	↑↑↑ 3.5°C	No change
	D85	**30%**	↑↑ 1.5°C	↑↑ 10%	↑↑ 2°C	↑↑ 10%	↑↑↑ 3.5°C	↑↑↑ 15%
	UE	-	↑ 1°C	↑↑ 10%	↑↑ 2°C	↑↑↑ 15%	↑↑↑ 3.5°C	↑↑↑↑ 20%
	LE	-	↑ 1°C	↓↓ 10%	↑↑↑ 3.5°C	↓↓ 10%	↑↑↑↑↑ 5°C	↓↓↓ 15%

SUMMARY FOR THE SOUTHWESTERN CLIMATE ZONE

Future Climate Change Scenarios (Comparison of CORDEX, CMIP5 and CMIP6 climate model ensembles)

The below graphs show how mean annual temperature in the Southwest Climate Zone is expected to increase under RCP2.6 and RCP4.5 until mid century, but with a significant increase under RCP8.5 continuing to the end of the century. The rainfall trends show very little change under RCP 2.6 and with an equal change of slight increase (+5%) or decreases (-5%) under RCP 8.5 by the end of the century. The range of uncertainty is relatively narrow under RCP 2.6, but much wider under RCP 8.5 indicated greater uncertainty and likely increased variability.

	Temperature trends	Rainfall trends	Seasonal changes in rainfall (2035-2065)
RCP 2.6			
RCP 4.5			
RCP 8.5			

CORDEX ensemble median
CMIP5 ensemble median
CMIP6 ensemble median
CRU TS 4.05
ERA5
GPCC
CORDEX 23 member ensemble
CMIP5 31 member ensemble
CMIP6 32 member ensemble

historical 1981-2010 (CRU)
CMIP6 2035-2065
CORDEX 2035-2065

SUMMARY FOR THE COASTAL CLIMATE ZONE

Joint Climate Change Scenarios Pathways and Likelihood

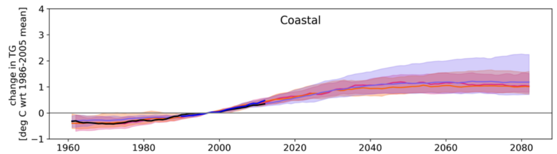
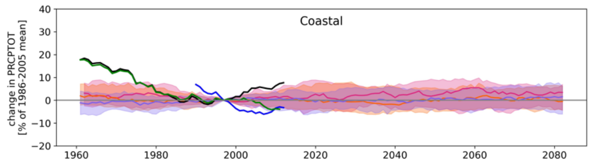
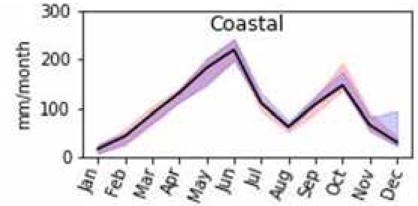
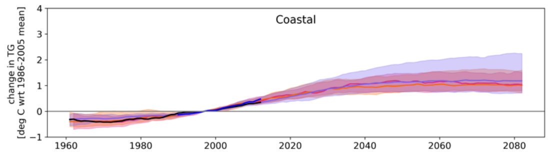
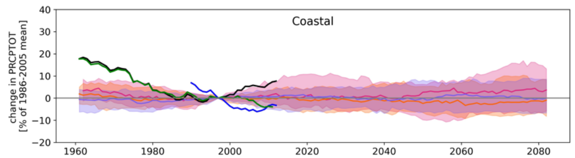
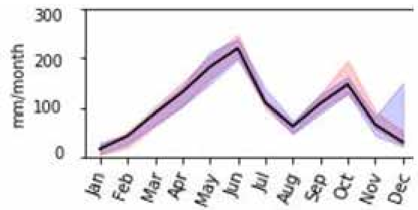
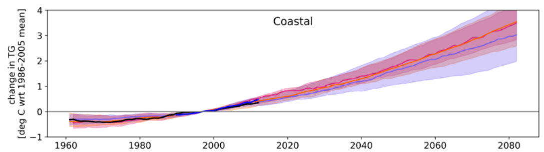
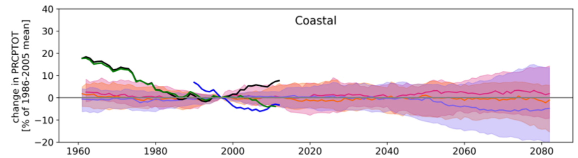
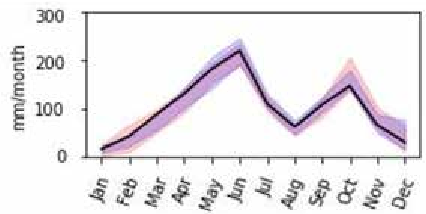
The below table shows the most likely scenario pathways for each of the three emissions scenarios.

	Scenario	Likelihood of Scenario	Expected Temperature (°C) and Rainfall (%) Impacts Relative change from base year.					
			2035		2060		2080	
			Temp	Rainfall	Temp	Rainfall	Temp	Rainfall
RCP 2.6: Strong mitigation efforts are implemented	**A26**	**35%**	↑ 0.5°C	↑ 5%	↑ 0.5°C	↑ 5%	↑ 0.5°C	↑ 5%
	B26	**20%**	↑↑ 1.5°C	↑ 5%	↑↑ 1.5°C	↑ 5%	↑↑ 2°C	↑ 5%
	C26	**15%**	↑ 1°C	No change	↑ 1°C	No change	↑ 1°C	No change
	D26	**30%**	↑ 1°C	↓ 5%	↑↑ 1.5°C	↓ 5%	↑ 1°C	↓ 5%
	UE*	**-**	↑ 1°C	↑↑ 10%	↑↑ 1.5°C	↑↑ 10%	↑↑ 1.5°C	↑ 5%
	LE	**-**	↑ 1°C	↓ 5%	↑ 1°C	↓ 5%	↑↑ 1.5°C	↓↓ 10%
RCP 4.5: Greenhouse gas emissions are stabilised at a moderate level	**A45**	**N/A**	-	-	-	-	-	-
	B45	40%	↑ 1°C	No change	↑↑ 1.5°C	↑ 5%	↑↑ 1.5°C	↑ 5%
	C45	**45%**	↑ 1°C	↓ 5%	↑↑ 1.5°C	↓ 5%	↑↑ 2°C	↓↓ 10%
	D45	**15%**	↑ 1°C	↑↑ 10%	↑↑ 1.5°C	↑↑ 10%	↑↑ 1.5°C	↑↑ 10%
	UE	**-**	↑ 1°C	↑↑↑ 15%	↑ 1°C	↑↑↑ 15%	↑↑ 2°C	↑↑↑ 15%
	LE	**-**	↑ 1°C	↓↓ 10%	↑↑ 2°C	↓↓ 10%	↑↑ 1.5°C	↓↓↓ 15%
RCP 8.5: High greenhouse gas emissions and limited mitigation efforts	**A85**	**30%**	↑ 1°C	↑ 5%	↑↑ 2°C	↑ 5%	↑↑↑ 3.5°C	↑ 5%
	B85	**30%**	↑↑ 1.5°C	↓ 5%	↑↑↑ 2.5°C	↓ 5%	↑↑↑↑ 4.5°C	↓↓ 10%
	C85	**40%**	↑↑ 1.5°C	No change	↑↑↑ 2.5°C	No change	↑↑↑ 3.5°C	No change
	D85	**N/A**	-	-	-	-	-	-
	UE	**-**	↑ 1°C	↑↑ 10%	↑↑ 2°C	↑↑↑ 15%	↑↑↑ 3.5°C	↑↑↑↑ 20%
	LE	**-**	↑ 1°C	↓↓ 10%	↑↑↑ 3.5°C	↓↓ 10%	↑↑↑↑↑ 5°C	↓↓↓ 15%

SUMMARY FOR THE COASTAL CLIMATE ZONE

Future Climate Change Scenarios (Comparison of CORDEX, CMIP5 and CMIP6 climate model ensembles)

The below graphs show how mean annual temperature in the Coastal Climate Zone is expected to increase under RCP2.6 and RCP4.5 until mid century, but with a significant increase under RCP8.5 continuing to the end of the century. The rainfall trends show very little change under RCP 2.6 and with an equal change of slight increase (+5%) or decreases (-5%) under RCP 8.5 by the end of the century. The range of uncertainty is relatively narrow under RCP 2.6, but much wider under RCP 8.5 indicated greater uncertainty and likely increased variability.

	Temperature trends	Rainfall trends	Seasonal changes in rainfall (2035-2065)
RCP 2.6			
RCP 4.5			
RCP 8.5			

CORDEX ensemble median
CMIP5 ensemble median
CMIP6 ensemble median
CRU TS 4.05
ERA5
GPCC
CORDEX 23 member ensemble
CMIP5 31 member ensemble
CMIP6 32 member ensemble

historical 1981-2010 (CRU)
CMIP6 2035-2065
CORDEX 2035-2065

SUMMARY IMPACTS OF CLIMATE CHANGE AND ADAPTATION RESPONSES FOR PRIORITY SECTORS

The future climate change scenarios described above will exert significant impacts across multiple sectors, regions, and communities, and particularly on vulnerable groups like women, children, the unemployed, small-scale farmers and fishers. The table below outlines some of the key **National Risk Assessment** findings alongside proposed **Adaptation Response Options** that can be implemented to mitigate climate change related impacts.

NATIONAL RISK ASSESSMENT FINDINGS	ADAPTATION RESPONSE OPTIONS
Primary sectors such as agriculture and fisheries are the most sensitive to the impacts of climate change, but all sectors will be affected. These sectors are most directly influenced by climate events and typically apply to more vulnerable communities.	• Scale up climate smart agriculture and improved resilience for small-scale fishers. • Provide additional water storage and irrigation infrastructure. • Consider alternative economic activities, livelihood support, and insurance options.
Water insecurity will increase due to more variable rainfall, higher temperatures and increasing demand. Local water sources (surface and groundwater) are the most vulnerable with less of an impact on larger water supply systems if there is an overall increase in wetness over the Volta Basin, and there is proactive water resources management.	• Support the transition to water sensitive cities and access to basic services. • Improved regional collaboration on IWRM and protection of natural catchments. • Increase water storage capacity. • Prevent illegal sand mining.
Extreme events including both very hot days and more intense rainfall will increase, contributing to an increased risk of flooding, wildfires, and landslides. These will also threaten critical infrastructure including roads, hospitals, power lines, water treatment works, airports, and water supply pipelines.	• Invest in improved monitoring and early warning and disaster management, disaster risk reduction, and disaster response systems. • Improve urban storm-water systems and clearing of drains to reduce flooding. • Prevent catchment degradation, and restore natural systems, such as forests, wetlands and mangroves.
Climate change will have a disproportionately high impact on **vulnerable communities and women,** particularly those dependent on subsistence agriculture and fishing or located in informal settlements and in areas exposure to flooding.	• Prioritise vulnerable communities for support and improved resilience by ensuring access to basic services, early warning, and improved disaster response systems.
Agriculture will be impacted by the change in rainfall patterns and increasing temperature, which will result in increasing dryness and evaporation, particularly inland. Maize in the Northern Region will be most severely impacted.	• Assist farmers with access to information.. • Promote Climate Smart Agriculture • Provide additional irrigation infrastructure and improved water use efficiency. • Provide support for markets, access to crop insurance, and alternative livelihoods.
The **fishing industry** will encounter challenges resulting from increased storminess, accelerated coastal erosion, increasing sea temperature and coastal flooding. Sea-level rise and coastal erosion also threatens cultural sites such as forts that support the local **tourism industry**.	• Improve coastal protection measures and access to sheltered harbours. • Improve access to information on weather and storms and communication equipment for fisherman to help improve sea-rescue.
Energy security will be affected through possible changes in the availability of hydropower from the Volta, thermal energy will likely be negatively impacted by increasing temperatures which reduce efficiency and power stations along the coast that are at risk of being affected by coastal erosion and/or flooding.	• Increase investments in renewable energy sources such as wind and solar. • Improve regional IWRM to improve resilience of hydropower and management of the Volta River Basin. • Improve coastal and flood protection of exposed power stations.
The impacts will be acutely felt in the **health sector** with temperatures above 35°C increasing threefold by 2050. Warmer temperatures will also increase the risk from diseases such as malaria and dengue fever.	• Identify critical health facilities and access routes that require protection from flooding and other natural disasters. • Improve monitoring and ability to response to increased health risks from extreme temperatures and other diseases. • Provide green spaces to help cool towns and cities and reduce pools of stagnant water and risks from flooding.

OVERALL ADAPTATION RESPONSE OPTIONS - NO-REGRETS OPTIONS:

In responding to the likely impacts of **climate change**, the following potential overarching **adaptation solutions**, amongst others, should be considered:

- Improved co-ordination of policies & collaboration across government departments and co-creation of adaptation solutions with stakeholders and vulnerable communities.
- Incorporating climate change into infrastructure design & adoption of climate resilient development pathways that are flexible and consider adaptation and mitigation co-benefits.
- Investing in ecological infrastructure & ecosystems-based adaptation (EbA): rehabilitation & protection of forests and catchment areas, protection and restoration of rivers and wetlands, protection of coastal mangroves. Preventing illegal sandmining in rivers.
- Improve monitoring systems to support decision making, flood early warning for vulnerable communities, weather warnings for small scale fishers, and seasonal forecasts for small scale farmers.
- Supporting the transition to more water sensitive cities and communities through improved urban stormwater drainage, maintaining green spaces and natural systems, improved water use efficiency, and consideration for alternative, integrated, and more diverse water supply options.
- Mainstreaming of climate smart agriculture (CSA) practices to improve agriculture yields particularly for high-risk crops such as maize and to reduce the impacts of higher evaporation and rainfall intensities and also to prevent further loss of soil carbon.
- Improved Integrated Water Resources Management (IWRM) and including engagement with upstream countries of the Volta River Basin to improve both water and energy security. Where possible increase water storage capacity to provide more reliable water supply to all sectors.
- Climate resilient health care facilities and improved access. Prepare for increase in heat related impacts and disease due to increased flooding.
- Diversify economic activities, insurance, healthcare, and livelihood support for small-scale farmers and fishers.
- Improved coastal protection for transport infrastructure, power stations and cultural sites at risk from sea level rise.

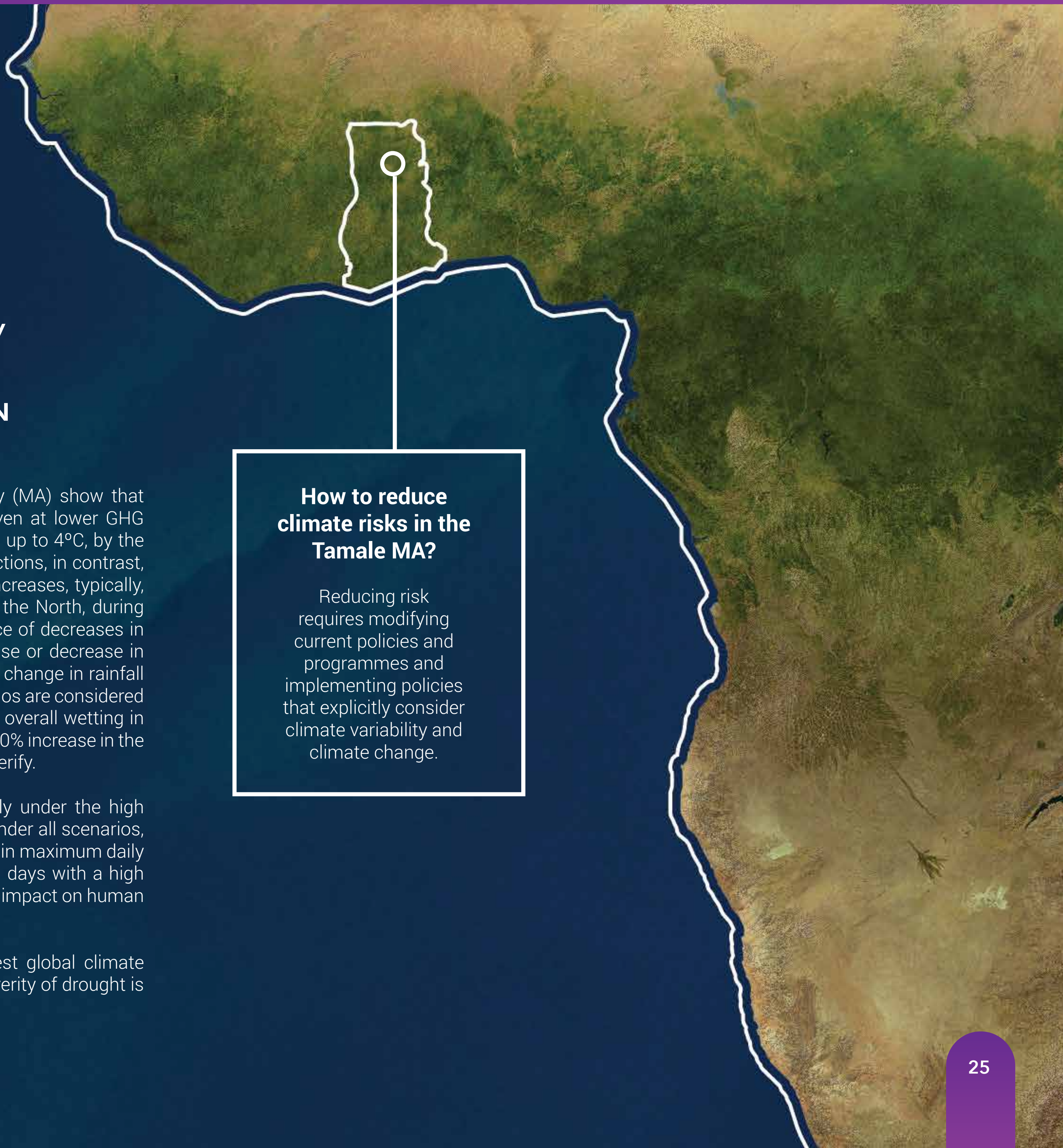
5 CLIMATE CHANGE RISK ASSESSMENT SUMMARY: Tamale Metropolitan Assembly

AN INTRODUCTION TO TAMALE METROPOLITAN ASSEMBLY'S CLIMATE RISKS

Future climate change projections by Tamale Metropolitan Assembly (MA) show that there is a risk of significantly higher temperatures for Tamale MA even at lower GHG concentration scenarios, by mid-century, by 2 °C, and varying from 1.5 up to 4°C, by the end of the century, depending on the emission scenario. Rainfall projections, in contrast, carry large uncertainties. There is a slightly greater chance of small increases, typically, around 5%. in annual average rainfall compared to the base years in the North, during the first half of this century. There is also a relatively significant chance of decreases in rainfall to a similar degree. By the end of the century, either an increase or decrease in mean annual rainfall appears possible, as the extremes suggest that a change in rainfall is possible of up to +/-15/20%. The latest CMIP6 climate change scenarios are considered to be much more sensitive and suggest a much greater probability for overall wetting in the Northern Region of Ghana with some scenarios suggesting up to a 20% increase in the mean annual rainfall by mid-century. This requires further research to verify.

Heavy rainfall events will become more likely in the future, especially under the high emission scenario, as maximum daily rainfall is expected to increase under all scenarios, but particularly under CMIP6 with the greatest increase, of around 20%, in maximum daily rainfall under SSP5-8.5. Increases in the number of very hot days and days with a high heat index could double for Tamale MA and this will have a very serious impact on human and livestock health as well as increased fire and water security risks.

Given the likely reduced impact on rainfall, particularly with the latest global climate models, it is likely that while still a concern, the risk from increasing severity of drought is reducing overall for Ghana.



How to reduce climate risks in the Tamale MA?

Reducing risk requires modifying current policies and programmes and implementing policies that explicitly consider climate variability and climate change.

The information below captures key climate change findings in Tamale MA:

Temperature: Greater likelihood of significant temperature increases in the North Climate zone and the Central zone compared to the other two identified climate zones for Ghana.

Anticipated future state	**Under RCP2.6** Tamale's temperatures are projected to increase and then stabilise after mid-century.	**Under RCP4.5** temperatures are expected to increase and then stabilise in the last two decades. By mid-century, Tamale is expected to experience a temperature increase of 1.2°C to 2.2°C. By the end of the century, a mid-point temperature increase of about 2.0°C is expected.	**Under RCP8.5** continuous temperature increase throughout the century is anticipated. By the end of the century, an average temperature rise of almost 4°C is expected. By mid-century, Tamale will see a temperature increase of about 1.7°C to 3.0°C.

Extreme heat: Extreme heat, characterised by days with a maximum temperature exceeding 30°C (known as SU30), is becoming increasingly frequent and intense in Ghana due to the impacts of climate change.

Current state	Tamale is a city in the Northern Region known for its hot and dry climate throughout the year.	The city's average temperature hovers around 29°C.	The hottest months are from **March to May.**
Anticipated future state	**Under RCP4.5** all models predict a significant rise in the number of days with temperatures exceeding 30°C by the 2050s.	**Under RCP4.5** the city is projected to see an increase in extreme heat days of 2%-24% by the 2050s.	**Under RCP8.5** some models, predict a slight decrease of 1% in the number of extreme heat days, but with low likelihood.
Conclusion	By 2100, the increase in extreme heat days is expected to range from 3% to 24% compared to the baseline.		

Rainfall: Expected rainfall in Ghana do not appear to be as significant as with other regions in Africa. There is, on average, a slightly greater chance of **small increases (around 5%)** in annual average rainfall compared to the base years, but with greater variability.

Anticipated future state	**Under RCP 4.5** and RCP 8.5 scenarios, there's a chance of significant rainfall increases, possibly up to 20% by the end of the century.	The latest global **CMIP6 models** indicate a higher likelihood of increased rainfall for Tamale and the northern climate region of Ghana.

Extreme rainfall:

Anticipated future state	**Maximum daily rainfall** is expected to increase under all scenarios, but particularly under **CMIP6** with the greatest increase in maximum daily rainfall under **SSP5-8.5**.	**Under SSP5-8.5**, the median projected increase in maximum daily rainfall is approximately 20% by 2050. In extreme cases, the increase could exceed 40%.	The likelihood of heavy rainfall events will increase in the future. This trend is especially pronounced under high emission scenarios.
Conclusion	The increased frequency of heavy rainfall events will heighten the risk of flooding in Tamale, but this could be combined with increased variability of rainfall and increased frequency of drought.		

THE CURRENT SOCIOECONOMIC LANDSCAPE OF TAMALE METROPOLITAN ASSEMBLY

Tamale MA is already experiencing significant challenges due to population growth, failing infrastructure, and climate change. With a rapidly growing population, limited water resources, and a fragile economy largely dependent on farming and trading, the city's vulnerability, exposure, and adaptive capacity to climate change are crucial factors to consider in building the resilience of the people of Tamale MA. Below is an outline of Tamale MA's climate vulnerabilities based on the current socioeconomic state.

ECONOMIC VULNERABILITY

Tamale's vulnerability to climate change is primarily due to its geographic location and socioeconomic factors. The city is situated in the Northern Region of Ghana within the Guinea Savannah belt, known for its semi-arid climate and seasonal rainfall patterns. The majority of the population depends on farming and trading for their livelihoods, rendering them particularly susceptible to the impacts of climate change on agriculture and food security. Furthermore, the Northern Region is one of Ghana's three poorest regions, exacerbating people's vulnerability to climate risks. The city's economy needs to be developed and diversified more to enable the necessary investments in climate adaptation measures.

PHYSICAL / ENVIRONMENTAL VULNERABILITY

Tamale MA is exposed to multiple climate change-related hazards, including harmattan winds during the dry season from November to January. These winds contribute to soil erosion and decreased fertility, negatively affecting agriculture. Limited water resources, with few seasonal streams, exacerbate the local water supply challenges, threatening farmers' and traders' livelihoods, as well as water security for households. The main water supply for Tamale MA is from the White Volta which is impacted by the activity of upstream users, poor catchment management, and sand mining. These combined to increase the vulnerability of Tamale MA to the potential impacts of climate change on water security.

Suggested action to reduce this vulnerability: Current initiatives such improvements to the water abstraction point and water treatment plant as well as the potential for establishing a Tamale Water Fund will help in reducing this vulnerability.

During the rainy season, flooding caused by heavy rainfall and water releases from the upstream Bagre dam poses a problem. This flooding damages infrastructure and degrades water quality due to sediment. Catchment degradation and sand mining in the region further heightens the vulnerability of Tamale communities. Climate change is anticipated to worsen these issues, with predictions of rising temperatures, unpredictable rainfall, and extended dry seasons. Flooding risk is increased in Tamale due to a lack of maintenance of the stormwater system, unplanned development and deforestation.

SOCIAL VULNERABILITY AND ADAPTIVE CAPACITY

The city's rapid population growth, at a rate of 3.5%, places significant pressure on the limited natural resources, such as water and arable land. As the population increases, farmers are being pushed into less favourable locations to continue production, including flood plains and along public drains where wastewater is used for irrigation. To prevent food security from deteriorating, there is a need to protect urban and peri-urban agricultural lands by mapping and preserving the high-potential production areas. Furthermore, the region's relative poverty and limited infrastructure hinder the development and implementation of effective adaptation strategies. Nevertheless, Tamale has a strong sense of community, and people tend to rely on traditional social support systems. However, the city needs to strengthen the capacity of the existing social systems and institutions, both governmental and NGOs, to facilitate collective action to address climate change.

The level of awareness about climate change risks and adaptation options also needs to be improved to enhance the adaptive capacity and enable traditional systems to support the communities.

STAKEHOLDER ENGAGEMENT

Climate change risk assessment should be a participatory process, sensitive to issues of gender, youth, and the possible presence of vulnerable groups (unemployed for example). To this end, all interested and affected parties (I&APs), including members of local communities, were involved in the risk assessment process and phases. During the stakeholder workshop, the common climate hazards specific to Tamale were validated by assessing stakeholders' perceptions of these hazards.

While identified climate hazards reflect important threats to stakeholders, they may not capture the full extent of climate hazards in the area, such as impact to water resources on the White Volta. The below lists highlights the top climate hazards identified by the stakeholders as the main hazards that pose climate-related risks to the livelihoods and lives of the communities under current conditions for Tamale.

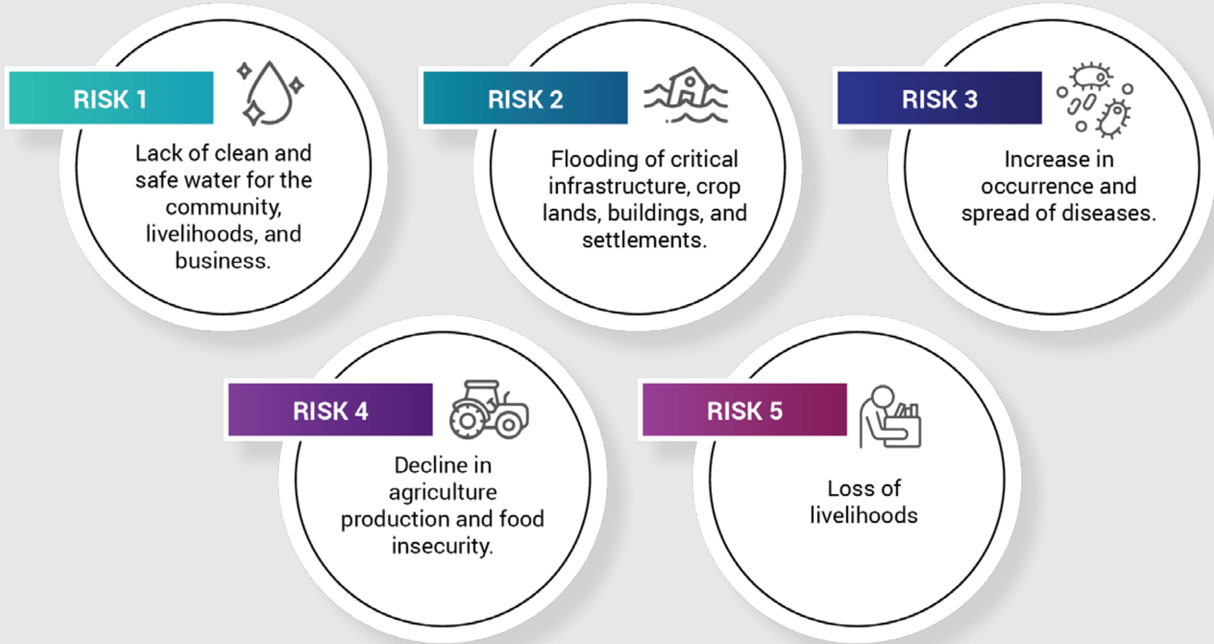


Figure 9: Stakeholder engagement session in Tamale

IMPACT CHAIN ANALYSIS FOR CRITICAL SYSTEMS AND ASSETS IN THE TAMALE METROPOLITAN ASSEMBLY

An impact chain diagram (or risk flow diagram) is an analytical tool that helps to better understand, systematise, and prioritise the factors that drive risk in a system.

The information provided in this section is an example of one of the Impact Chain Analysis that were completed for the Tamale MA .

IMPACT CHAIN ANALYSIS FOR RISK 2: FLOODING OF CRITICAL INFRASTRUCTURE, CROP LANDS, BUILDINGS, AND SETTLEMENTS

Flooding has become an annual phenomenon in the Tamale metropolis, affecting livelihoods and causing significant property damage and loss of lives. A combination of factors, including heavy rainfall, deforestation, and changes in land use, increase the risk of flooding. The impacts of fluvial flooding can be severe for communities and the natural environment. Flooding can cause damage to homes along the riverbanks and infrastructure and disrupt transportation and communication systems. For the environment, river flooding can cause erosion, and sedimentation, destroy habitats and displace wildlife.

Floods also have long-term impacts on the soil and water quality, affecting agriculture and livestock.

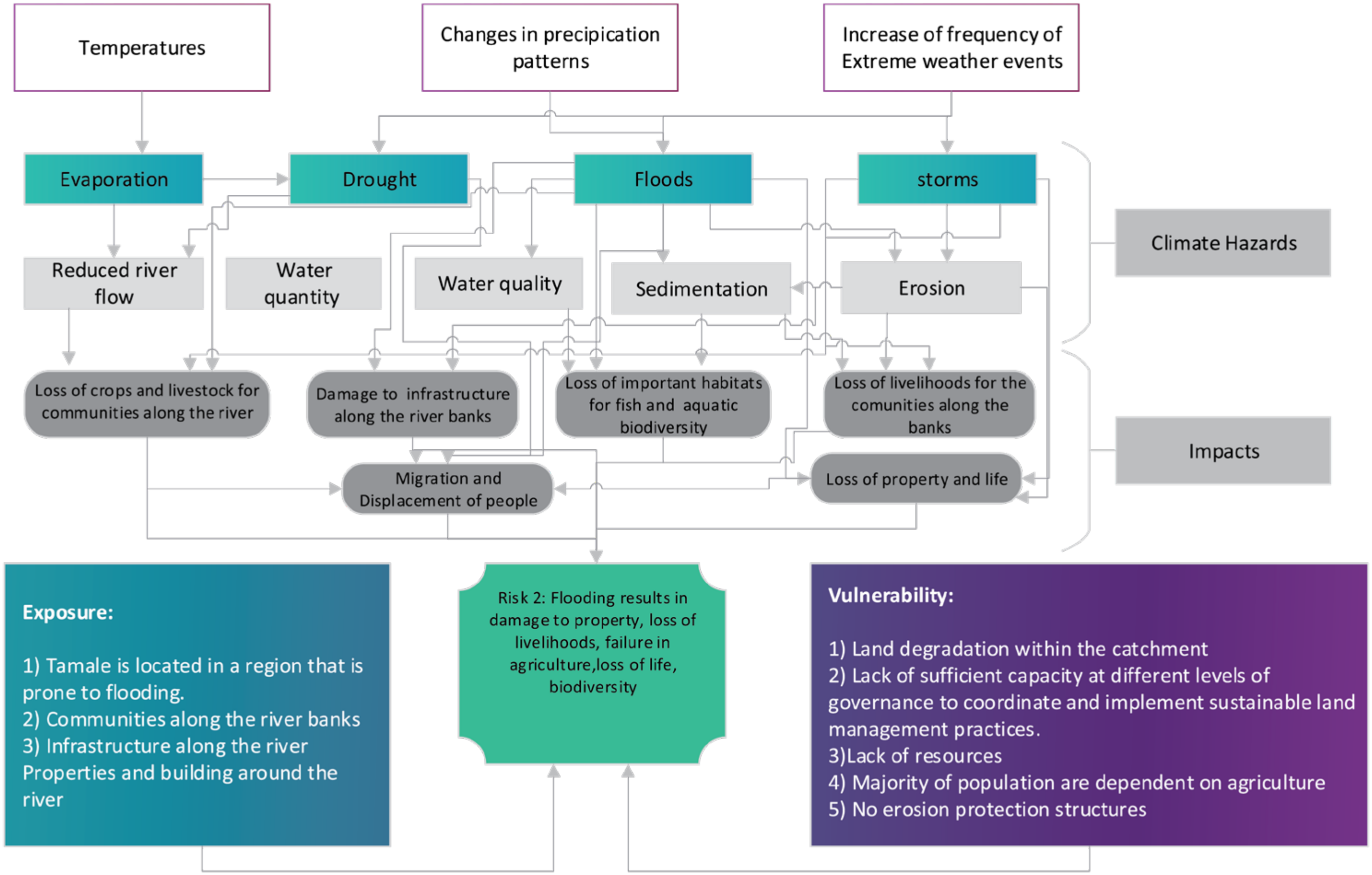
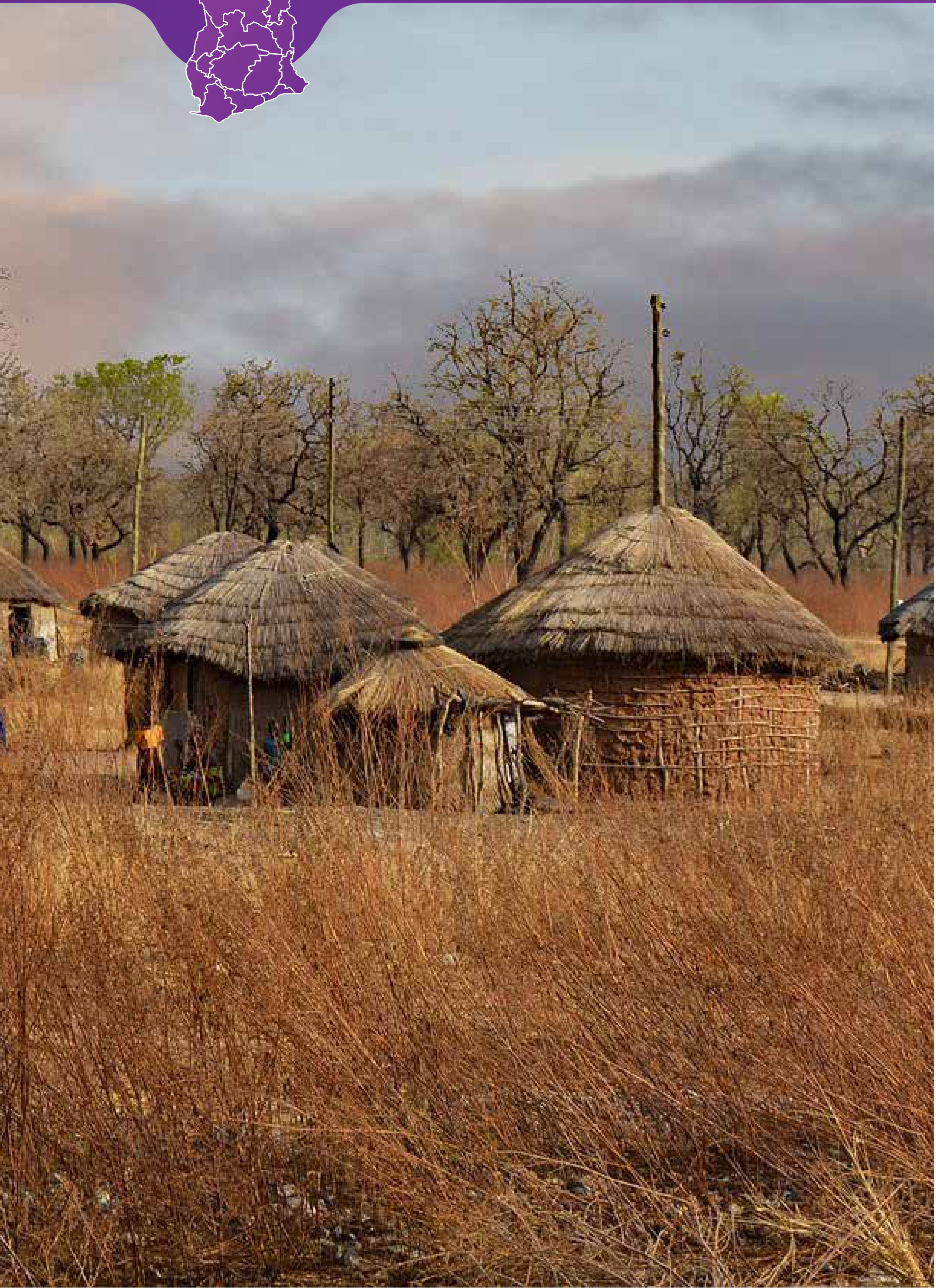


Figure 10: Flooding impact chain diagram



TAMALE METROPOLITAN ASSEMBLY'S CLIMATE RISK NARRATIVES

Impact storylines or climate risk narratives are descriptions of the future climate, environment, economic activities and society under changed climate for a given location or region and a specific climate scenario. As a communication tool, the climate scenario analysis forms the basis for developing the impact storylines, describing a range of future climates including various interactions between climate variables (e.g. temperature, wind, evapotranspiration etc.) and potential impacts.

The purpose of developing impact storylines is to identify the specific climate related risks, and the causal links to priority sectors, that should be evaluated.

Two climate risk narratives were developed for Tamale Metropolitan Assembly representing a 2053 future state, based on an initial assessment of the underlying social and economic conditions, the critical economic sectors and the anticipated climate related hazards, and after stakeholder engagements. The two scenarios are:

Warmer and Drier	**Hotter and Wetter**

It is important to note that the two narratives selected do not represent every scenario projected by the climate models but are considered representative of a possible range of future climate scenarios.

CLIMATE RISK NARRATIVE 1:
TAMALE METROPOLITAN ASSEMBLY CLIMATE 2053 - WARMER AND DRIER

Welcome to Tamale Metropolitan Assembly in Ghana. The year is 2050 and the changing climate has presented myriad challenges for the people of Tamale. With 10% less rain and average temperatures 2ºC warmer than in the past, droughts and sizzling heat waves are now part of the region's rhythm.

In this ever warming and dry city, health troubles like heatstroke and dehydration affect everyone, especially the elderly, outdoor workers, and children. Wealthier populations have opted for air conditioning, which only pushes electricity demand, adding more pressure on Tamale's already stretched energy network. Local water sources have run dry and crop yields are significantly less.

Decades ago, Tamale had a thriving farming industry. Sadly, those days are fading. For the past 30 years the dry spells have become longer and more frequent during the growing season, alternating with unpredicted intensive rainfall events, and food security has become a pressing issue due to declining crop yields and scarce water resources. The city's population has been growing by 3.5% annually, adding to the water security risk. As water shortages grip the area, people find it increasingly difficult to access clean drinking water. Traditionally, women and girls bear the responsibility of water collection and household chores. This burden now weighs heavier than ever as they travel great distances to secure water for their families. Unfortunately, their health suffers, and education and income generation opportunities are slipping away.

Due to the impacts of catchment degradation, evapotranspiration, pollution, and sand mining, water resources in Tamale are diminishing, making it challenging to access clean water. Additionally, rain is no longer sufficient to recharge aquifers for groundwater extraction. Nevertheless, Tamale remains committed to protecting its community and way of life by implementing climate and gender-sensitive plans to make businesses and communities less vulnerable to climate risks and help citizens adapt.

A particular focus for Tamale is on protecting critical water sources. This includes both the protection of local catchment area as well as addressing major concerns of sand mining and catchment degradation in the White Volta, which is the major water supply source for the city. Furthermore, efforts to minimise the impact of increasing temperatures on heat stress in the city requires not only the design of more energy efficient houses, that are better insulated against the heat, but also efforts to protect and rehabilitate green spaces within the city, particularly the tress indigenous to the area.

Tamale stands at a turning point, with people from all walks of life joining hands to tackle the challenges of climate change. With determination and unwavering spirit, the people of Tamale are paving the way for a sustainable, inclusive, and resilient future, including investing in nature.

by 2053

RCP 4.5

40%

likelihood

Climate Zone: **North**

2053 CLIMATE SCENARIO FOR RISK NARRATIVE 1

POTENTIAL IMPACTS AND ADAPTATION MEASURES - WARMER AND DRIER

CLIMATE SCENARIO

Average annual temperature will increase +4% (~1.5°C)

There is chance of decrease in mean annual rainfall: -8%

There is a slight chance for increase in dry spells and in number of hot days: +2% (~1 day)

There is a chance for increase in extreme rainfall events: +25%

POTENTIAL IMPACTS

Energy Security	Failure to meet energy demand during heatwaves and hot days for the growing population due to reduced hydropower potential.	**Forestry**	Increase in loss of forest resources due to drying and increased fire risk.
Water security	Failure to meet water demands for growing population, agriculture and other water intensive industries due to increasing variability in rainfall and drought and failure of Integrated Water Resources Management.	**Livelihoods**	Loss of livelihoods which includes: crop failures, loss of grazing land, and reduced access to fresh water, all leading to food insecurity andeconomic hardship for communities.
Agriculture Crops	Decline in agriculture production and increase in food insecurity due to drought, change in rainfall patterns and water availability.	**Migration**	High rates of migration due to drought, water scarcity and changes in livelihoods, particularly in rural areas.
Health	Increase in heat stress and stroke related diseases, vector and water borne diseases, respiratory problems and psychological challenges due to the displacement of communities.	**Infrastructure**	Economic and social disruptions due to critical infrastructural failure because of flooding and increased number of hot days.

NO- OR LOW-REGRET ADAPTATION MEASURES

Energy Sector
1) Resilient and green energy access in drought prone districts.
2) Capacity development and regulatory frameworks to support local renewable energy generation, including solar energy, to enhance resilience of remote, vulnerable communities.
3) Update energy sector design standards to incorporate climate risks and adaptation measures.

Water Sector
1) Water supply resilience through increased storage capacity and regional collaboration on Integrated Water Resources Management.
2) Improved access to secure water sources and water supply system.
3) Improved Integrated Water Resources Management and regional collaboration.
4) Climate adaptation alignment across water sector institutions and planning mechanisms to ensure integrated water resources management including with upstream countries.
5) Proactive risk informed asset management of infrastructure.
6) Reduce sand mining and catchment degradation.

Agriculture Sector
1) Promote climate resilient crops and agricultural practices.
2) Enhance capacity building and training in climate resilient agriculture practices.
3) Improve access to climate information and knowledge on climate change impacts.
4) Develop insurance schemes and risk mitigation tools for agriculture.
5) Diversification of crop types and drought resistant varieties.
6) Investment in irrigation systems and water storage facilities.

Health Sector
1) Strengthen health infrastructure and emergency preparedness.
2) Develop and implement early warning systems for disease outbreaks.
3) Enhance community health and engagement.
4) Promote environmental health and sustainability.
5) Integrate climate change into health policies and programs.
6) Adopt nature based solutions to help with 'cooling' of the city.

CLIMATE RISK NARRATIVE 2:
TAMALE METROPOLITAN ASSEMBLY 2053
- HOTTER AND WETTER

The year is 2050, and the vibrant city of Tamale, Ghana's fourth largest metropolis, faces a challenging future. Climate change has redefined the region, with sweltering heat and torrential rains becoming the new norm. In this era, temperatures have soared by an astonishing 2°C, and annual rainfall has surged by 10%. Gone are the days when a once-in-a-century rainfall was a rarity; now, such events are 3.6 times more likely to occur, escalating the risk of catastrophic floods.

The citizens of Tamale confront a new reality, as the harsh conditions not only threaten their homes but also contribute to the spread of deadly diseases. The climate change trifecta of rising temperatures, increased rainfall, and elevated humidity has created the perfect storm for vector and water-borne illnesses. Mosquitos and ticks, thriving in these conditions, carry diseases like malaria and dengue fever, while stagnant water becomes a breeding ground for infectious agents.

Toxic algal blooms, too, have become a common occurrence, further endangering public health. This is as a result, not only of the hotter and wetter conditions, but also the failure to manage pollution and in particular poor sanitation. Amidst this turmoil, women, who have long faced marginalisation in Tamale, bear the brunt of the consequences, their vulnerability intensified by the city's climate risks.

The situation is further complicated by Tamale's reliance on climate-sensitive industries, such as agriculture and trading, for its economic livelihood. High poverty levels leave communities with limited resources to adapt to these new and every changing conditions, making it crucial for the city to develop gender-sensitive strategies that prioritise women and other vulnerable groups.

Faced with crumbling infrastructure and eroding landscapes, increasing flood risks, and soaring health costs, the people of Tamale continue to persevere, striving to build a future that is both resilient and inclusive. They recognise that, while the challenges are great, there is still hope and opportunity for change as they work together to navigate the uncertain waters of climate change.

Addressing the increasing flood risks is a priority requiring significant investments in improved urban drainage systems and flood early warning. It has also been recognised how important it is to invest in nature-based solutions as these help by absorbing some of the flood peaks and also help with cooling the city. The hotter and wetter climate makes it even more important to invest in sustainable sanitation and improved public health systems including better protection and access to critical health facilities.

by 2053

RCP 8.5

25%

likelihood

Climate Zone: North

CLIMATE RISK NARRATIVE 2:
POTENTIAL IMPACTS AND ADAPTATION MEASURES - HOTTER AND WETTER

CLIMATE SCENARIO

Average annual temperature will increase +8% (~2.1°C)

There is chance of increase in mean annual rainfall: +22%

There is a chance of increase in number of hot days: +10% (~3 days)

There is chance of increase in extreme rainfall events: +120%

POTENTIAL IMPACTS

Energy Security	Failure to meet energy demand during heatwave and hot days for the growing population and reduced efficiency of thermal power.	**Forestry**	Increase in loss of forest resources, since wetter climate conditions could increase the prevalence of pests and diseases, which could harm trees.
Water security	Failure to meet water demands for growing population, agriculture and other water intensive industries due to increasing variability in rainfall and drought and failure of Integrated Water Resources Management.	**Livelihoods**	Loss of livelihoods leading to food insecurity and economic hardship for communities.
Agriculture Crops	Excessive rainfall and flooding could damage crops and reduce yields, particularly if the intensive rain occurs during sensitive stages of plant growth. The wetter climate conditions could also increase the prevalence of pests and diseases, which could harm the crops.	**Migration**	Increased rainfall, flooding and landslides could force people to migrate to safer areas.
Health	Increase in vector- and water-borne diseases due to flooding and psychological challenges due to the displacement of communities.	**Infrastructure**	Economic and social disruptions due to critical infrastructural failure because of flooding and increased number of hot days.

NO- OR LOW-REGRET ADAPTATION MEASURES

Energy Sector
1) Resilient and green energy access.
2) Capacity development and regulatory frameworks to support local renewable energy generation, including solar energy, to enhance resilience of remote, vulnerable communities.
3) Update energy sector design standards to incorporate climate risks and adaptation measures.

Water Sector
1) Water supply resilience, and flood risk reduction, through investing in improved catchment management and nature based solutions.
2) Enhancing service delivery, focusing on human rights alongside the responsibilities and obligations.
3) Improved and more equitably Integrated Water Resources Management.
4) Climate adaptation alignment across water sector institutions and planning mechanisms to ensure integrated water resources management at local level and with upstream countries.
5) Proactive risk informed asset management of infrastructure.
6) Reduce sand mining and catchment degradation.
7) Protect water infrastructure facilities against floods.

Agriculture Sector
1) Promote climate resilient crops and agricultural practices.
2) Enhance capacity building and training in climate resilient agriculture practices.
3) Improve access to climate information and knowledge on climate change impacts.
4) Develop insurance schemes and risk mitigation tools for agriculture.
5) Enhance the governance of climate sensitive resources.
6) Diversification of crop types and resistant to pests.
7) Investment in irrigation systems and storage facilities.

Health Sector
1) Strengthen health infrastructure and emergency preparedness.
2) Develop and implement early warning systems for disease outbreaks.
3) Enhance community health and engagement.
4) Promote environmental health and sustainability.
5) Integrate climate change into health policies and programs.
6) Adopt nature based solutions to help with 'cooling' of the city.

6 CLIMATE CHANGE RISK ASSESSMENT SUMMARY: Sekondi-Takoradi Metropolitan Assembly

AN INTRODUCTION TO SEKONDI-TAKORADI METROPOLITAN ASSEMBLY'S CLIMATE RISK

Future climate change projections show a risk of significantly higher temperatures for Sekondi-Takoradi MA even at lower GHG concentration scenarios, by mid-century, by 2 ºC, and varying from 1.5 up to 4ºC, by the end of the century, depending on the emission scenario. However, rainfall projections remain highly variable and uncertain. There is a roughly equal chance of small increases and decreases in annual average rainfall compared to the base years, typically around a 10% increase and decrease. The extremes suggest the possibility of change of up to 20% +/- in mean annual rainfall. Heavy rainfall events will become more likely in the future, especially under the high-emission scenario, as maximum daily rainfall is expected to increase under RCP 4.5 and RCP 8.5 scenarios for most of the models leading to potential increase in flooding.

How to reduce climate risks in the Sekondi-Takoradi MA?

Reducing risk requires modifying current policies and programs and implementing policies that explicitly consider climate variability and climate change.

The information below captures key climate change findings in Sekondi-Takoradi MA:

Temperature: There is a likelihood for a significant increase in temperature in the coastal climate zone in Ghana, although this will be less than the inland regions and in the north of Ghana.

Anticipated future state

Under RCP 2.6 there is an expected temperature increase of around 1.5 °C by the end of the century and between 3.5 to 4 °C **under RCP 8.5,** with **RCP 4.5** suggesting a mid-point of 2.0 °C increasing in temperature.	**RCP 8.5** represents a step change in temperature. The plume plots, particularly when incorporating **CMIP 6**, suggest a potential additional increase in temperature of 0.5 °C.

Conclusion

There is a risk of significantly higher temperatures for Sekondi-Takoradi MA even at lower GHG concentration scenarios.

Extreme heat:

Current state

Sekondi-Takoradi is a coastal city that currently enjoys temperatures of around 26.5°C.	The current situation is expected to change as extreme heat events are expected to be more frequent and intense over time and more flooding.	Currently, there's an average of only 1 day per year with temperatures exceeding 30°C.

Conclusion

Minor increases in the number of very hot days will lead to a substantial percentage increase. Despite this, the total number of very hot days might remain limited and can be easily managed.

Rainfall:

Anticipated future state

There is a chance of either a **10% increases or decreases** in annual rainfall compared to the base years.	Potential changes in annual rainfall could be up to +/- 20%.	**Under RCP 4.5 and RCP 8.5**, there's a chance of substantial rainfall increases, possibly ranging from 20% to 30%, but with low probability.

Extreme rainfall:

Anticipated future state

Maximum 1-day total rainfall is expected to increase under almost all future climate scenarios.	**The Upper Extreme (UE) model** projected an increase in max 1-day rain of about 78%.	Climate projections suggest a possibility of an increase in extreme rainfall especially under the high emission scenario.	Over the next decade, the maximum 1-day rainfall is projected to increase by 25% to 40%, in terms of the latest **CMIP6 projections.**

Conclusion

The increase in extreme rainfall projections will have a significant impact on the potential for increased flood risk in Sekondi-Takoradi, particularly if combined with increased sea-levels.

Extreme rainfall and sea level events, such as high tides, storm surges, strong winds, and changes in ocean currents, will become more frequent at most locations. This will threaten critical infrastructure such as roads, bridges, power stations, as well as cultural heritage sites.

Under RCP4.5, sea levels near Sekondi-Takoradi are expected to rise by approximately 0.4 meters by 2100 relative to historical sea levels, exacerbating the risk of coastal erosion and flooding. This is combined with hotter temperatures and potential for more intense rainfall.

THE CURRENT SOCIOECONOMIC LANDSCAPE OF SEKONDI-TAKORADI METROPOLITAN ASSEMBLY

Due to Sekondi-Takoradi MA's (STMA) location in the coastal western region of Ghana it is highly vulnerable and exposed to climate risks, including extreme weather events, sea level rise, and flooding. Various factors, including economic, social, human, and political resources, influence Sekondi-Takoradi MA's vulnerability to climate change. Below is an outline of Sekondi-Takoradi MA's climate vulnerabilities based on the current socioeconomic state.

ECONOMIC VULNERABILITY

Sekondi-Takoradi is an important centre of economic activity in Ghana, with a thriving port, oil and gas industries, and other sectors. The city has a strong social fabric, with community organisations, non-governmental organisations, and other groups working to support vulnerable communities and promote resilience to climate impacts. The STMA has systems established within the local government authority responsible for managing the city's infrastructure, services, and development. These systems and economic opportunities provide an opportunity for decision-making and action on climate change issues.

While commerce and industry-related activities are the major contributors to the economic development of STMA, agriculture and fisheries continue to play an essential role in the economy of the Metropolis, with agriculture providing both full-time and part-time employment for about 20% of the total population.

In addition to the commercial activities associated with the port, the Western Region of Ghana also contains several forts that are tourist attraction and also help in supporting the local economy. These facilities, however, are located along the coastline and are threatened by increased sea-level rise.

PHYSICAL / ENVIRONMENTAL VULNERABILITY

Sekondi-Takoradi is a relatively urbanised Metropolitan Area and because of development expansion, limited areas of natural vegetation remain. Much of the southern and coastal parts of the district are settled, while the northern area contains some agricultural areas. There are however a few critical natural areas including limited remaining forested areas such as the Monkey Hill Conservation Forest and also mangroves in the coastal lagoons and Whin River estuary. This all help in reducing the potential impacts of sea level risk as well as increasing flooding risk and also help in reducing heat impacts.

Encroachment represents a more acute threat to the existing natural forest and wetland areas than changing climate, however changing climate conditions could threaten these critical natural areas through shifting climatic conditions and increase wildfire risk (high heat and drought conditions), sea level rise and increased rainfall intensity and associated risk of flooding. Threats from pests and microbes also increase with climate change as new invasive species move into the area which can be particularly dangerous for forest stands already weakened by drought and wildfire. Urban tree cover has become a priority in recent years with numerous efforts to plant trees both in reserves and in the metropolitan area, for example the Sekondi-Takoradi Metropolitan Assembly plan to plant 10 000 fruit trees throughout the twin cities.

In addition to providing habitat for birds and other species, urban tree coverage can reduce heat island effects and mitigate potential human health risks from extreme heat as well as reducing flooding risks.

Wetlands and mangroves are also at risk from encroachment, fill, illegal mining, and pollution. Nationwide, mangrove coverage fell by nearly half between 2006 and 2014. Residents of Sekondi-Takoradi have reported awareness of depleting wetlands in recent years. These areas provide important ecosystem services including habitat, particularly as a nursey and spawning ground for fish species important for nutrition and livelihoods, water filtration, flood protection, and materials provision (e.g., construction materials and fuelwood including for the smoking of fish).

SOCIAL VULNERABILITY AND ADAPTIVE CAPACITY

The most vulnerable groups within STMA are women (elderly and orphans), children, people with disabilities and low-income individuals and households in both rural and urban settings. These groups are disproportionately affected by the loss of services when infrastructure fails due to the impacts of climate change and environmental shocks. Often, it is these groups that bear the brunt of damages caused by natural disasters, as they may lack the resources to rebuild their homes, communities, and livelihoods, and may be disproportionately affected by health and other impacts caused by disruptions to basic services. Households dependent on primary economic activities such as small-scale fishermen and subsistence agriculture are the most vulnerable to the potential impacts of climate change as they are more directly exposed and have limited resources.

Sekondi-Takoradi faces challenges in building its adaptive capacities and reducing vulnerability due to limited financial resources, inadequate infrastructure, and insufficient technical capacity and expertise. However, by building on the existing strengths, including economic diversity, and addressing the challenges, the city can improve its adaptive capacity and build a more sustainable and resilient future.

The level of awareness about climate change risks and adaptation options also needs to be improved in STMA to enhance the adaptive capacity and enable existing systems to support the communities.

STAKEHOLDER ENGAGEMENT

Through a multi-stakeholder workshop, the climate hazards most common to the Sekondi-Takoradi MA were identified and validated by engaging with stakeholders to determine climate related hazards through their perceptions, knowledge, and personal experiences.

In order to better understand the climate change related hazards, vulnerability and exposure for in the critical assets identified by the stakeholders, individual impact change where developed. These were developed based on information provided by the stakeholder for the following priority risks identified:

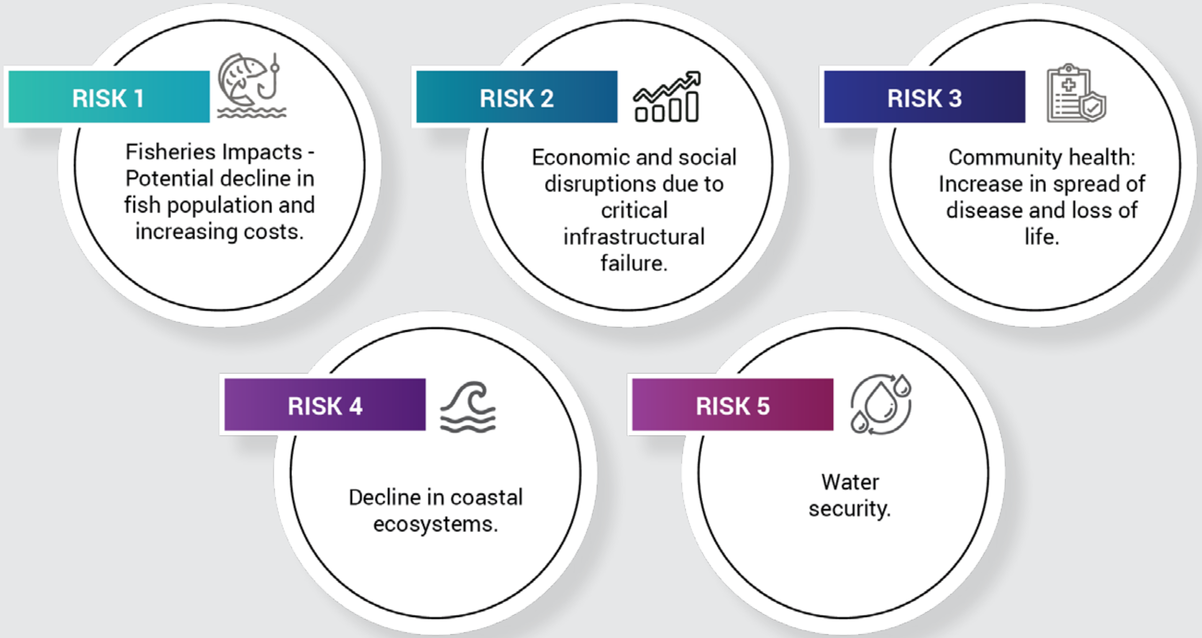


Figure 11: Stakeholder engagement sessions in Sekondi-Takoradi Assembly

IMPACT CHAIN ANALYSIS FOR CRITICAL SYSTEMS AND ASSETS IN THE SEKONDI-TAKORADI

An impact chain diagram (or risk flow diagram) is an analytical tool that helps to better understand, systematise, and prioritise the factors that drive risk in a system.

The information provided in this section is an example of one of the Impact Chain Analysis that were completed for the Sekondi-Takoradi MA .

IMPACT CHAIN ANALYSIS FOR RISK 2:
ECONOMIC AND SOCIAL DISRUPTIONS DUE TO CRITICAL INFRASTRUCTURAL FAILURE

Climate hazards such as sea-level rise, storm surges, flooding, and erosion threaten Sekondi-Takoradi's critical infrastructure, primarily in the form of inundation and destruction of energy, transport, and water infrastructure assets or a reduction in the efficiency of infrastructure services and operations. The critical infrastructure in Sekondi-Takoradi, such as power plants, gas pipelines, and roads, are located along the coastline rendering the infrastructure highly exposed to climate risks.

Human activities such as illegal mining, deforestation, and failure to comply with the existing regulations and policies further exacerbate the vulnerability of the factors contributing to economic and social disruptions due to critical infrastructural failure are shown in the figure.

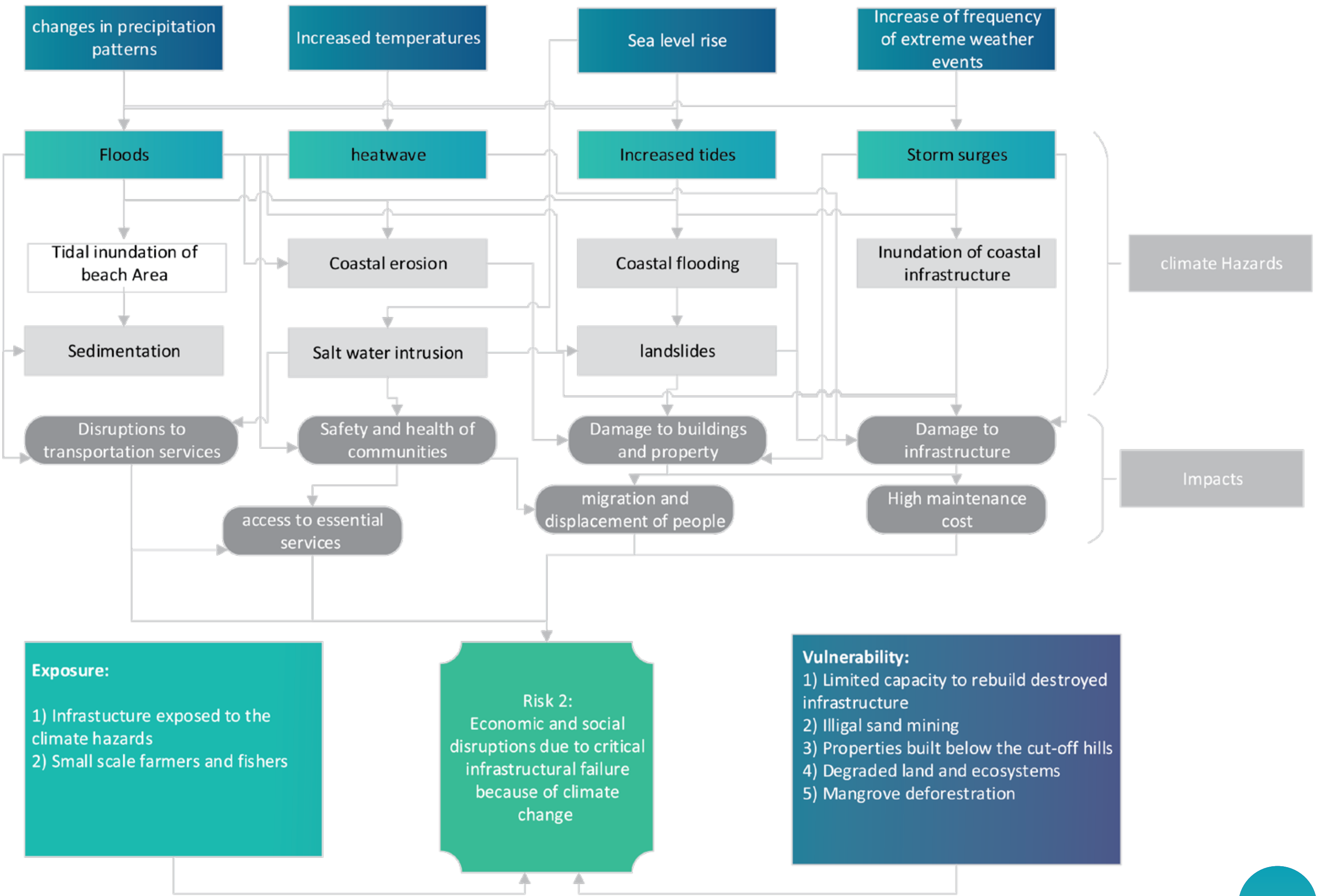


Figure 12: Critical infrastructure Impact Chain Diagram

SEKONDI-TAKORADI METROPOLITAN ASSEMBLY'S CLIMATE RISK NARRATIVES

The impact storylines or **climate risk narratives** are based on analogues of major climate events or disasters that have happened in the past in the area or nationally and, based on that, an analysis of what main factors gave rise to the vulnerability. This gives a credible basis to the projected impacts in the storylines.

The two climate risk narratives were developed for Sekondi-Takoradi Metropolitan Assembly representing a 2053 future state, based on an initial assessment of the underlying social and economic conditions, the critical economic sectors and the anticipated climate related hazards, and after stakeholder engagements. The two scenarios are:

Warmer and Drier	Hotter and Wetter

It is important to note that the two narratives selected do not represent every scenario projected by the climate models but are considered representative of a possible range of future climate scenarios.

CLIMATE RISK NARRATIVE 1:
SEKONDI-TAKORADI METROPOLITAN ASSEMBLY 2053 - WARMER AND DRIER

The residents of Sekondi-Takoradi Metropolitan Assembly, a coastal city in southern Ghana, reflect on life in the late 21st century, when early summer temperatures had only risen by a mere 1°C compared to the early 21st century. Back then, the effects of climate change were just beginning to manifest, and the city's inhabitants were yet to face the full extent of the challenges that lay ahead.

The year is now 2053, and Sekondi-Takoradi's people have endured decades of rapidly changing climate. Extreme climatic events like sea-level rise, flooding, and extreme heat have become more common, disrupting their daily lives. The once-thriving metropolis now grapples with escalating risks of infrastructural damage, loss of livelihoods, and community displacement and migration, with the most vulnerable groups, such as women and the elderly, bearing the brunt of these impacts.

Despite global efforts to mitigate climate impacts, temperatures in Sekondi-Takoradi have risen by around 1.5°C and mean annual rainfall has decreased by around 5%. The rising sea levels continue to exacerbate coastal impacts through coastal erosion, affecting various sectors such as fisheries, water resources, critical infrastructure, coastal ecosystems, health, and dry-land agriculture.

In a significantly dryer climate, water shortages have hit the local population hard, especially women and girls who shoulder the burden of fetching water for their families. It also impacts energy supply. Reduced rainfall and increased evapotranspiration, worsened by catchment degradation, sedimentation, and illegal sandmining, have led to even scarcer water resources. The decline in agricultural productivity in the region has compelled people to abandon their homes in search of better opportunities.

Health issues have also become more prevalent as warmer and drier conditions lead to a rise in heat-related illnesses like heatstroke and dehydration, particularly among vulnerable groups. While these are not as intense as inland, coastal communities grapple with mental health challenges due to displacement and loss of livelihoods caused by flooding, erosion, and landslides. Water scarcity has heightened the risk of water-borne diseases, especially in areas without access to essential services.

Sekondi-Takoradi's vulnerability to climate change is amplified by its proximity to the sea, reliance on coastal resources, and extensive coastal and environmental degradation, including the loss of coastal mangroves. In response, the city has embraced climate and gender-sensitive, nature-based solutions. These initiatives aim to reduce the sensitivity of key economic sectors to climate risk and boost communities' adaptive capacity while prioritising the needs of women and other vulnerable groups.

As the city looks ahead to 2100, Sekondi-Takoradi municipality remains steadfast in its commitment to protect and empower its people in the face of an uncertain future. The community is united in their determination to build resilience and ensure that everyone, regardless of age, gender, or socio-economic background, has the support and resources needed to thrive in a rapidly changing world.

by 2053

RCP 4.5

45%

likelihood

Climate Zone: **Coastal**

CLIMATE RISK NARRATIVE 1:
POTENTIAL IMPACTS AND ADAPTATION MEASURES - WARMER AND DRIER

CLIMATE SCENARIO

- **Average annual temperature will increase +4% (~1.3°C)**
- **There is chance of decrease in mean annual rainfall: -5%**
- **There is a chance for increase in dry spells and in number of hot days: +321% (~5 days)**
- **There is a chance for decrease in extreme rainfall events: -40%**
- **Increase in sea level rise: +0.4m**

POTENTIAL IMPACTS

Infrastructure	Economic and social disruptions due to critical infrastructural failure because of coastal erosion.	**Coastal ecosystems**	Loss of mangrove forests, wetlands, and coral reefs due to sea level rise erosion, inundation of coastal ecosystems, increasing temperature and acidification.
Water security	Failure to meet water demands for growing population, agriculture and other water intensive industries due to increasing variability in rainfall and drought and failure of Integrated Water Resources Management.	**Livelihoods**	Loss of livelihoods leading to food insecurity and economic hardship for communities.
Fisheries	Decline in fish population due increased temperature and changes in sea water's PH level and reduced flow to estuaries and rivers.	**Migration**	High rates of migration due to drought, water scarcity and changes in livelihoods.
Health	Increase in heat stress and stroke related diseases, vector and water borne diseases, respiratory problems and psychological challenges due to the displacement of communities.	**Energy Security**	Failure to meet energy demand during heatwaves and hot days due to reduced hydropower output and damage to energy infrastructure that is in close proximity to the sea due to storm surges and coastal erosion, causing power outages and disruptions in the energy supply chain.

NO- OR LOW-REGRET ADAPTATION MEASURES

Infrastructure Sector
1) Adaptive management practices.
2) Implement nature based solutions and green infrastructure as protection of the coastal infrastructure.
3) Develop and strengthen early warning systems.
4) Implement coastal protection solutions for roads, ports, power stations and historical sites.

Water Sector
1) Improved access to secure water sources and water supply system.
2) Water supply resilience through regional harvesting and storage solutions and improved Integrated Water Resources Management.
3) Climate adaptation alignment across water sector institutions and planning mechanisms to ensure integrated water resources and catchment management.
4) Proactive risk informed asset management of infrastructure.
5) Protection of water supply sources and infrastructure from sea level rise and coastal erosion.

Fisheries Sector
1) Build seawalls, breakwaters, and other physical structures can help protect fishery infrastructure from sea level rise, storm surges, and other extreme weather events.
2) Implement ecosystem based or nature based solutions, such as mangrove restoration.
3) Develop and strengthen early warning systems for coastal storms.

Health Sector
1) Strengthen health infrastructure and emergency preparedness.
2) Develop and implement early warning systems for disease outbreaks.
3) Enhance community health and engagement.
4) Promote environmental health and sustainability.
5) Integrate climate change into health policies and programs.
6) Adopt nature based solutions to help with 'cooling' of the city.

CLIMATE RISK NARRATIVE 2:
SEKONDI-TAKORADI METROPOLITAN ASSEMBLY 2053
- HOTTER AND WETTER

The year is 2053, the bustling coastal city of Sekondi-Takoradi in Ghana faces the grim reality of a changing climate. With average temperatures soaring by 2°C, frequent torrential downpours, and encroaching sea levels, the city's infrastructure and livelihoods are increasingly threatened.

At the heart of the city, we follow the story of Ama, a strong-willed fisherwoman who is struggling to maintain her livelihood amid a decline in fish production and loss of revenue from the fishery industry. As a single mother, Ama is disproportionately affected by the climate crisis. The burden of managing her household, providing for her children, and ensuring their safety in a rapidly changing environment weighs heavily upon her. As a result, her health is beginning to suffer leading to further challenges.

Ama's days are filled with long hours of fishing, followed by managing the household chores, preparing meals, and caring for her children. The increased frequency and intensity of storms make it harder for her to secure a stable income, while the loss of coastal ecosystems affects the availability of fish. The added stress of declining fish stocks exacerbates the gender inequality in her community, as women like Ama struggle to maintain their traditional roles in the face of environmental upheaval.

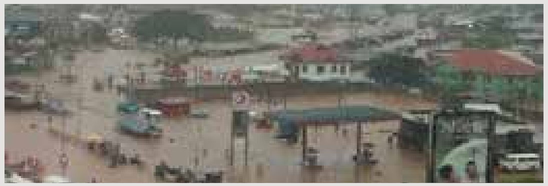
In addition to the economic challenges, Ama is increasingly concerned about her children's health as the risk of vector and water-borne diseases, such as malaria and dengue fever, increases due to warmer temperatures and the presence of stagnant water. As a mother, Ama bears the additional responsibility of caring for her sick children, further straining her already limited resources.

Meanwhile, Kofi, an engineer working at the nearby coastal power plant, faces the constant threat of storm surges that could damage critical infrastructure, disrupt energy supply chains, and displace communities. Kofi is part of a team tasked with finding innovative solutions to protect the city's vital installations and prevent widespread power outages and damage to critical infrastructure.

As climate risks escalate, the people of Sekondi-Takoradi find themselves uniting to confront the mounting challenges. At the forefront of this movement is Mayor Adwoa Mensah, an unwavering advocate for climate action and resilience. She inspires her community, rallying a diverse coalition of individuals, including Ama and Kofi to join forces with Mayor Mensah to form a community task force dedicated to tackling these pressing issues. They recognise the need for climate and gender-sensitive, nature-based solutions that prioritise the needs of women and other vulnerable groups and are determined to convince the government that protecting natural systems and providing support for vulnerable communities is essential. In their quest for a more resilient city, the task force members, led by Mayor Mensah, work closely with local authorities and international organisations to implement adaptive strategies. They advocate for the improvement of drainage systems, the development of sustainable infrastructure, and the implementation of land use policies that take climate risks into account. Under Mayor Mensah's guidance, the task force also champions women's empowerment and supports initiatives that help women like Ama and her family adapt to the challenges of climate change. Through their collaborative efforts, Mayor Mensah and the task force work tirelessly to lead Sekondi-Takoradi into a more climate-resilient future.

Through Mayor Mensah, Ama and Kofi's eyes, we witness the struggle and determination of a city to adapt to the new climate reality. Their story becomes a testament to the power of unity, innovation, and resilience in the face of overwhelming challenges while highlighting women's unique and disproportionate burdens amidst the climate crisis.

As Sekondi-Takoradi's future hangs in the balance, will the city be able to overcome the stormy days ahead, or will it succumb to the relentless forces of climate change? The fate of women like Ama rests on finding solutions that address all residents' needs as they navigate the uncharted waters of a changing world.



by 2053

RCP 8.5

30% likelihood

Climate Zone: **Coastal**

CLIMATE RISK NARRATIVE 2:

SEKONDI-TAKORADI METROPOLITAN ASSEMBLY 2053 - HOTTER AND WETTER

CLIMATE SCENARIO

Average annual temperature will increase +6% (~1.65°C)

There is chance of increase in mean annual rainfall: +8%

There is a chance for increase in number of hot days: +487% (~7 days)

There is chance of increase in extreme rainfall events: +101%

Increase in sea level rise: +0.4m

POTENTIAL IMPACTS

Infrastructure	Economic and social disruptions due to critical infrastructural failure because of coastal erosion and flooding	**Coastal ecosystems**	Loss of mangrove forests, wetlands, and coral reefs due to sea level rise coastal flooding and erosion, inundation of coastal ecosystems, increasing temperature and acidification
Water security	Failure to meet water demands for growing population, agriculture and other water intensive industries due to increasing variability in rainfall, damage to infrastructure, siltation and floods and failure of Integrated Water Resources Management	**Livelihoods**	Loss of livelihoods leading to food insecurity and economic hardship for communities in Sekondi-Takoradi
Fisheries	Decline in fish population due more frequent and severe flooding, causing damage to coastal infrastructure and coastal habitats and loss of the coastal ecosystems	**Migration**	High rates of migration due to sea level rise coastal flooding and erosion and changes of livelihoods
Health	Increase in heat stress and stroke related diseases, vector and water borne diseases, respiratory problems and psychological challenges due to the displacement of communities	**Energy Security**	Damage to energy infrastructure that is in close proximity to the sea due to storm surges, extreme rainfall, flooding and coastal erosion, causing power outages and disruptions in the energy supply chain.

NO- OR LOW-REGRET ADAPTATION

Infrastructure Sector
1) Adaptive management practices.
2) Implement nature based solutions and green infrastructure as measures for protection of the infrastructure.
3) Increase resilience of infrastructure by elevating structures, strengthening foundations, and adding barriers to protect the infrastructure against sea level rise, storm surge, and floods.
4) Implement redundant or backup systems, such as power generators and alternative routes for transportation.
5) Develop and strengthen the early warning systems.

Water Sector
1) Water supply resilience through investing in Nature Based Solutions to reduce both increasing flood risk and water security.
2) Enhancing service delivery, focusing on human rights alongside the responsibilities and obligations.
3) Improved and more equitably Integrated Water Resources Management.
4) Climate adaptation alignment across water sector institutions and planning mechanisms to ensure integrated water resources and catchment management.
5) Proactive risk informed asset management of infrastructure.
6) Protection of water supply infrastructure from, flooding, sea level rise, and coastal erosion.

Fisheries Sector
1) Build seawalls, breakwaters, and other physical structures can help protect fishery infrastructure from sea level rise, storm surges, and other extreme weather events.
2) Implement ecosystem based or nature based solutions, such as mangrove restoration.
3) Develop and strengthen the early warning systems for coastal storms.

Health Sector
1) Strengthen health infrastructure and emergency preparedness.
2) Develop and implement early warning systems for disease outbreaks.
3) Enhance community health and engagement.
4) Promote environmental health and sustainability.
5) Integrate climate change into health policies and programs.
6) Adopt nature based solutions to help with 'cooling' of the city.