Climate Change Risk Assessment for Tamale Metropolitan MMDA

Enhancing Multi-Sector Planning and Capacity for Effective Adaptation in Ghana

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Acronyms

AR	Assessment Report of the IPCC (AR5 published 2013-4; AR6 2021-2)
CCKP	Climate Change Knowledge Portal
CCRA	Climate Change Risk Assessment
CCV	Climate Change Vulnerability
CORDEX	Coordinated Regional Downscaling Experiment
CRIDF	Climate Resilient Infrastructure Development Facility
CMIP	Climate Model Intercomparison Project; CMIP5 was used extensively in the IPCC AR5 and CMIP6 in the AR6
EPA	Environmental Protection Agency
GCF	Green Climate Fund
GHG	Greenhouse Gas
GIS	Geographic Information System
GMet	Ghana Meteorological Agency
I&APs	Interested and Affected Parties
IPCC	Intergovernmental Panel on Climate Change
LE	Lower Extreme
MESTI	Ministry of Environment, Science, Technology and Innovation
MMDAs	Metropolitan, Municipal and District Assemblies
NAP	National Adaptation Plan
NDC	NDC Nationally Determined Contribution
RCP	Representative Concentration Pathways
SOM	Self-Organising Map, an artificial intelligence technique used to analysis the CMIP ensembles
SPEI	Standardised Precipitation and Evaporation Index
SSP	Shared Socioeconomic Pathways
UNFCCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environment Programme
UE	Upper Extreme
WGII	Working Group II of the IPCC

1 Introduction

1.1 Study Aims and Objectives

The Government of Ghana, through the Environmental Protection Agency (EPA), under the auspices of the Ministry of Environment, Science, Technology, and Innovation (MESTI), has successfully obtained a grant from the Green Climate Fund (GCF) for a three-year project to build capacity to advance National Adaptation Plan (NAP) process in Ghana. The United Nations Environment Programme (UNEP) is the Delivery Partner, supporting and overseeing the project implementation.

The project entitled "**Enhancing multi-sector planning and capacity for effective adaptation in Ghana"** is being implemented by a small project team headed by a National Coordinator. The NAP project seeks to support multi-sectoral, medium- to long-term adaptation planning and budgeting in Ghana and promote the integration of climate change adaptation issues into development planning processes and policies. Systems for developing and sharing climate risk and vulnerability information will be reinforced, and sustainable financing mechanisms for climate change adaptation initiatives are set to be developed. To support the objectives of the NAP program, Zutari consortium was appointed to be the technical service provider to support Producing Climate Change Scenarios and Risk Assessments for Ghana based on best available techniques and data that can be used as the basis for national and sub-national climate change adaptation planning.

Central to the preparation of effective climate change risk assessments (CCRAs) is the ability to understand the science behind the projections, manage the inherent uncertainty associated with them, analyse them using a variety of techniques and then communicate the impact risks clearly and concisely in an actionable format for decision makers and wider non-technical stakeholders and users.

This work is intended to support several national initiatives in Ghana, including the updated NAP. However, it must also be able to underpin the climate rationales necessary to secure international climate finance. This requires 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.

1.2 Document Purpose

The specific activities to be undertaken under this consultancy, supported by UNEP, are as follows:

- Task 1: Develop a methodology for producing national climate change scenarios.
- Task 2: Develop downscaled/area-based climate change projections for Ghana,
- Task 3 & 4: Develop national and sub-national level climate risk assessments for two MMDAs
- Task 5: Summary for Policy Makers, Training and Capacity Building.

This report is the deliverable from Task 3.4 and provides the CCRA for ***Tamale Metropolitan MMDA***, for up to ***four first order (biophysical) risk domains***, and ***up to three second order (economic sectors) risk domains***, developed in collaboration with national stakeholders in Ghana.

The methodology used to assess the climate change risk for Tamale Metropolitan MMDA follows the approach developed under Task 3.3 and it is summarized in Section 2 of this Report.

2 Background and Context

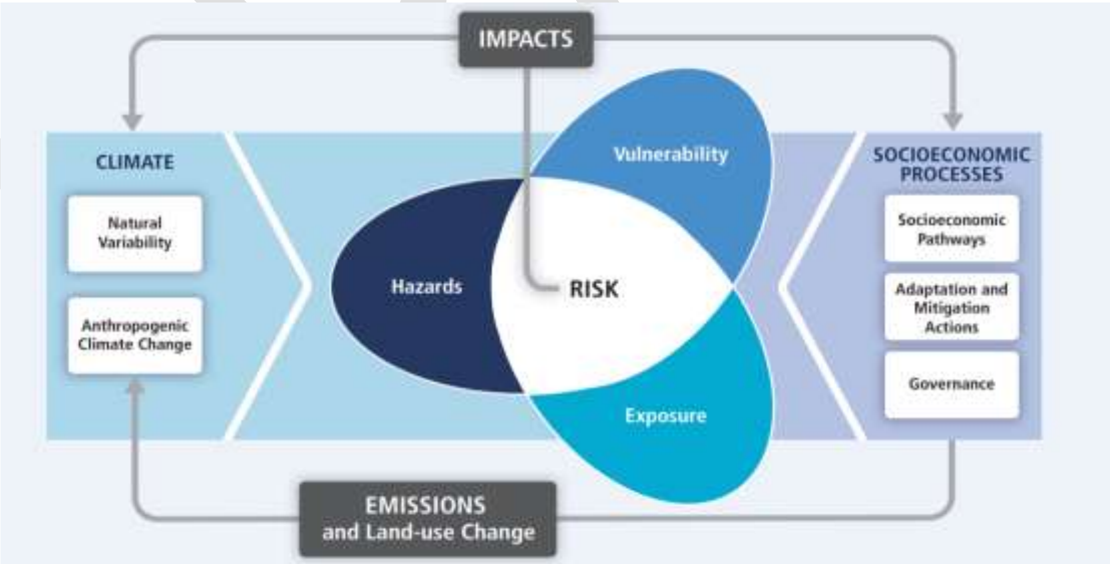
2.1 Defining Climate Change Risk and Vulnerability

According to the Intergovernmental Panel on Climate Change (IPCC), climate risk results from the interaction of hazard, exposure, and vulnerability. In the IPCC online glossary[1] the revised definition of **Risk** [used in the Special Report on Climate Change and Land and Special Report on the Ocean and Cryosphere in a Changing Climate – SRCCL (09/2019)] is the following, and is shown graphically in Figure 1 (from IPCC, 2014):

Climate Change Risk *is defined as the potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species.*

- *In the context of climate change impacts,* ***risks*** *result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards.* ***Hazards****,* ***exposure,*** *and* ***vulnerability*** *may each be subject to uncertainty in terms of* ***magnitude*** *and* ***likelihood of occurrence****, and each may change over time and space due to* ***socio-economic changes*** *and* ***human decision-making****.*
- *In the context of climate change responses, risks result from the potential for such responses not achieving the intended objective(s), or from potential trade-offs with, or negative side-effects on, other societal objectives, such as the Sustainable Development Goals. Risks can arise for example from uncertainty in implementation, effectiveness or outcomes of climate policy, climate-related investments, technology development or adoption, and system transitions.*

Source: IPCC online glossary (https://apps.ipcc.ch/glossary/)



Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability.

Source: IPCC's Fifth Assessment Report (WGII AR5) (Field, et al., 2014)

Figure 1 | Risk assessment framework for evaluating climate change risks (IPCC, 2015)

[1] https://apps.ipcc.ch/glossary/

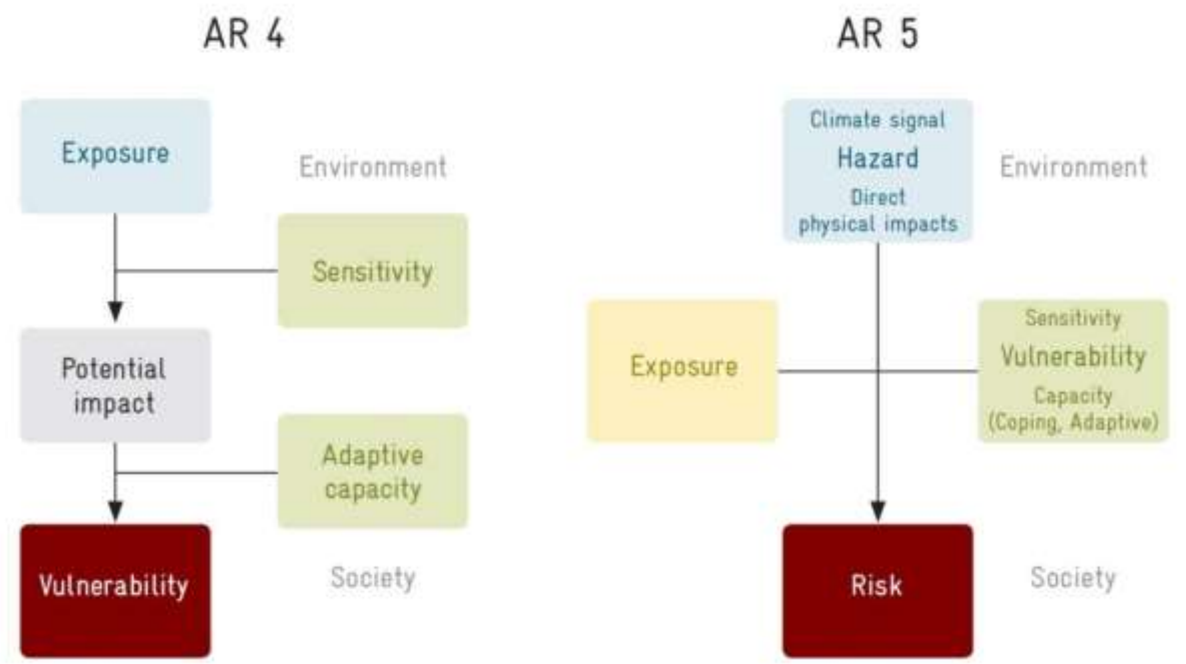
The following definitions of Hazard, Exposure, Sensitivity and Adaptive Capacity are used:

- ***Hazard*** *is the potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.*
- ***Exposure*** *entails the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.*
- ***Vulnerability*** *deals with the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including* ***sensitivity*** *or susceptibility to harm and lack of* ***capacity to cope and adapt****.*
- ***Sensitivity*** *refers to the degree to which a system is affected by, or responsive to a hazard. In other words, sensitivity captures the potential of a system to be impacted by a hazard. Sometimes sensitivity is determined by the criticality of the service that the system provides. For example, a community uses a road located close to the low-lying area of the coast as its main access to a major hospital. In the past, this road has been inundated during a storm event making access to the hospital difficult. Because the hospital provides such an essential service, this community should be considered more sensitive to coastal inundation event.*
- ***Adaptive Capacity*** *is the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.*

Source: IPCC online glossary (https://apps.ipcc.ch/glossary/)

In summary, a **climate risk** (e.g. drought damage in agriculture) results from interactions between **climate-related hazards** (e.g. the frequency and intensity of droughts) with **exposure** (e.g. agriculture land) and **vulnerability** (e.g. drought resistance of crops, presence or absence of irrigation) of natural and human systems.

It is important to note the change in the definitions used for determining vulnerability and risk, as discussed above, between the fourth (AR4) and fifth (AR5) assessment reports as shown in Figure 2.

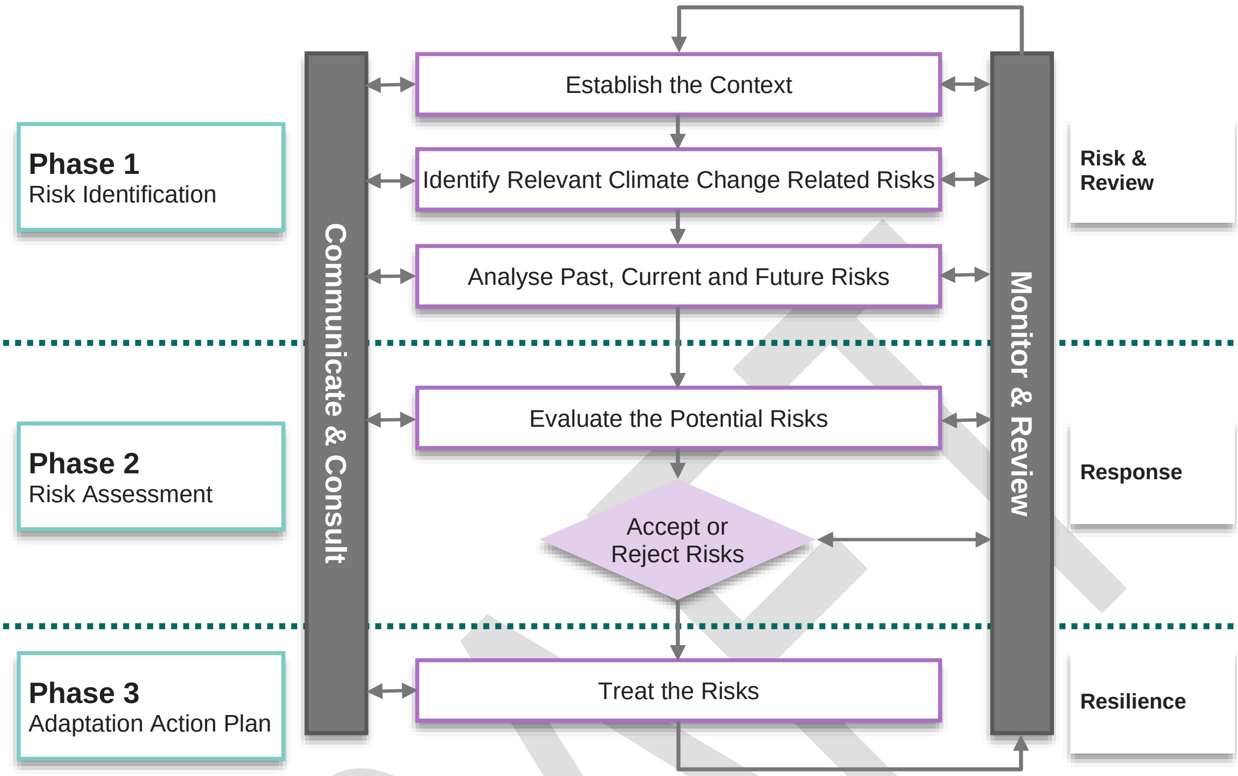


Source: (Zebisch, et al., 2021)

Figure 2 | Change in the conceptual approach to climate change risk and vulnerability assessments

2.2 Approach and Methodology

The approach undertaking in determine the Climate Change Risk and Vulnerability Assessment (CCRVA) for Tamale Metro follows the general risk assessment process as shown in Figure 3.



Source: Adapted from (Norman, et al., 2014)

Figure 3 | General overview of the risk assessment process

The steps covered under this assignment relate to Phase 1 (Risk Identification) and Phase 2 (Risk Assessment). The results of the risk assessment can then be used to inform adaptation planning.

Climate change risk assessment should be a participatory process, sensitive to issues of gender, youth and the possible presence of vulnerable groups (indigenous peoples, for example). To this end, the involvement and commitment in the assessment process of all interested and affected parties (I&APs), including members of local communities, should be integrated throughout the risk assessment process and phases. The level of engagement will vary depending on the aims and objectives of the study, the relevant scope and the process to be followed.

To ensure that the risk identification process is grounded in the local context and considers the specific needs and concerns of the communities within the 2 MMDAs, our team undertook a site mission from 28 November to 9 December. Specifically, the purpose of this trip was to engage stakeholders in Tamale MMDA, to collect data and anecdotal evidence to understand better the climate change risks, their impacts and the adaptive capacity of local communities. The basic approach to identifying the climate risk involved identifying the relevant key risk domains and then determining the relevant climate hazards and level of exposure and sensitivity and the potential for adaptive capacity pertinent to that specific risk domain or sub-sector.

Figure 4 summarises the specific steps, and timeline, followed for undertaking the Climate Change Risk and Vulnerability Assessment (CCRVA) for Tamale Metropolitan MMDA in Ghana.

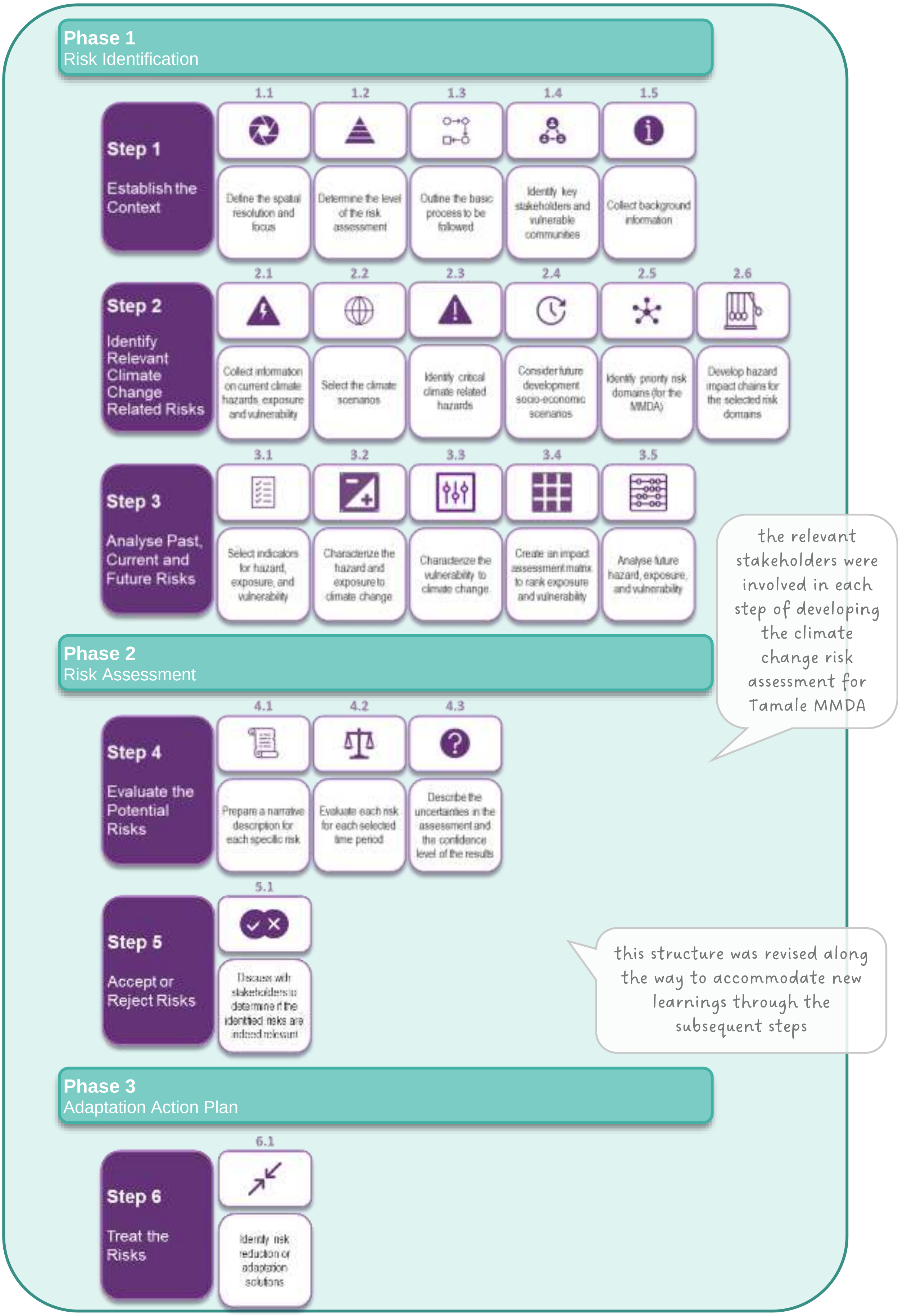


Figure 4 | Process followed during the Climate Change Risk and Vulnerability Assessment (CCRVA)

2.3 Climate Change Policy and Context

Ghana’s Environmental Protection Agency (EPA) is responsible for coordinating the country’s national climate change strategy. Strategy leadership is conducted in partnership with the Ministry of Environment, Science, Technology and Innovation (MESTI). Climate change is recognized as a cross-cutting issue in Ghana and policies and implementation include cross-sector efforts and coordination including the National Development Planning, Forestry, and Energy Commissions and the Ministries of food and Agriculture, Lands and Natural Resources, and Power.

In recent decades, Ghana has made significant progress in the field of climate change on putting in place suitable policy conditions to enable the country to increase its efforts on tangible climate actions:

- Ghana became a member of the United Nations Framework Convention on Climate Change (UNFCCC) after ratification in September 1995
- The Kyoto Protocol ratified in May 2003
- National Climate Change Policy (2015-2020)
- Climate Change Adaptation Strategy (2010-2020) published in 2012
- Low carbon development strategy published in 2015
- The Paris Agreement ratified in September 2016
- Nationally Determined Contributions (NDC) (2020-2030) updated under the Paris Agreement (2016)
- Ghana’s National Adaptation Plan Framework published in 2018, to provide an overall framework to guide the country in developing, coordinating, and implementing its NAP process.
- Fourth National Communication for the UNFCCC published in 2020

Despite the progress made in recent years, Ghana must continue to strengthen local capacities and planning instruments at the national and sub-national levels to address medium and long-term adaptation needs. In this context, the project “**Enhancing multi-sector planning and capacity for effective adaptation in Ghana”** led by the Environmental Protection Agency (EPA), on behalf of the Ministry of Science, Environment, Technology, and Innovation (MESTI).

Implementation of climate change activities has been relatively slow; however, the Ghanaian Government continues to make concerted efforts to integrate climate change objectives and priorities into sector-specific development plans in agriculture, transportation, and energy to mainstream climate change strategies. Ghana submitted its Fourth National Communication to the UNFCCC in 2020, its Second Biennial Update Report in 2018, and its Nationally Determined Contributions to the UNFCCC, updated under the Paris Agreement in 2016. These documents, in conjunction with its National Climate Change Adaptation Strategy (2015) provide the guidance and platform to integrate responsible environmental management with climate change adaptation strategies, in line with the country’s social and economic development targets. These strategies focus on the preparation and strengthening of institutional frameworks for improved management of climate change effects and to make available the necessary resources to support strategic adaptation activities and to advance low emission and climate resilient development (The World Bank Group, 2021).

This CCRA for Tamale MMDA was also informed by the following national and sub-national level risk assessments undertaken in the last decade, verifying the results based on the updated climate scenarios and the data was downscaled at the Tamale MMDA level where possible:

- CIG Ghana: Flood risk mapping and modelling report, 2022
- Development of a Business Case for the Tamale Water Fund, 2022
- Ghana: Roadmap for resilient infrastructure in a changing climate, 2022
- Climate Risk Profile: Ghana (The World Bank Group), 2021

- Climate Change Profile: Ghana (Ministry of Foreign Affairs of the Netherlands), 2019
- Ghana Disaster Risk Profile (UNDRR and CIMA), 2019
- Climate Risk Analysis for Identifying and Weighing Adaptation Strategies in Ghana's Agricultural Sector, 2019
- Climate Change Risk Profile – Ghana (Fact Sheet), 2017
- Ghana agricultural sector risk assessment, 2016
- Climate and health country profile- 2015 Ghana, 2015
- UNDP climate change country profiles: Ghana, 2012

2.4 National Level Risk and Vulnerability Assessment

As part of the Fourth National Communication (FNC) a national level climate vulnerability assessment was undertaken to determine the overall climate vulnerability for each of the 216 MMDAs.

The national level vulnerability assessment undertaken for the FNC was based on the original AR4 definition of climate change vulnerability (CCV) as (Exposure x Sensitivity) – Adaptive Capacity.

Data was collected at the MMDA level for a range of representative variables and used to determine a CCV score for each MMDA based on the relative ranking for each of the representative variables.

For this analysis exposure to climate change risk was determined based on the relative change in temperature and precipitation derived from an ensemble of 10 general circulation models downscaled using five regional climate models and for four sub-parameters including percentage change by: i) 2060 under RCP2.6; ii) 2060 under RCP 8.5; iii) 2080 under RCP 2.6; and iv) 2080 under RCP 8.5.

Sensitivity was determine based on the population employed in the agriculture sector, and adaptive capacity was based on the results from the District League Table (DLT) which incorporates measures of education, sanitation, rural water availability, health, security, and governance effectiveness to assess development across Ghana's 2016 districts and several other development related variables.

The final derived CCV for each district as well as the total population is shown in Figure 5.

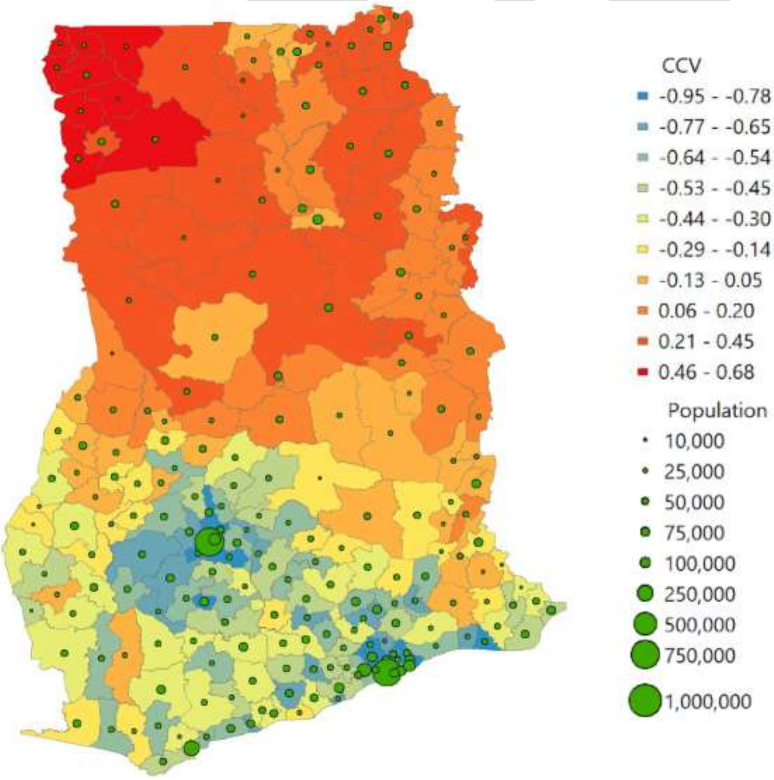


Figure 5 | Climate change vulnerability scores for Ghana's 216 districts

Source: (National Climate Change Report, 2020, 2020)

Based on the result for the 4NC, the Northern was the second most vulnerable regions, and Tamale is ranked number **64** (out of 2016 districts) in terms of climate change vulnerability.

2.5 Initial Assessment of Critical Climate Related Hazards

The preliminary critical climate related risks can be assessed using a tool like the ***ThinkHazard! Tool***[2].

Table 1 | Summary of critical climate related hazards for Tamale Metro and Sekondi Takoradi MMDAs.

District	Hazard										
	River flood	Urban Flood	Coastal Flood	Earthquake	Landslide	Tsunami	Volcano	Cyclones	Water Scarcity	Extreme Heat	Wildfire
Tamale	Medium	Very Low	N/A	Very Low	Very low	N/A	N/A	N/A	Low	High	High

Source: ThinkHazard! (Global Facility for Disaster Reduction and Recovery (GFDRR) , 2022)

The results shown in Table 1 show that the critical climate related hazards for Tamale are Extreme Heat (high), Wildfire (high) and River Flooding (medium). It is interesting to note that urban flooding was not consider high risk and yet, there is increasing evidence that an increase in urban flooding is a major are of concern for Tamale and most cities in Ghana. This is likely because Thinkhazard is based mainly on the result of the climate models, i.e. based on the relative change in critical climate variables and does not necessarily take into considerations the underlying vulnerability of each location.

2.6 Identification of Priority MMDAs and Risk Domains

To determine the specific priority risk domains considered for each of the MMDAs, it is necessary to consider the location and the specific economic activities in each area that would determine which would be the most appropriate risk domains to address as part of the CCRVA.

The criteria used in selecting first and second order risk domains is shown in Figure 6.

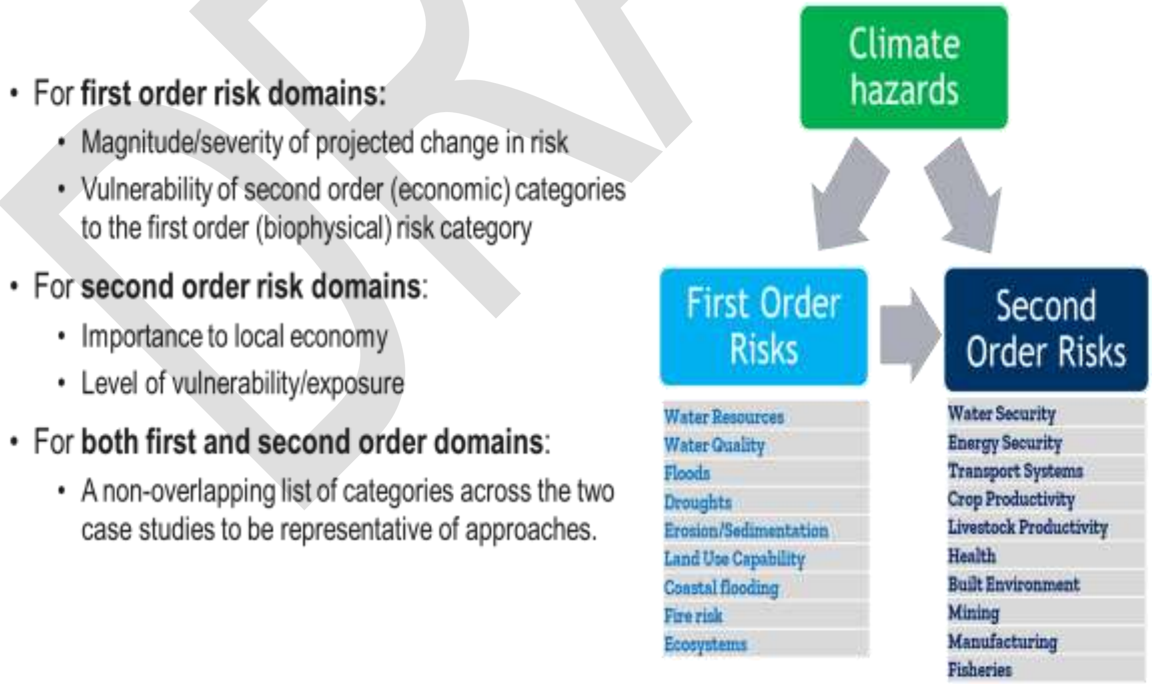


Figure 6 | Criteria in selecting first and second order risk domains

[2] https://thinkhazard.org/en/

A preliminary list of first and second order risk domains considered relevant for Tamale Metropolitan was developed based on a desk top study of available data (Table 2) and presented to the key stakeholders to determine the relative importance to the MMDA. This list was then discussed with the key stakeholders and the first and second order risk domains selection was finalised (Table 3).

Table 2 | Considerations for identifying critical first and second order risk domains for Tamale

Second order risk domains	First order risk domains
Tamale city and the region around it, are recognised as the "breadbasket" of Ghana; the potential climate change risks to agriculture and livestock farming will be a very important consideration in particular changes in **crop and livestock productivity**.	Important first order risks that support agriculture, water security and human health are **water resources** availability and quality, **flooding**, **droughts, fire risk** and **natural ecosystems**, particularly in terms of the potential for ecosystem-based adaptation. Hence these are proposed as the key first order risk domains for Tamale City. The impact of **flooding** is also a particular concern for Tamale Metro for multiple sectors.
Water security, in terms of reliability of supply, is a significant challenge for all cities in Ghana and is particularly sensitive to the impacts of climate change. This is likely to be of much greater concern in the dry land ecosystem region and so this is an important second order risk.	
The potential impact of heat on **human health** is another important second order risk domain. ThinkHazard classifies the extreme heat hazard in Tamale Metro as High.	

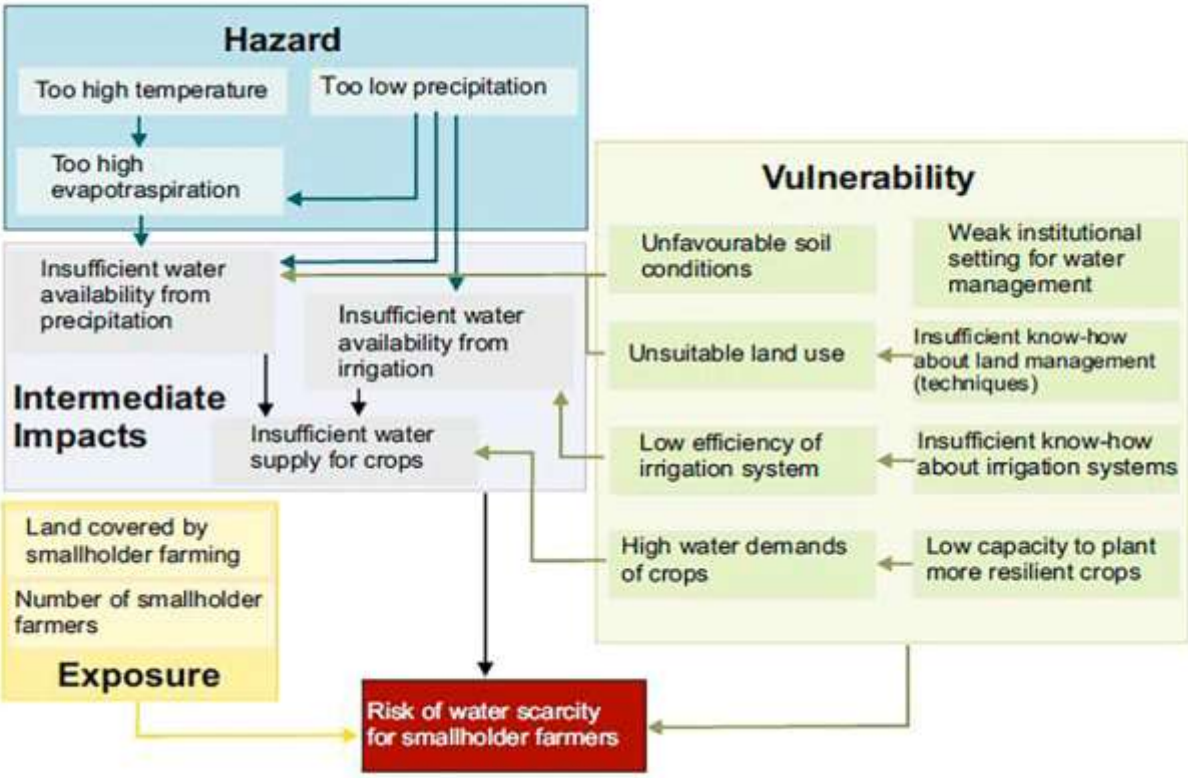
Table 3 | Identified Critical first and second order risk domains selected for Tamale

First Order Risk Domain	Second Order Risk Domain
Water Resources (Surface water)	Water Security (water and sanitation)
Fluvial Flooding	Agriculture – Crop Productivity
Droughts	Agriculture – Livestock Productivity
Fire Risk	Health (Heat Stress, Diseases, etc.)

2.7 Impact Chain Analysis

An impact chain diagram (or risk flow diagram) is an analytical tool that helps to better understand, systematize, and prioritize the factors that drive risk in a system. They are generally represented as a schematic that allows the key components of the conceptual framework presented in the previous section to be identified. This means that, for each impact that causes a risk, the components of the danger that cause it, the exposure that may be affected, and the vulnerability that relates the level of damage on the exposure to the magnitude of the risk are identified and represented. impact.

The impact chain (IC) method is a conceptual framework used to capture the most relevant risk factors contributing to a specific risk ((Menk, et al., 2022)). It structures the risk factors based on the IPCC AR5 risk definition, defining risk into the hazard, exposure, and vulnerability factors (IPCC, 2014; Huq et al, 2014). An example for water scarcity risk of small holder farers in shown in Figure 7.



Source: (Menk, et al., 2022)

Figure 7 | An example impact chain for water scarcity risk for small holder farmers

An example of a generic climate hazard impact chain for key risks in Gahan is shown in Figure 8. This includes a summary of all the relevant climate hazards and the likely first and second order risk domains. Some of the causal links are shown in the impact chain diagram, however this will need to be adapted for use in each specific MMDA based on the identified priority hazards and risk domains.

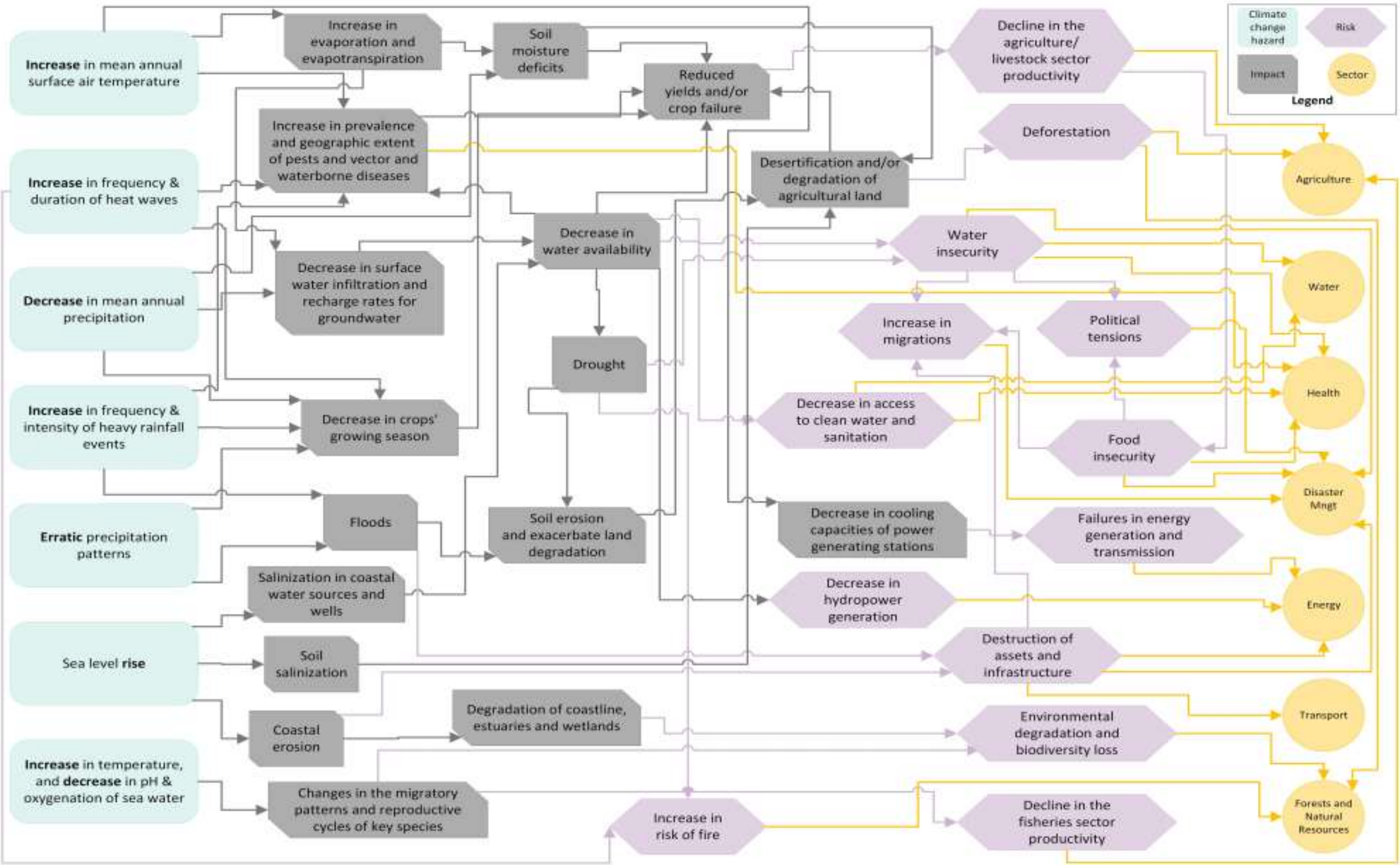


Figure 8 | Impact chain diagram for selected climate hazards and risk domains relevant for use at the MMDA level in Ghana

2.8 Stakeholder Engagement

Climate change risk assessment should be a participatory process, sensitive to issues of gender, youth, and the possible presence of vulnerable groups (indigenous peoples, for example). To this end, the involvement and commitment in the assessment process of all interested and affected parties (I&APs), including members of local communities, should be integrated throughout the risk assessment process and phases. The level of engagement varies depending on the aims and objectives of the study, the relevant scope, the available time, and the process to be followed.

In order to inform the development of the **climate risk assessment for Tamale Metro** the project team undertook a site mission from 28 November until 9 December. The purpose of this trip was to engage key stakeholders in Tamale and a national level with the purpose of:

a. Introduce the NAP (National Adaptation Plan) project and process.
b. Provide stakeholders with an overview of climate change, the potential impacts and various aspects that will be evaluated in the climate change risk assessment.
c. Present the outcomes of the down-scaled temperature and precipitation scenarios.
d. Validate the findings of the climate change projections.
e. To identify critical climate related risks and collect data and anecdotal evidence to better understand these risks, their impacts, and adaptive capacity of local communities.

Following the engagement with key stakeholders in Tamale, as second 2-days workshop was held in Accra with national level stakeholders and government representative with the purpose of:

a. Presenting the outcomes of the down-scaled temperature and precipitation scenarios, including the evidence and data provided by the MMDA's on the priority risk domains.
b. Capture additional information on the critical climate related risks and adaptive capacity.
c. Provide training on the approach to undertaking a local level climate risk assessment.

The sessions in Tamale were coordinated through the local EPA offices. A joint stakeholder session was held on 29 November including various departments of the Assembly together with public and private sector stakeholders. In total 51 participants (excluding the project team) attended (Figure 9).

Figure 9 | Stakeholder engagement session in Tamale

Using the climate projections and other studies relating to the potential impact of climate change on the critical risk domains in Tamale, together with the key findings from the interactive sessions and additional data collection, the project team was able to proceed with the local level risk assessments.

The process followed and the results of the assessment for Tamale are presented in later sections.

3 Overview of Tamale Metropolitan District

3.1 Location and Climate

Tamale Metropolitan District is located in the Northern Region of Ghana, at an elevation of approximately 180 metres above sea level and has an area of about 650 km^2 (PHC, 2010). Tamale Metropolitan District shares boundaries with the Sagnarigu District to the North-West, Mion District to the East, East Gonja to the South and Central Gonja to the Southwest. The location of Tamale Metropolitan District is shown in Figure 10.

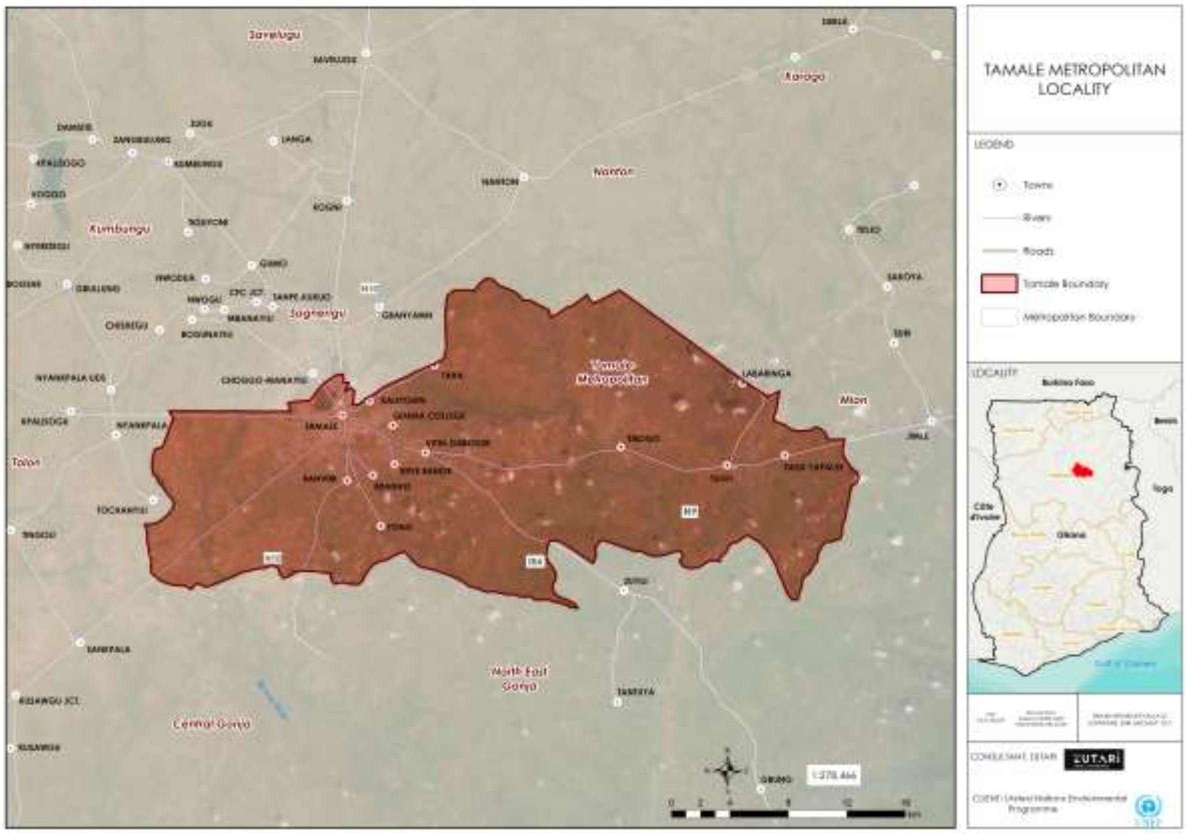
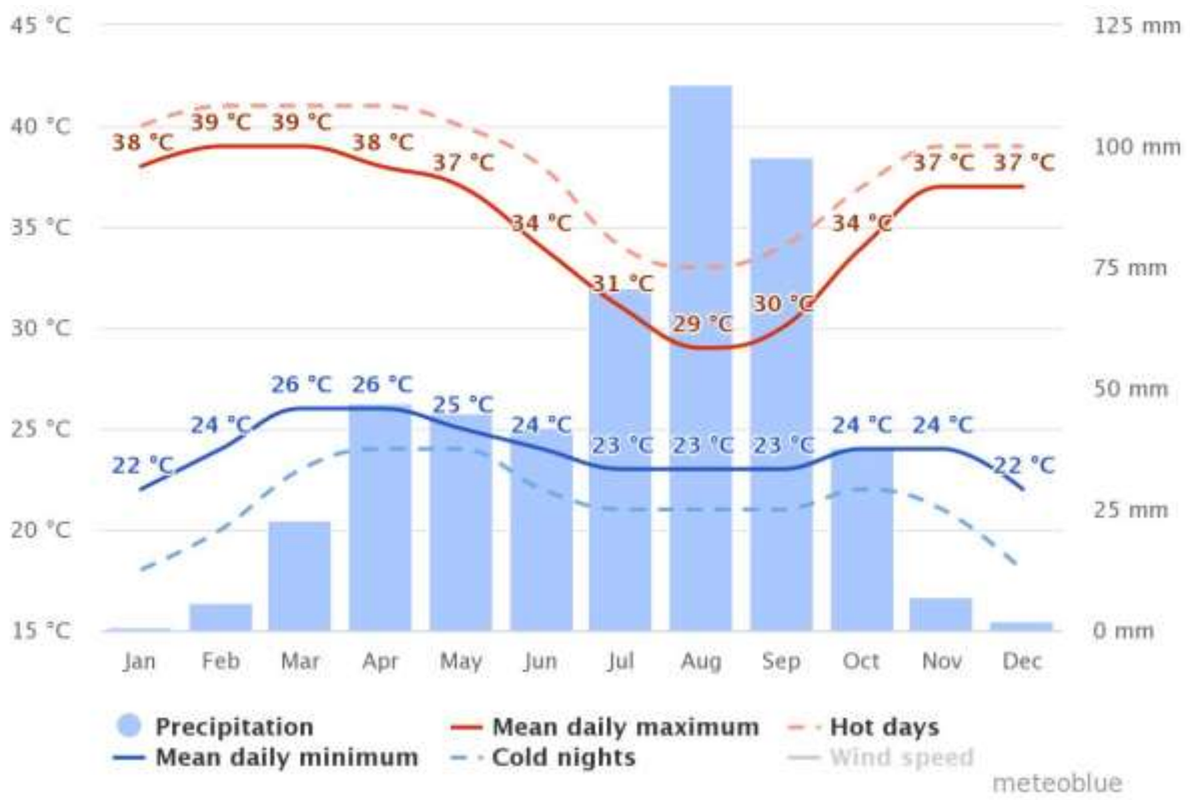


Figure 10 | Location of Tamale Metropolitan District

According to the Köppen-Geiger climate classification, Tamale has a tropical savanna climate, Aw, with one rainy season from April to September or October (with a peak in July and August). The dry season is influenced by the very dry north-easterly winds (Harmattan) that blow across the West African subregion from the Sahara Desert between about October and February each year. This period of Harmattan is characterised by dry, and dusty conditions as well as wide fluctuations in the day and night air temperatures. The effect of dust and sand stirred by the wind is known as Harmattan haze (He, Breuning-Madsen, & Awadzi, 2007).

The average annual temperature in Tamale is around 28 °C. The mean daytime temperatures range from 28 °C (December and mid-April) to 43 °C (March, early April) degrees Celsius, and the mean night-time temperatures range from 18 °C (December) to 25 °C (February, March) degrees Celsius. The mean annual rainfall is around 1100 mm within 95 days of rainfall in the form of tropical showers (intense rainfall). The climate diagram for the average temperature and precipitation for Tamale shown in Figure 11, is based on 30 years of hourly weather model simulations (Source: Meteoblue.com).



Source: (www.meteoblue.com, 2022)

Figure 11 | Average temperatures and precipitation, in Tamale Metropolitan MMDA

3.2 Natural Environment

3.2.1 Geology, Geomorphology and Soils

The Tamale Metropolitan area is underlain by sandstone, mudstone, and shale, which over time, have been weathered to different degrees. The main soil types include sand, clay, and laterite ochrosols. These soil types are inadequately protected resulting in serious erosion during the rains. The area is generally flat with gentle undulating low relief and altitude ranging from 400 to 800 ft. above sea level.

The area has sandstone, gravel, mudstone, and shale weathered into different soil grades as its major soil types. Owing to seasonal erosion, soil types resulting from this phenomenon are sand, clay, and laterite ochrosols. The availability of the various soil types has aided rapid real estate development such as sea sand, gravel, and clay being used by developers especially in urban areas. In the rural parts, the soil type is sandy loam, and it is suitable for growing crops such as millet, maize, guinea corn, groundnuts, yam, and beans.

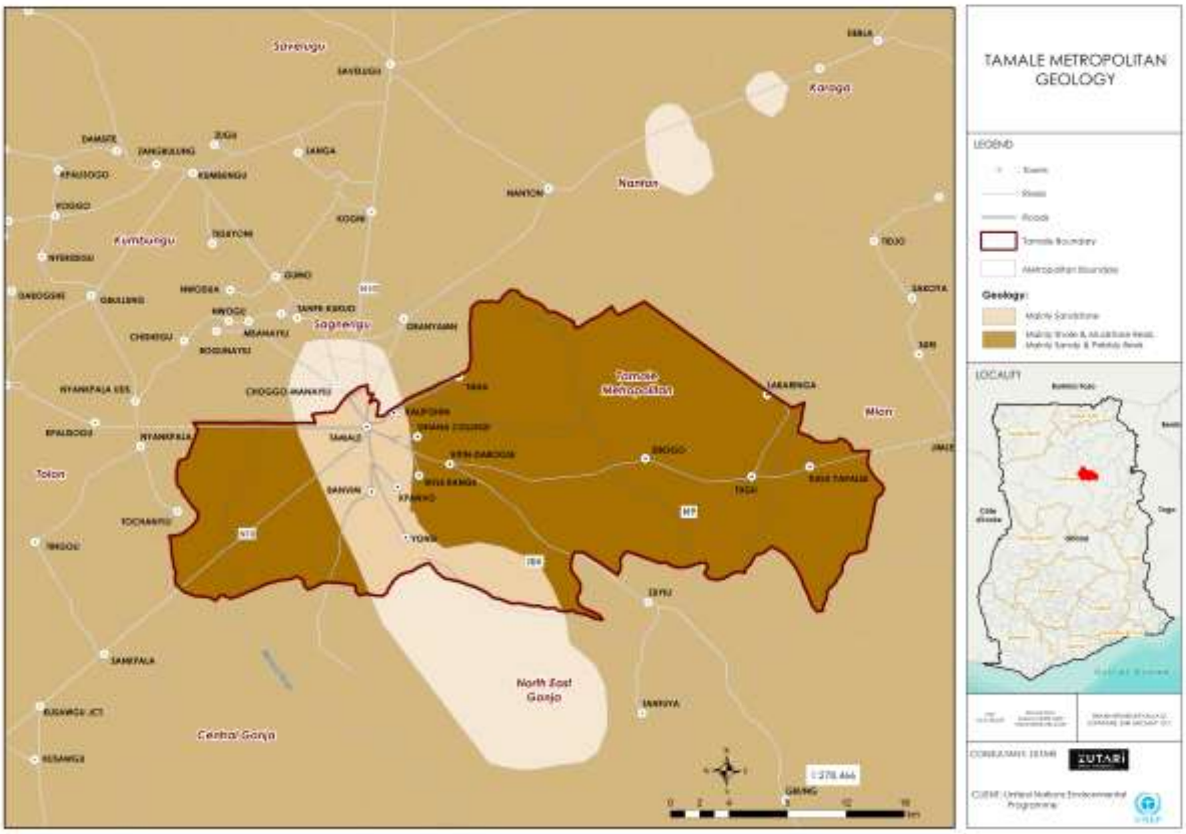


Figure 12 | Geology of Tamale Metropolitan District

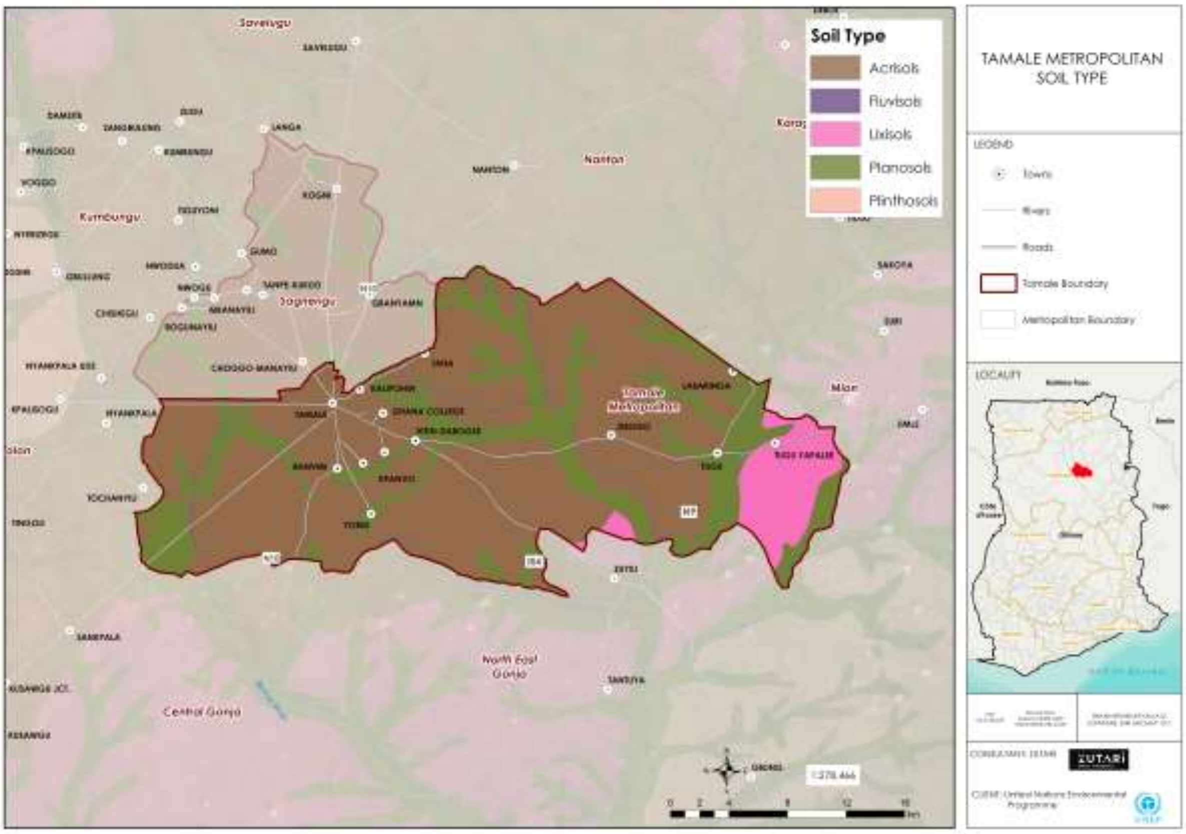


Figure 13 | Soil types in Tamale Metropolitan District

3.2.2 Water Resources

The Tamale Metro is poorly endowed with water bodies. The only natural water systems are a few seasonal streams which dry up during the dry season. The Pasam, Dirm-Nyogni and Kwaha streams, in the Kalurakun river basin, have their headwaters in Tamale. Some artificial dams and dugouts have been constructed either by communities or Non-Governmental Organizations to serve as water sources for animals as well as for domestic purposes. SAL Consult Ltd, 2022).

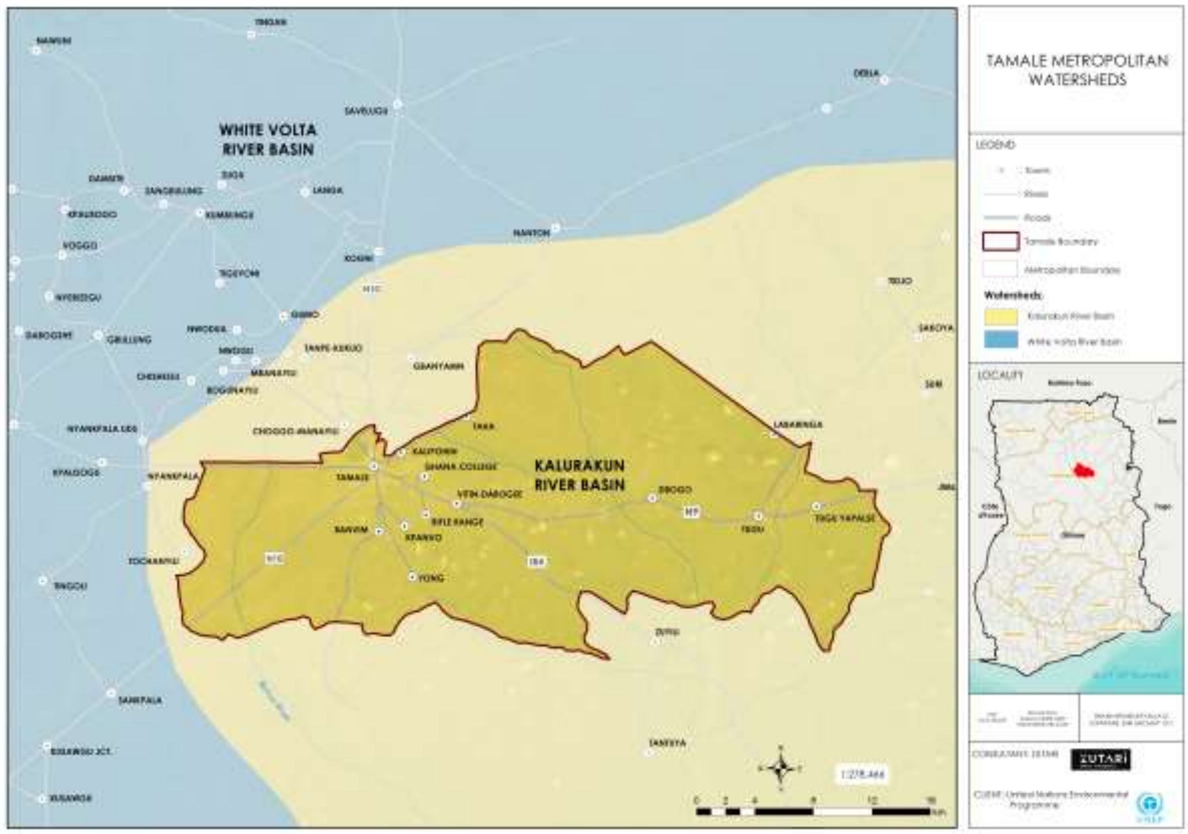


Figure 14 | Watersheds in Tamale Metropolitan District

3.2.3 Ecosystems and Biodiversity

The Tamale Metro lies within the Guinea Savanna belt of Northern Ghana. The vegetation of the area is characterised by tall grasses interspersed with drought-resistant tree species such as the Dawadawa, Nim, Acacia, Mahogany, and Baobab (Fuseini, 2016). There are two main forest reserves located in the central part of the Metropolis namely the Nyohini and Agric Forest Reserves. However, these are being encroached upon by private developers with other portions used for open defecation. There are naturally grown tall grasses during the rainy season that are woven into a mat called "Zanamat", (a type of local mat for roofing and for fencing) (SAL Consult Ltd, 2022).

The shea and dawadawa are the most important tree species in the area. The shea tree forms the anchor of women's livelihoods either through gathering and sale of the nuts or agroprocessing by which shea-butter is extracted for cooking and for use in the cosmetic industry. Urbanisation pressures and associated environmental degradation have caused women in the TAMA a partial loss of their livelihoods as much bush from which they gather the nuts has disappeared. The option for them is to engage in nut processing and other agro-processing activities (e.g. rice, groundnuts). The dawadawa tree has two basic important uses, namely as a local condiment and as symbol of authority in the chieftaincy institution of the Dagbong Kingdom (Fuseini, 2016).

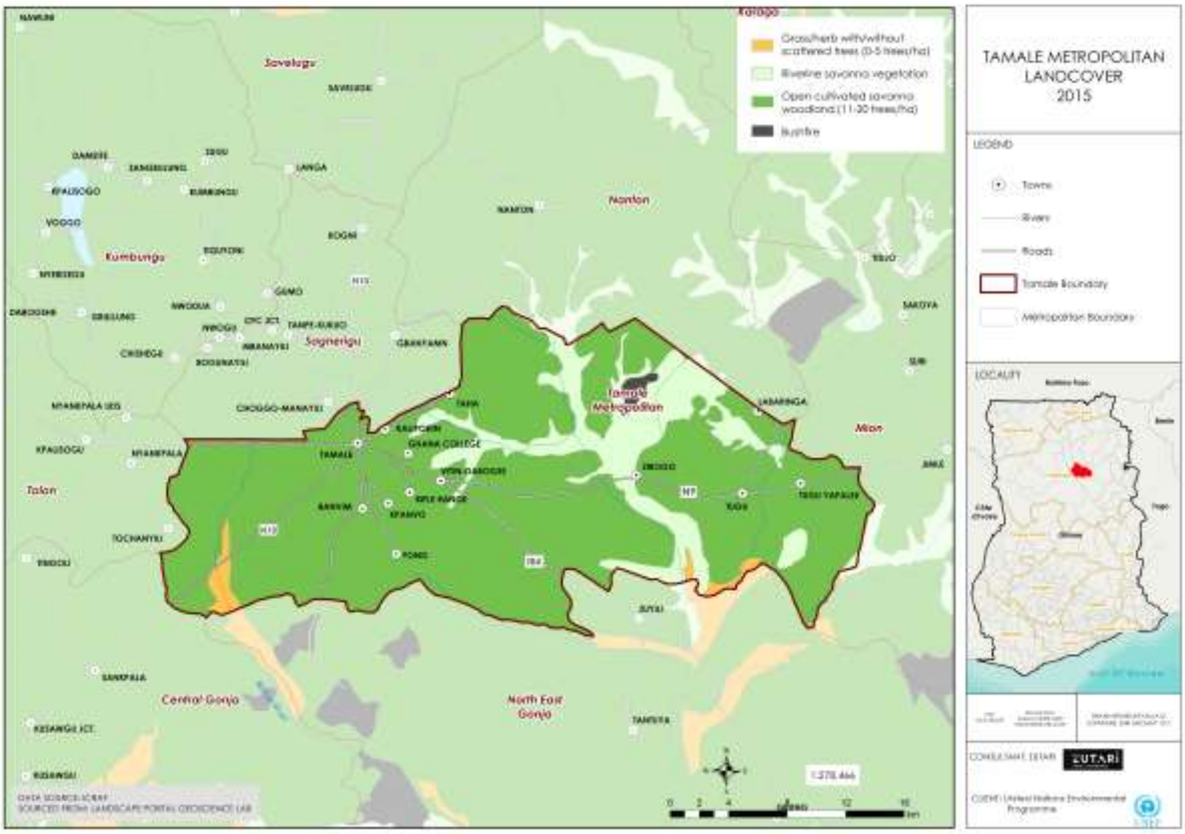
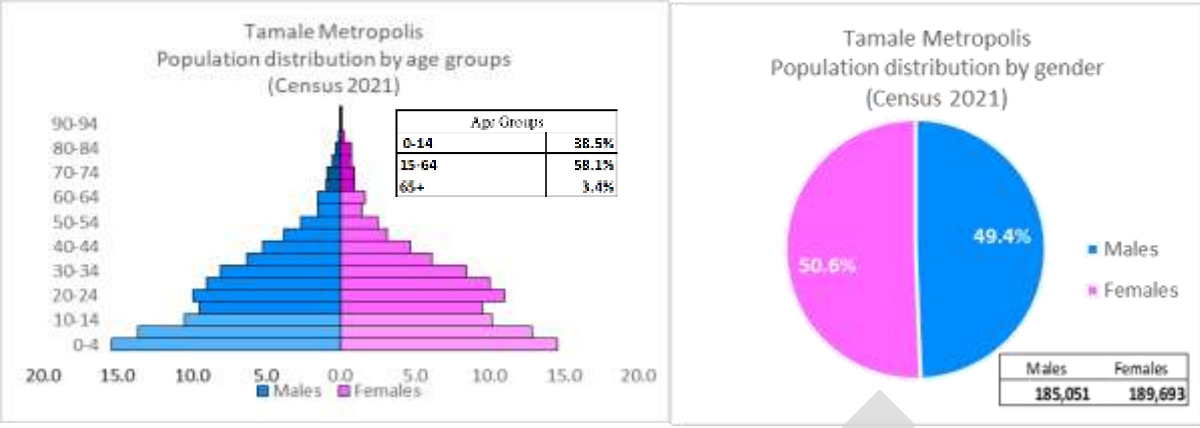


Figure 15 | Land cover in Tamale Metropolitan District

3.3 Demographics

According to the 2021 Ghana Population and Housing Census, the Tamale Metropolis has a total population of around 374,744 comprising 185,051 (49.4%) males and 189,693 (50.6%) females (Figure 16). This represents 16.2% and 1.2% of the regional and national population respectively. The population density is 825 per km^2 with a total of 89,011 households and a household size of 4.1 persons per household which is lower than the regional average of 5.2 persons per household.

The district has a very youthful population with about 96% below 60 (Figure 16). The age structure of the population of a high fertility country such as Ghana is basically shaped by the effect of mortality. As it is the case with the Metropolis the structure of the population indicates a broad base that gradually tapers off with increasing age due to death. The youthfulness of the population implies high potential for human resource development to enhance social, economic, and political development. On the other hand, the proportion of the elderly at 4.1% is lower than the regional and national averages of 4.5 percent and 5.3 percent respectively, an indication of a comparably low life expectancy. In this regard pragmatic efforts would have to be made to make primary health care delivery more accessible and affordable to the aged. (2020 Composite Budget - Tamale Metropolitan)



Source: Census 2021

Figure 16 | Population distribution by age and gender in Tamale Metropolitan District

The results from the 2021 Census report also show that the Metropolis is the only district in the Region with 100% urban population, while in the previous census (2010), the urban proportion of the total population was 80.8 percent, and the rural population was 19.2 percent. The latest Census report also does not categorise the peri-urban areas.

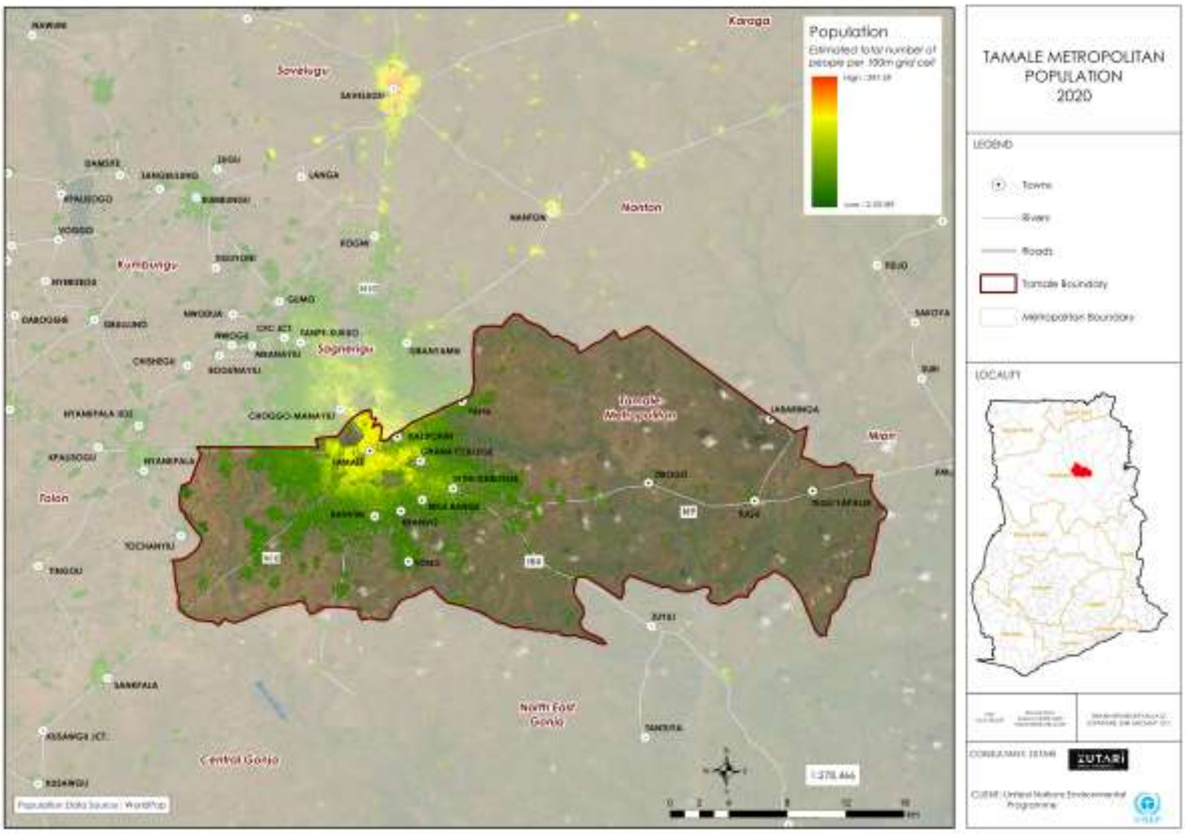


Figure 17 | Population distribution in Tamale Metropolitan District, 2020

The Metropolis has a diversity of ethnic and tribal groups. Theh Dagombas are the traditional occupants of this area (more than 80%), but several other tribal groups are now in the area including the Gonja, Mamprusi, Nanumba, Konkomba, Asantes, Ewes, Hausa and some other minorities.

Most (60.1%) of those aged 11 and above are literate. About 27.2% are literate only in English, 9.4% in a Ghanaian language, and 61.8% are literate in both English and a Ghanaian language (2010 Population and Housing Census). Less than 1% of the population is literate in English and French (0.4%) and for all the three languages (English, French and a Ghanaian language) the proportion is 1.1%. The number of female illiterates is higher than that of males (2010 GSS PHC).

3.4 Land Use and Spatial Planning

Rated as one of the fastest growing cities in West Africa, Tamale in northern Ghana is a major urban, economic, financial, cultural and political centre (Abu & Peprah, 2020). There are 117 communities in the Metropolis of which 41 (35%) are urban communities, 15 (13%) being peri-urban and 61 (52%) of them being rural in nature.

The rural parts of Tamale are the areas where land for agricultural activities is available to a large extent and serve as the food basket for the Metropolis. However, these communities still lack basic social and economic infrastructure such as good road network, school blocks, hospitals, market and recreational centres. The large proportion of per-urban communities is also a concern as these are often areas particularly vulnerable to climate hazards.

Land ownership in Ghana follows a patrilineal system with regards to land inheritance. Accordingly, inheritances can go to the male's sons or brothers. Land ownership in traditional society tends to be acknowledged by communal recognition and observation, or that of the ruling traditional elder. Deeds or papers are not usually involved, nor are lawyers. The existence of deeds or papers usually indicates a previous dispute over the land which was taken to the court system. When a conflict emerges the traditional avenue for resolution is to have the traditional elder arbitrate. However, this process usually only works when both parties respect the traditional elder. If one or both parties lack confidence in the traditional elder, local politicians are frequently asked to arbitrate. Land disputes may be taken to the court system, but these are costly. In some areas, recourse to the courts is less likely because of the costs involved and less acceptance of that system as a dispute settling mechanism. Nevertheless, even if a case goes before the courts, the land may still be used and/or occupied by the disputants since it often is the source of livelihood of the disputants. Force may be used to settle cases where traditional authority is ineffective.

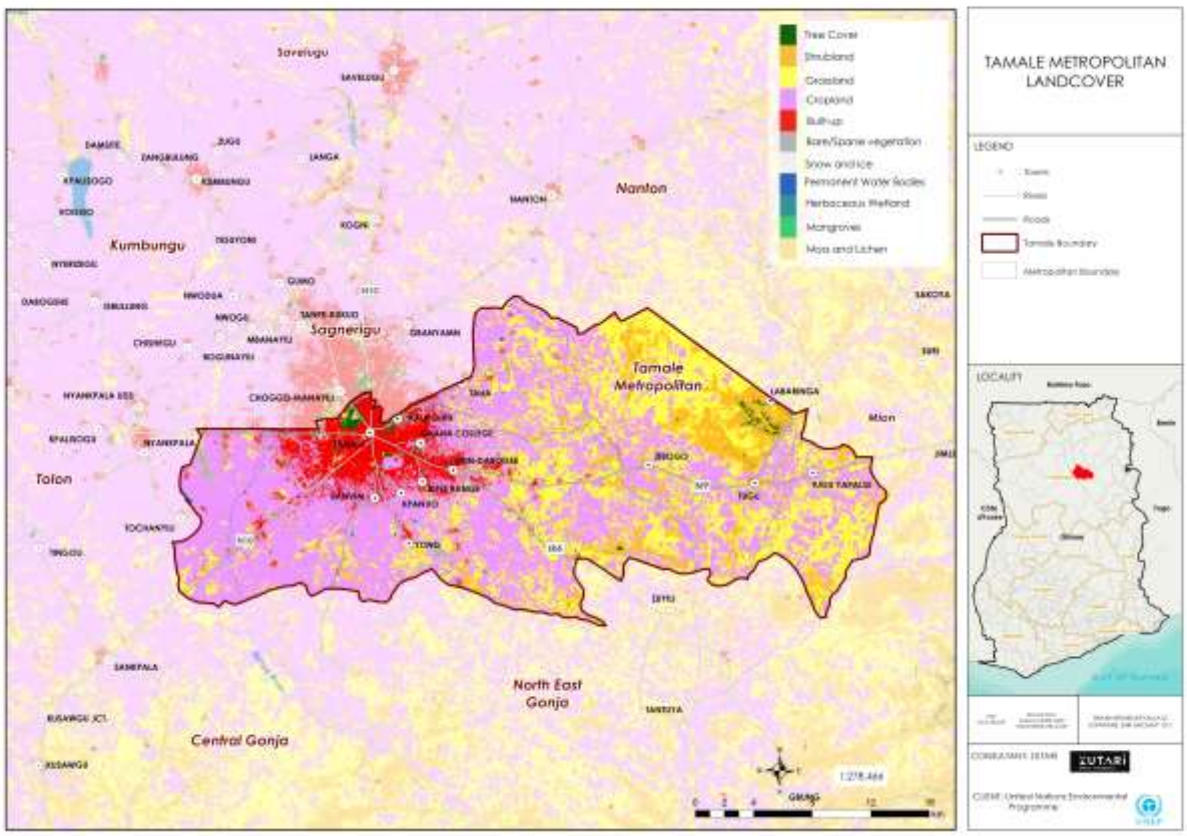


Figure 18 | Land use in Tamale Metropolitan District, 2021

3.5 Economy and Employment

The economic sector of highest employment in Tamale is service and sales (33.0%). This is followed by those in the craft and related trades workers (21.5%). The proportion of the employed persons engaged in skilled agriculture, forestry and fishery is (17.6%). The next occupation that follows is manufacturing (12.5%). Wholesale, agriculture and retail and manufacturing account for 64.1% of the industrial base of the Metropolis.

Agriculture is an important sector of Ghana’s economy, employing about 60.0% of the economically active population of the nation, in 2010 (GSS, 2010). The sector is critical to the national economy, contributing 21.3% to the Gross domestic product (GDP) in 2013 (MOFEP, 2013). The 2010 PHCR revealed that more than half (56.3%) of the population in the urban areas are engaged in agriculture, whereas less than half (43.3%) of the population in the rural areas are also engaged in agriculture.

The main types of farming activities considered in the 2010 population and housing census in Ghana are crop farming (excluding gardening), tree growing, livestock rearing, and fishing. Crop farming was the most dominant in the Metropolis as a whole accounting for more than half (52.9%) of the population in the urban areas while less than half (43.3%) of them are in the rural areas. Livestock rearing accounted for 49.8% and 50.2% of urban and rural households respectively. Fish farming was virtually non-existent due to the lack of water bodies suitable for that purpose GSS, 2010)..

In 2010 there was more livestock rearing in the rural areas (50.2%) as compared to the urban areas (49.8%). Livestock such as chicken, goat and sheep have large numbers of keepers but relatively small holdings. This perhaps explains the subsistence nature of farming in the Metropolis. The dove has the highest holding (28 per farmer) followed by cattle (26 per keeper).

In recent year, the economy of Tamale has transitioned from agrarian to service based. The proportion of the population engaged in agriculture (crop farming and livestock rearing) was around 70% until the early 1980s. It is now at less than 18%. This was made possible by several factors including the post-independence governments’ support for agriculture through input subsidies, low level of industrialisation to generate non-farm jobs and the population’s limited access to public-sector jobs due to low levels of educational attainment among the populace (Songsore, 2009; Fuseini, 2014). It was noted that a vibrant rice industry impacted positively on the growth of Tamale. Songsore (2009) suggests that the collapse of the rice industry following political instability in Ghana in the late 1970s and early 1980s, coupled with the poor economic performance and the subsequent introduction of the World Bank and International Monetary Fund (IMF) sponsored SAPs affected the agricultural sector and its capacity to generate employment which contributed to the decline of the agriculture industry (Fuseini, 2016).

The rural parts of Tamale are the areas where land for agricultural activities is available to a large extent and serve as the food basket for the Metropolis. However, these communities still lack basic social and economic infrastructure such as good road network, school blocks, hospitals, market and recreational centres (Ministry of Finance of Ghana, 2021).

3.6 Livelihoods and Community

3.6.1 Housing and Living Environment

Most of the housing in Tamale composes of compound houses constructed from mud and thatch. The housing stock of Tamale Metropolis is 19,387 representing 7.5% of the number of houses in the Northern Region. There are a total of 35,408 households and the average household size is 6.3 persons per household, which is lower than the regional average.

There are four main types of dwelling units in Tamale. These are the separate, isolated houses (Self Contained), the semi-detached houses, separate room (s) within a compound usually with common cooking and toilet facilities, and several huts or buildings within a common compound (2020 Composite

Budget - Tamale Metropolitan). The majority of the population are living in the compound house structures where toilet, bath and kitchen structures are shared by two or more families. These are largely privately constructed for renting to the general population. The Metropolis currently has a deficit in housing stock which is mainly attributed to a backlog in government housing initiatives. Due to this backlog, individual private landlords take advantage to extract high rents from tenants.

There is a high demand for affordable housing units for the high population in the formal sector. There is therefore the need for government and private sector intervention in the provision of housing units.

The central government and international bodies are normally responsible for the preparation and implementation of slum upgrading projects within Ghana. Consequently, individual cities such as Tamale do not have their own strategies aimed at slum upgrading. Individual cities should make a conscious effort to establish these guidelines and strategies. Other challenges for cities in Ghana such as Tamale include services have not been extended to all areas, low levels of service provision where they exist, non-conformity to development and building regulations, interspersed development of housing in new area, the high cost of servicing such developments, and the old housing stock[3].

3.6.2 Food Security

A study conducted by Abdul-Fatahi Alidu (2020) that of all the households in Tamale, 8.66% were severely food insecure, 36.67% were moderately food insecure, 40.67% were mildly food insecure and 14% were food secure. The results indicated that location, income, household size, credit, education, assets, and household farm size significantly influence the level of household food security. The study also showed that there is no significant relationship between gender and household food security status (Alidu, 2020).

The Metropolitan Department of Agriculture is a decentralized department under the Tamale Metropolitan Assembly. This department is under the Ministry of Food and Agriculture (MoFA). The department is located at Vittin in the Tamale South Sub-Metro and the Vittin Town Council in general. This department is tasked with responsibility of ensuring food self-sufficiency and the provision of services aimed at increasing agricultural productivity in the Tamale Metropolis. To achieve food self-sufficiency and increase productivity, Department of Agriculture collaborates with several other governmental and non-governmental organizations especially the farmer population in the Metropolis.

3.6.3 Poverty

Poverty is a huge concern among urban dwellers due to an average monthly income of GHS150 with an exorbitant basket of expenditure. This is based on the expenditure of urban dwellers, which is far more than the average income earned (Damba, Abarike, Nabilse, & & Akudugu, 2019). This is a concern even among household heads as remittances and other sources of income are not forthcoming.

Urban poverty is enhanced by the lack of social capital coupled with increasing utility tariffs with a translated cost in production and processing activities. The result is an increase in food prices and cost of utility tariffs (Damba, Abarike, Nabilse, & & Akudugu, 2019). Tamale which is noted for male-dominated household roles coupled with low or lack of assets control by women further worsen the poverty situation among households as household expenses are borne by the man who is the head of the household.

Urban dwellers consider themselves as either poor or rich and perceive poverty as either a lack of money or their inability to meet basic household needs. Urban dwellers consider unemployment as poverty but still consider living in urban areas better compared to rural areas due to the availability of basic amenities such as toilets, access to portable drinking water and electricity. Poverty and low income are associated with the sex of household heads and an indication that the lack of gainful economic activity worsens the plight of women in the urban areas. Control and access to resources are associated with males. This

[3] Source: 2020 Composite Budget - Tamale Metropolitan.

therefore calls for livelihood intervention programmes to address unemployment situations of women (Damba, Abarike, Nabilse, & & Akudugu, 2019).

3.6.4 Migration

Tamale has attracted migrants from the impoverished rural areas of northern Ghana in particular and has experienced annual urban growth rates of 4% during the past decade. This rapid urban growth poses challenges for urban infrastructure and service provision and has resulted in increased competition over land use, while effective planning to address present and future urban growth is lacking. In Tamale, conflicts over the allocation and use of land between traditional authorities, responsible for managing 90% of the land, and governmental planning institutions makes proper urban planning even more difficult (Karg, et al., 2019).

3.6.5 Vulnerable Groups

Various documents and studies have highlighted that the most vulnerable groups within Ghana are women (elderly and orphans), children, people with disabilities and low-income individuals and households in both a rural and urban setting. According to these studies the main drives of vulnerability are social and physical identities (gender, age, disability, ethnicity, and refugee status), income, poverty, and political drivers (linkages to political networks and ethnic affiliations, and the key role of government).

Women, children, people with disabilities, people in remote or indigenous communities, and other vulnerable groups are usually disproportionately affected by the loss of services when infrastructure systems fail 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, who may lack the resources to rebuild their homes, communities, and livelihoods, and who may be disproportionately affected by health and other impacts caused by disruptions to basic services (Adshead, et al., 2022).

Further drivers for exclusions are income poverty, local of political and wealthy connection, gendered social roles, lack of access to key public services (water, drainage, health facilities, electricity and schooling), location (rural and remote are or excluded neighbourhood within an area) and social norms (Sarwar, Holmes, Korboe, Afram, & Salomon, 2022).

3.7 Infrastructure and Services

3.7.1 Transport

The roads in the Metropolis are fairly good especially those that link the Metropolis to other district capitals. The tarred roads in the area facilitate easy commuting from one place to the other. There is no traffic congestion. Most of the farming and the Peri-urban communities are linked to the marketing centres by feeder roads. The availability of access roads linking farming communities is an incentive to the farmers since post-harvest loses are reduced. Although most of the roads are tarred, some linking the regional capital to the remotest of areas are yet to be tarred. Others have been gravelled but still to be tarred (Ministry of Finance of Ghana, 2021).

3.7.2 Energy Supply

The Metropolis enjoys electricity supply from the National Grid and about 70% of the communities are connected. Electricity supply has been fairly stable. This could be an advantage to heavy industrial development that would depend mostly on energy for production. With the expansion of electricity in the Metropolis, there is also an expansion of the Small and Medium Scale Enterprise businesses in the area.

About 82.2% of households in the Metropolis have access to electricity from the main grid. The proportion of households connected to the main grid in the urban areas is 90.5% whiles 42.2% are connected in the rural areas. The three main sources of lighting for most households are electricity (main grid), constituting 82.2% of households, kerosene lamp (11.6%) and flashlight/torch (4.7%). The sources of lighting for dwelling units in the metropolis include electricity, kerosene lamp, solar energy, firewood and flashlight or torch. About 11.6% of dwelling units use kerosene as their main source of lighting. The proportion for the rural areas is (36.4%) whiles that of the urban areas is (6.4%). Access to electricity from the main grid is heavily skewed towards the urban areas. All other sources of lighting except flashlight/torch account for less than 1.0% of dwelling units (Ministry of Finance of Ghana, 2021).

The primary source of electrical power in Ghana is from hydropower, from the Akosombo Dam, which has a total Plant capacity of 1020 megawatts.

3.7.3 Water Supply and Sanitation

The Ghana Water Company Limited (GWCL) extracts raw water from the Nawuni abstraction point some 35 km north-west of the city and treats it at the Dalun Water Treatment Plant (WTP) for reticulation to the Tamale Metropolitan Assembly and surrounding communities where approximately 65% of the population has access to the piped water supply network. However, water supply to the city of Tamale and surrounding areas is severely compromised by indiscriminate sand mining activities and land degradation in the catchment, which is causing sedimentation of the river, with noticeable physical changes in riverbed structure. Not only is the river becoming shallower and wider at the Nawuni abstraction point, but the quality of water has fast deteriorated with turbidity being a major issue in the treatment of water for reticulation.

In 2022 the river was under serious threat from the illegal activities of sand mining and the Ghana Water Company Limited (GWCL) has threatened to shut down the water treatment plant. The depth of the river has reduced drastically due to siltation, which has undermined its water holding capacity (Fugu, 2022).

The main water system in the Metropolis is pipe borne water, served by an aged reticulation network that does not reach all the urban communities in the MMDA, especially those located on high land areas. Other sources of water are Town water systems, mechanized bore holes, wells, dams and dugouts. (Ministry of Finance of Ghana, 2021). Most households in the metropolis depend on either pipe-borne water outside their dwelling or pipe-borne water inside their dwelling (representing 41.4% and 39.8% respectively).

Only around 56.2% of households in Tamale have access to a public or private toilet while 7.1% of households have access to a twin-pit VIP latrine (KVIP). As much as 26.1% of households have no toilet facility and this is an area of concern in terms of the impact on the environment and the health of these communities.

The challenges for the provision of safe sanitation services in Tamale and across Ghana are linked to the inability to create proper disposal points for solid waste, lack of enforcement of sanitation laws, population growth, poor financing of sanitation policies among others[4].

[4] https://tamalemetro.gov.gh/2022/06/18/public-investment-in-the-wash-sector-in-ghana-has-not-kept-pace-with-service-needs-economic-growth-and-urbanization-crs/

3.7.4 Stormwater and Flood Risk Management

Urban flooding is a problem in Tamale due to a lack of adequate stormwater design and infrastructure and maintenance. The lack of stormwater drainage systems in informal settlements has negative implications for human life and livelihoods due to flooding. The impact of flooding, results in relocation, and the increased potential for water-borne diseases. Changes in rainfall and temperature, and the increase in the occurrence of short-term flood events will have a negative impact on human settlements in particular. The impact of flooding on human settlements may be temporary and relatively short-term – albeit costly – in nature (for example physical damage to infrastructure such as buildings, pipelines, roads, electricity substations, and railway lines), or might have lasting repercussions, such as loss of life, disruptions to livelihoods, physical isolation and relocation.

3.7.5 Waste Management

The most widely used method of solid waste disposal in Tamale Metro is by public dump (container) accounting for 98.3% households within the Tamale Metropolis. About 72.5% of households have their solid waste collected with the remaining households resorting to indiscriminate dumping. The inability to create proper disposal points for solid waste is considered a major challenge in Tamale and is also contributing to the sanitation and flooding risks and impacting on the health and well-being of people.

3.8 Health

The health services in the Metropolis are managed at three (3) levels namely: Metro Health Administration level, Sub-district level and the Community level. Health services are provided at the community level by sub-districts staff supported by traditional birth attendants (TBAs), Community Based Surveillance (CBS) volunteers, village Health Committees.

4 Current and Future Climate Change Related Risks (Hazards, Exposure and Vulnerability)

4.1 Observed Climate and Trends

4.1.1 National Summary of Climate and Trends

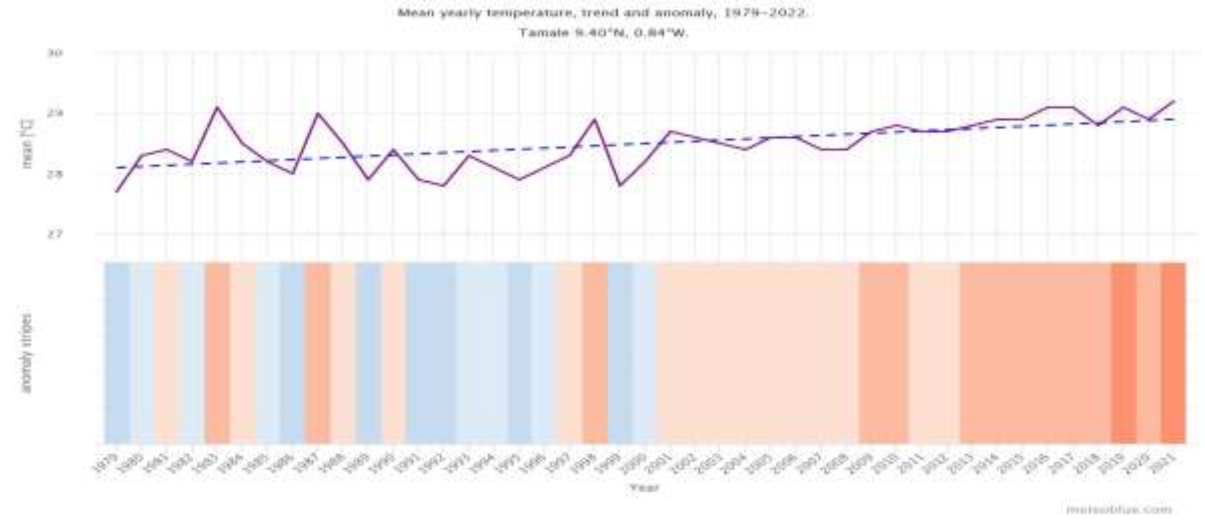
Ghana's generally tropical climate is strongly influenced by the West African monsoon winds, which varies slightly along with the country's varied topography. With most of the rain falling in intense storms of short duration, the country is vulnerable to extreme events such as heavy rainfall (with on average 44 mm per day) resulting in heavy runoff and erosion, especially at the beginning of the rainy season. At the same time, the long dry season in the north has led to serious droughts in the region (Ministry of Foreign Affairs of the Netherlands, 2019).

Ghana highly vulnerability to climate variability and change continues to pose a threat to future growth and development. There is evidence of a temperature increase over the past decades. Mean annual temperature has increased by 1.0˚C since 1960, an average rate of 0.21˚C per decade, with the strongest increase between April and July (+0.27 °C per decade). The rate of increase has been more rapid in the north of the country than in the south. Moreover, the number of 'hot'[5] days has increased significantly in all seasons except between December and February, and 'hot nights' has increased significantly in all seasons (by 13.2% and 20% respectively between 1960 and 2003), while the number of 'cold' days and 'cold' nights[6] has decreased (by 3.3% and 5.1% respectively over the same period). Annual rainfall in Ghana is highly variable on inter-annual and inter-decadal timescales. This means that long term trends are difficult to identify. There is no evidence of a trend in the proportion of rainfall that falls in 'heavy'[7] events between 1960 and 2006. (McSweeney, New, & Lizcano, 2012). Although interannual and interdecadal rainfall levels were highly variable, overall rainfall saw a well-defined cumulative reduction of 2.4 percent per decade (USAID, Climate Change Risk Profile – Ghana (Fact Sheet), 2017). No clear trend has been observed in the intensity or frequency of extreme rainfall events. (Ministry of Foreign Affairs of the Netherlands, 2019).

4.1.2 Local Level Climate and Trends

The mean annual temperature in Tamale is currently just below 29 C but has risen by approximately 1°C since the late 1970s. Since 2000 the mean annual and decadal temperatures have consistently been more than 28.4°C. Figure 19 shows the mean annual temperature changes, including its trend (dashed blue line) and annual temperature anomalies, during the past 40 years in Tamale. In the lower part of the graph, blue indicates years colder than on average and red indicates warmer years.

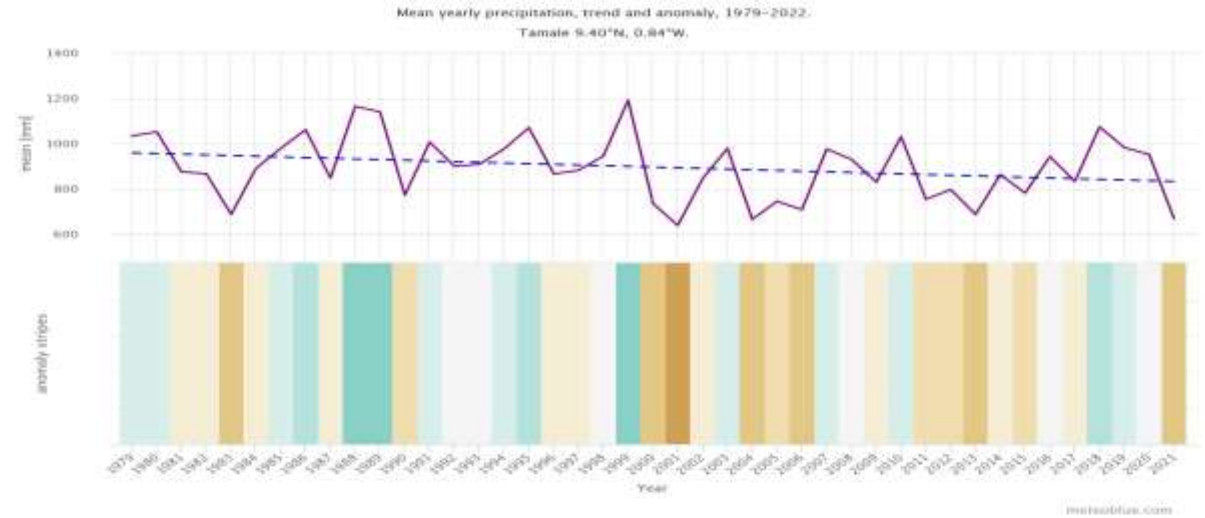
[5] 'Hot' day or 'hot' night is defined by the temperature exceeded on 10% of days or nights in current climate of that region and season.
[6] 'Cold' days or 'cold' nights are defined as the temperature below which 10% of days or nights are recorded in current climate of that region or season.
[7] A 'Heavy' event is defined as a daily rainfall total which exceeds the threshold that is exceeded on 5% of rainy days in current the climate of that region and season.



Source: (www.meteoblue.com, 2022)[8]

Figure 19 | Mean annual temperature, trend and anomaly in Tamale Metropolitan District, 1979-2022

Precipitation in Tamale, and the Northern region, experienced a high degree of interannual and interdecadal variability. However, since the 1960s, an overall reduction in cumulative rainfall per decade was observed. Changes in decadal rainfall declined in the middle of the country, with more intense rainfall events occurring in both the north and south of the country, indicating an increase in the intensity of rainfall events and possibility of increased dry spell durations. Figure 20 shows the mean annual precipitation changes, including its trend (dashed blue line) and anomalies, during the past 40 years in Tamale. In the lower part the graph shows the precipitation stripes, where each coloured stripe represents the total precipitation of a year – green for wetter and brown for drier years.

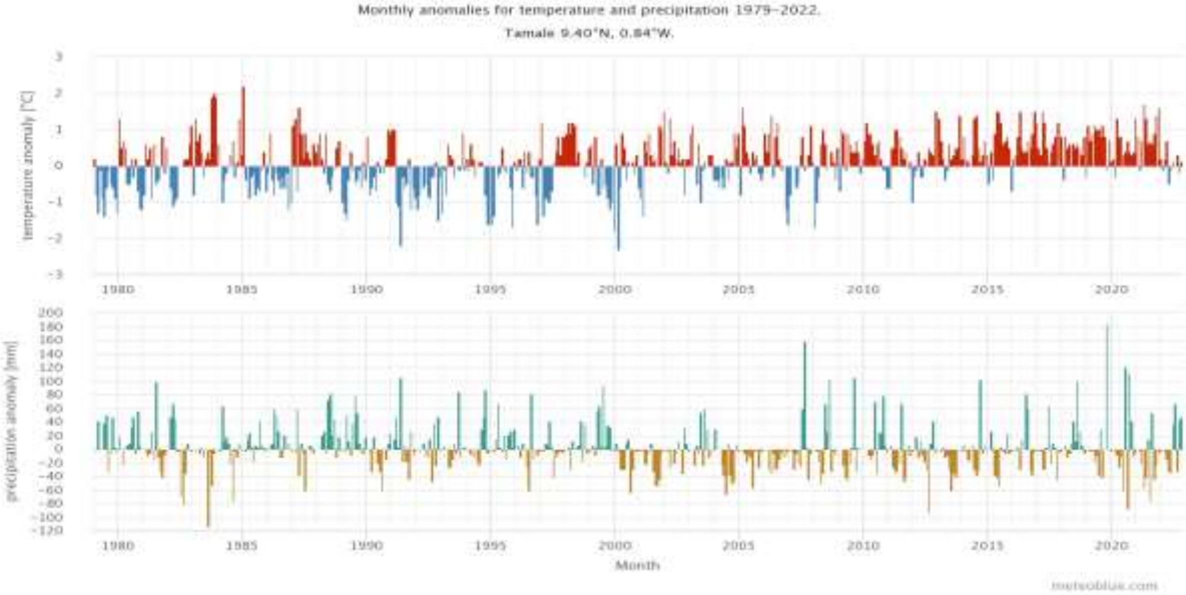


Source: (www.meteoblue.com, 2022)[4]

Figure 20 | Mean annual precipitation, trend and anomaly in Tamale Metropolitan, 1979-2022

Figure 21 shows the temperature and precipitation anomalies for every month between 1979 and 2022, comparing the mean monthly values with the 30-year climate mean of 1980-2010. The top graph shows the temperature anomaly, by how much each month was warmer or colder than the average – red months were warmer and blue months were colder. It is possible to observe an increase of warmer months over the years, which reflects the global warming associated with climate change. The lower graph shows the precipitation anomaly, if there was less or more precipitation that average – green months were wetter and brown months were drier. It is possible to observe that since 2000, the number of drier months has been increasing and the number of wetter months has been increasing and that the anomaly values have been greater, specially for the wetter months.

[8] The data source used is ERA5, the fifth generation ECMWF atmospheric reanalysis of the global climate, covering the time range from 1979 to 2021, with a spatial resolution of 30 km

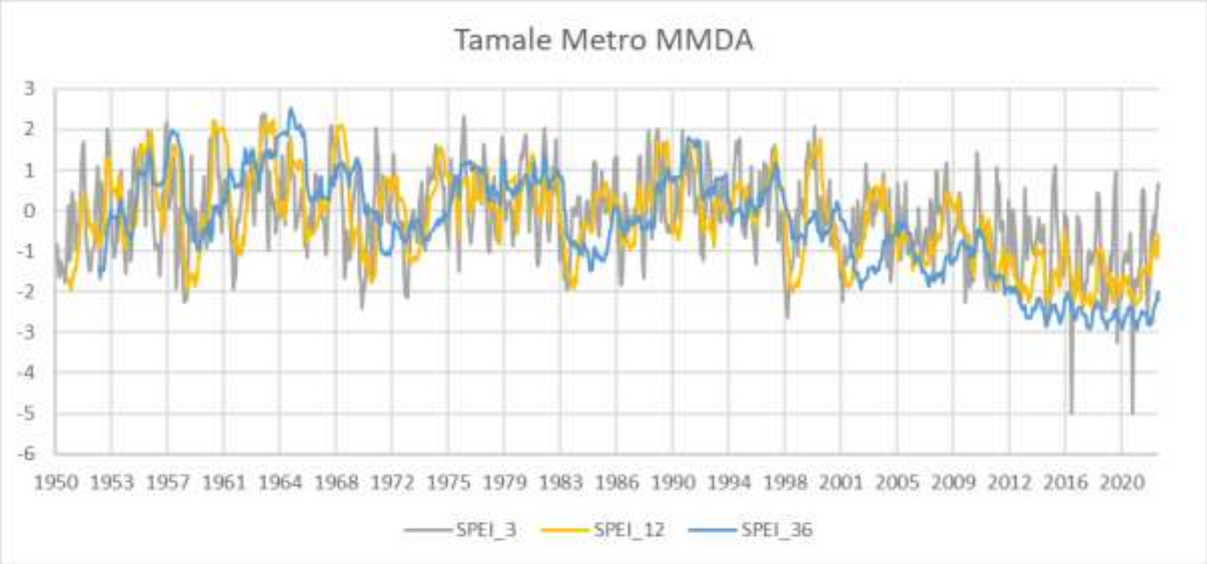


Source: (www.meteoblue.com, 2022)[9]

Figure 21 | Monthly anomalies for temperature and precipitation in Tamale Metropolitan, 1979-2022

A preferable method for the identification and analysis of drought conditions is to use the Standardised Precipitation and Evaporation Index (SPEI), as it can account for the possible effects of temperature variability and temperature extremes beyond the context of global warming. The SPEI represents the measure of the given water deficit in a specific location, accounting for contributions of temperature-dependent evapotranspiration and providing insight into increasing or decreasing pressure on water resources. The SPEI can measure drought severity according to its intensity and duration and can identify the onset and end of drought episodes (Beguería, Latorre, Reig, & Vicente-Serrano, 2022). Negative values for SPEI represent dry conditions, with negative values indicating increased likelihood of increased aridity and drought conditions, likewise positive values indicate increased wet conditions. This is an important understanding for the water sector regarding water quantity and quality of supply for human consumption and agriculture use as well as for the energy sector as reductions in water availability impacts river flow and the hydropower generating capabilities (The World Bank Group, 2021). Figure 22 shows the showing the observed trends in drying (negative SPEI) and wetting (positive SPEI), for three different timescales, 3, 12 and 36 months, as an indicator of current trends for increasing risk of floods and droughts. From the figure is possible to confirm that the conditions are becoming drier in Tamale over time, particular the past decade but with increasing annual variability.

[9] The data source used is ERA5, the fifth generation ECMWF atmospheric reanalysis of the global climate, covering the time range from 1979 to 2021, with a spatial resolution of 30 km



Source: Data retrieved from ***https://spei.csic.es/database.html#p5***

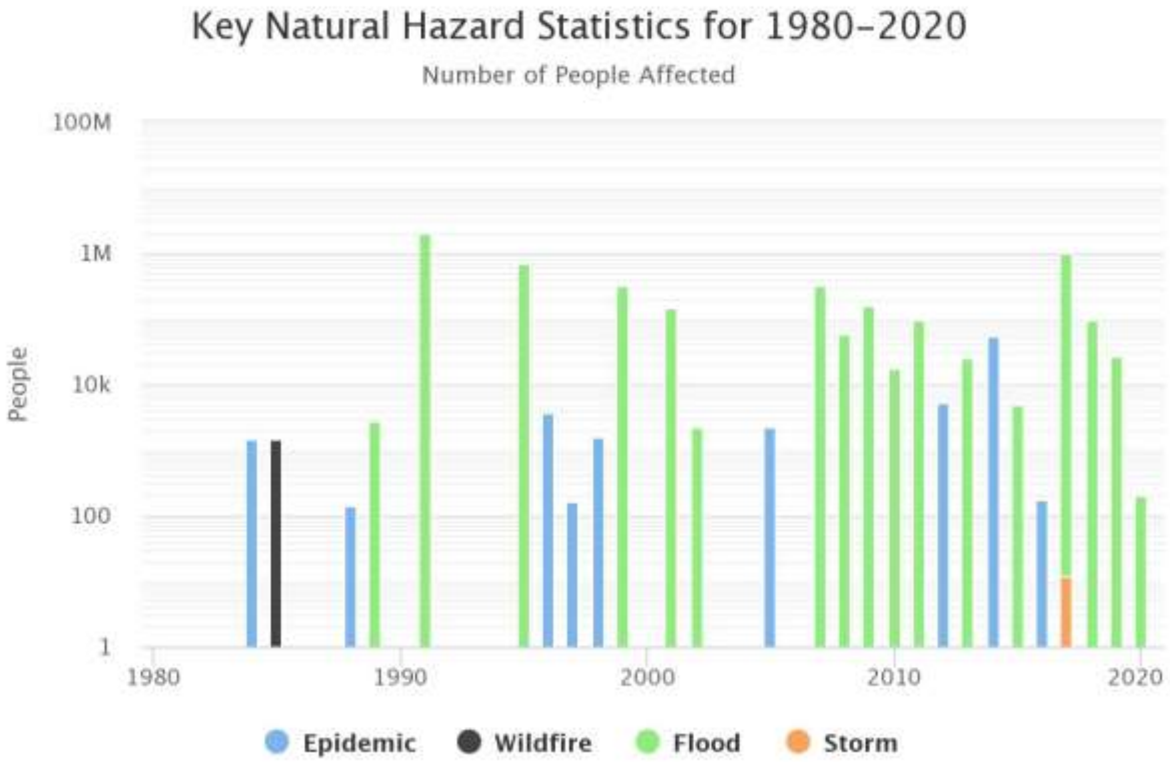
Figure 22 | Observed trends in the SPEI in Tamale Metropolitan District, 1950-2010

4.2 Observed Natural Hazard Events

Ghana is highly exposed to extreme hydrometeorological conditions, such as floods, particularly in the northern Savannah belt, and faces associated risks of landslides. In the past 50 years, 22 major hydrometeorological events (19 flood events and three drought events) in Ghana have affected 16 million people with over 400 deaths (Pwamanng, Appah-Sampong, & Oppong-Boadi, 2020). Extreme rainfall events have increased over the 1986-1995 period, including a high number of 24-hour maximum rainfall events—a trend that has continued in the last decade. Rising sea levels, drought, higher temperatures, and erratic rainfall negatively impacts infrastructure, hydropower production, food security and coastal and agricultural livelihoods. Approximately ¼ of the population lives along the coast in rapidly expanding urban areas and are especially vulnerable to flooding and waterborne diseases. Drought and reduced rainfall threaten access to reliable power sources, already erratic and insufficient. The climate and socio-economic environment in semi-arid, coastal and wetland areas make communities vulnerable to food insecurity and unstable livelihoods as well as leading to unsustainable agroecological systems, crop failure and unproductive rangelands (USAID, 2017).

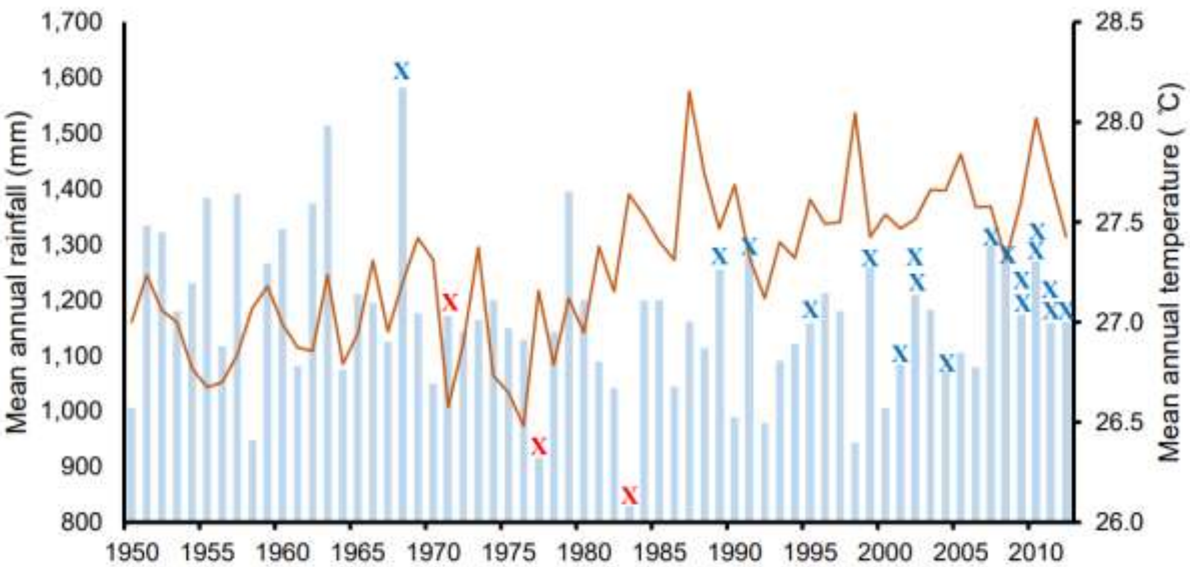
The recurrence of both floods and droughts in the Northern Savanna region of Ghana is becoming a common phenomenon, often associated with high temperatures and intense heat. Insufficient rainfall during the major cropping season during the last major severe drought in 1982-1983 affected more than 12 million people. More recently, the 2007 catastrophic floods in north Ghana occurred immediately after a period of drought affected more than 325,000 people and damaged the initial maize harvest (Ministry of Foreign Affairs of the Netherlands, 2019).

A summary of the key natural hazard events that have occurred in Ghana since 1980 and the number of people affected by these events is shown in Figure 23 from the Climate Change Knowledge Portal (CCKP). Figure 24 illustrates the extreme climate events (droughts and floods) relative to mean annual rainfall and mean annual temperature in Ghana from 1950 to 2012. These two figures indicate an increasing occurrence of flood related disasters in particular almost on a yearly basis since the late1990s.



Source: WB Climate Change Knowledge Portal

Figure 23 | Summary of Key Natural Hazard Events for Ghana from 1980 to 2020



(Pwamanng, Appah-Sampong, & Oppong-Boadi, 2020)

Figure 24 | Extreme climate events (droughts and floods) relative to mean annual rainfall (left-hand y-axis; bars) and mean annual temperature (right-hand y-axis; line) in Ghana from 1950 to 2012

Unfortunately, the availability of historical information on catastrophic natural hazard events in Tamale is limited, but there is lots of anecdotal evidence suggesting that natural hazard events, particularly floods are becoming more regular. Table 4 contains a list of natural hazard events, compiled based on the information collected from newspapers and press releases publicly available on the internet.

Table 4 | Historical catastrophic natural hazard events occurred in Tamale MMDA and surrounding areas

Date	Hazardous Event	Location	Impact	Reference
Jan – Dec 2022	391 Fires domestic fires – 203, commercial – 53, electrical – 42 and bushfires – 41. The rest are vehicular -19, institutional 12 and other fires – 21.	Northern Region – (94 fires in Tamale Metropolis)	87 injuries recorded. January and December recorded the highest fires of 81, representing 20.72%	https://www.myjoyonline.com/northern-region-recorded-391-fires-in-2022/
August 2022	Flood (torrential rainfall)	Some parts of Tamale Metropolis. Areas including Gummani, Shishegu, Tunaayili, Jisonaayili, Kanvili, Kunyevela, Nyohini and Kanvili Tunaayili were mostly hard-hit by the flood.	More than 100 homes, motorbikes, cars and tricycles were submerged; roads submerged; bridge linking Gummani and Kanvili Tunaayili was washed away; footbridges were washed away; Hundreds of residents have been displaced	https://allafrica.com/stories/202208150240.html
Jan – Dec 2021	367 Fires	Northern Region		https://www.myjoyonline.com/northern-region-recorded-391-fires-in-2022/
August 2021	Flood (torrential rainfall)	Parts of the Tamale metropolis and the Sagnerigu municipality, including Fou, Taha, Vettin, Gumani and Kalariga among others in the Northern Regional capital.	Several buildings have been inundated; several residents have been displaced.	https://www.myjoyonline.com/tamale-records-second-flood-in-3-days-more-residents-displaced/
October 2020	Flood (torrential rainfall)	Several communities(Sawaba, Taha, Gumani, Waterworks, Nyohini, Sagnarigu-Kukuo) in the Tamale metropolis and Sagnarigu municipality of the Northern Region have been flooded following heavy rainfall in the capital Tamale.	This flooding has affected the transportation of persons, goods and commodities within parts of the metropolis. Several homes and properties have also been destroyed by the floods.	https://www.myjoyonline.com/communities-in-tamale-flood-after-heavy-downpour/
July 2017	Flood (torrential rainfall)	Most areas of Tamale got flooded	Loss of properties, several buildings have been inundated, including the Tamale Teaching Hospital. Two people died and several residents have been displaced	https://www.africanews.com/2017/07/27/ghana-hit-by-deadly-floods-in-the-northern-region-vp-visits-victims/

Date	Hazardous Event	Location	Impact	Reference
July 2016	Flood (torrential rainfall)	Northern Ghana – Communities affected include Sawaba, Belpela, Gumani, Datoyili, Kalariga, Sagnarigu, and Kulnyevila.	Several houses, farms and livestock have been gravely affected by the floods. One person died and several residents have been displaced	https://www.pulse.com.gh/ece-frontpage/flood-tamale-floods-one-dead-tens-displaced/h6zklcm
September 2015	Flood (torrential rainfall)	Residents in Bilpela, Kalaraga and Darrigohi-Fong, suburbs of Tamale, were worst hit.	The heavy rains lasted for about an hour and half, flooding homes of the residents and destroyed many properties.	https://www.peacefmonline.com/pages/local/social/201509/255916.php
April 2014	Flood	The rainstorms destroyed houses in areas such as Gumbihini, Kukuo, Nyohini, Jakarayili, Kpanbegu and Sagnarigu, all within the Tamale Metropolis.	Hundreds of Northern Ghana residents have been displaced by severed rainstorms that battered towns and villages in parts of the Northern Region.	https://www.peacefmonline.com/pages/local/social/201404/197899.php
September 2007	Floods in the northern part of the country, immediately following a period of drought (overspill of the Bagre Dam in neighbouring Burkina Faso)	Upper East Region, Upper West Region, Northern Region and parts of the Western Region	The floods affected 332,600 people and caused the death of 56 according to the Government. Some 35,000 houses, 1,500 kilometres of road and thousand hectares of crops have been destroyed	**https://news.un.org/en/story/2007/09/231622** https://reliefweb.int/report/ghana/ghana-situation-report-floods-nov-2007

4.3 Future Climate Change Projections

For the analysis of future climate change scenarios, the country was separated into four homogenous climate zones, that are characterised by a relative homogeneity of climate in terms of its interannual variability – North, Central, Southwest and Coastal. These four homogenous climate zones were identified through the analysis of trends in observed climate data as well as similarity in the expect changes due to climate change. As a result, they are expected to respond in a similar way to future climate change, under the different global emission scenarios which can then be translated to expected changes at the level of individual MMDAs or for individual eco-region.

Figure 25 shows the four climate zones, where it is possible to observe that the Tamale Metro MMDA is located in the Northern Climate Zone.

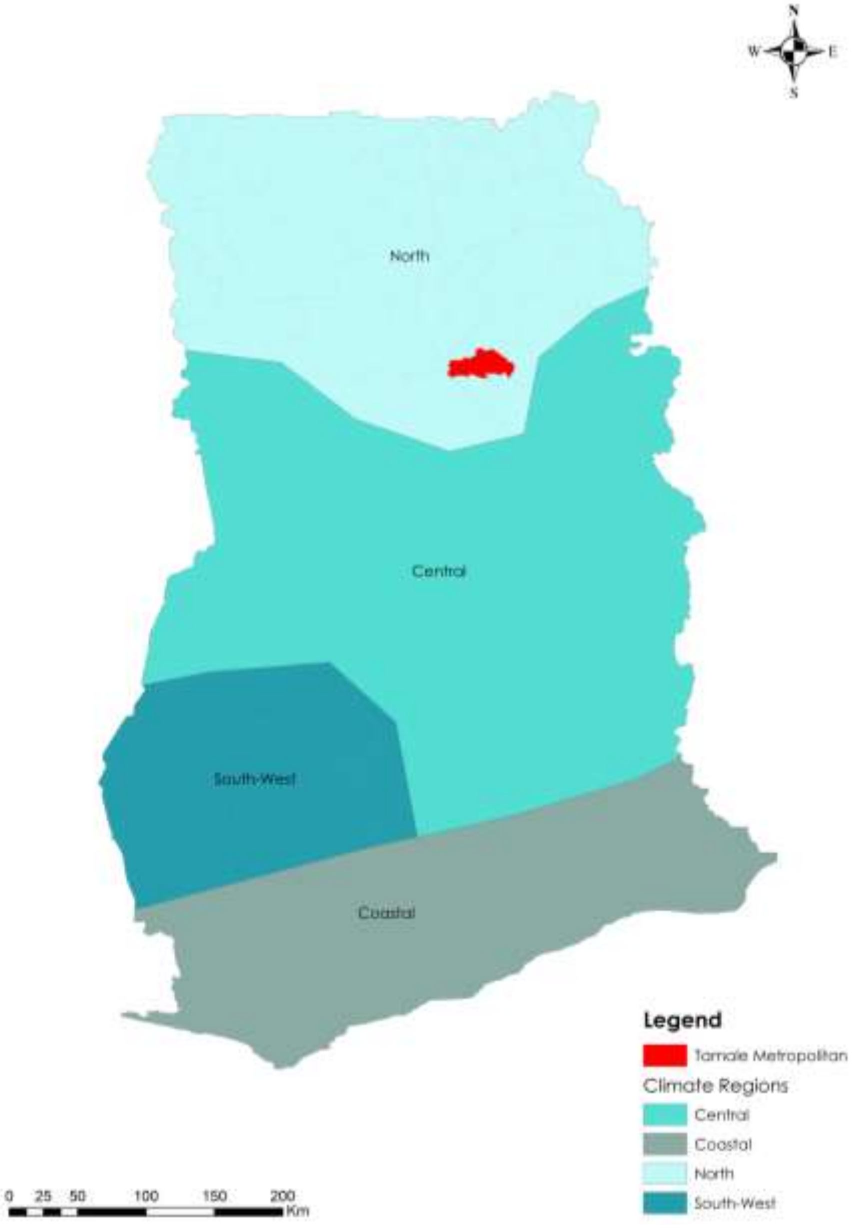
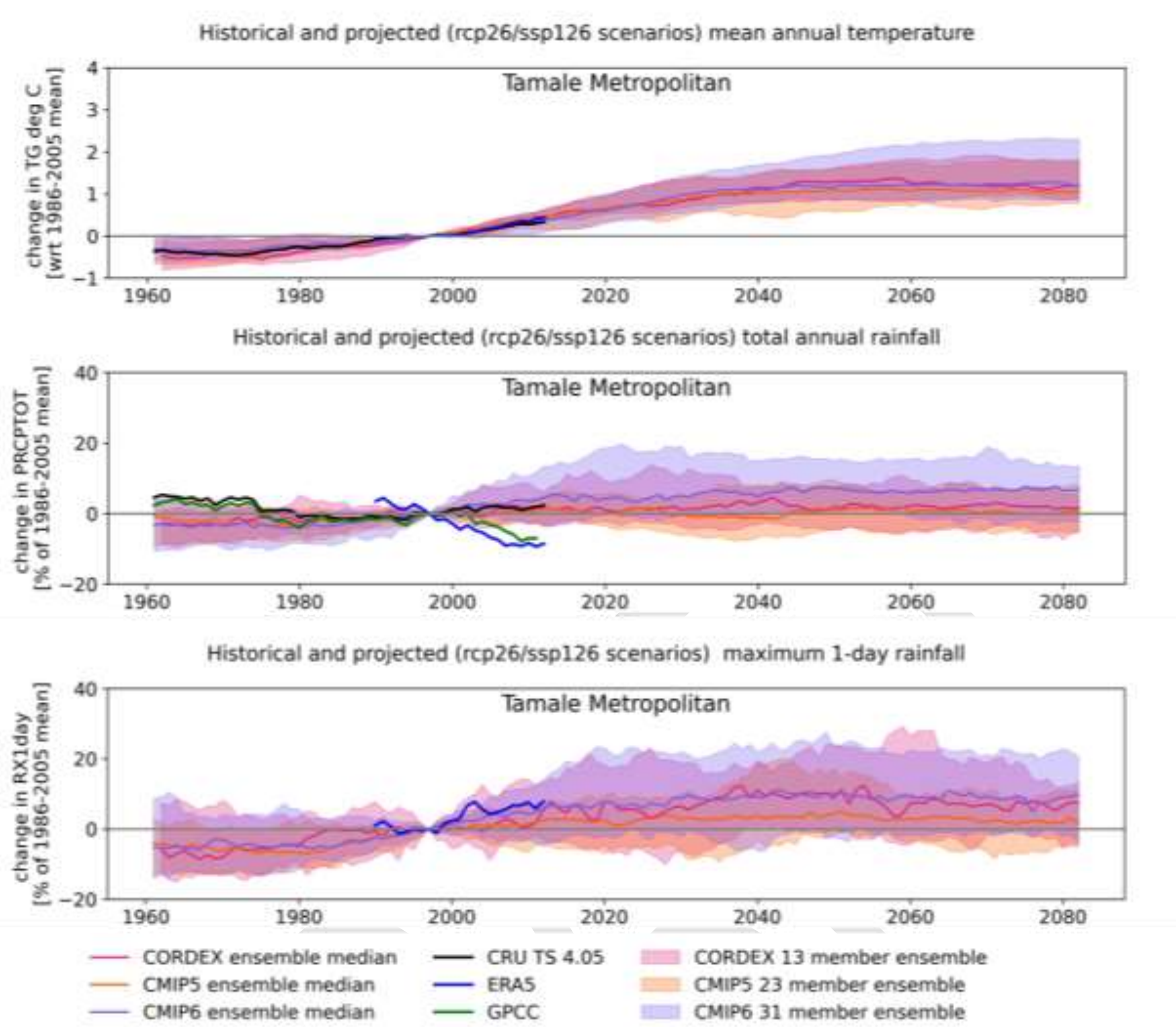


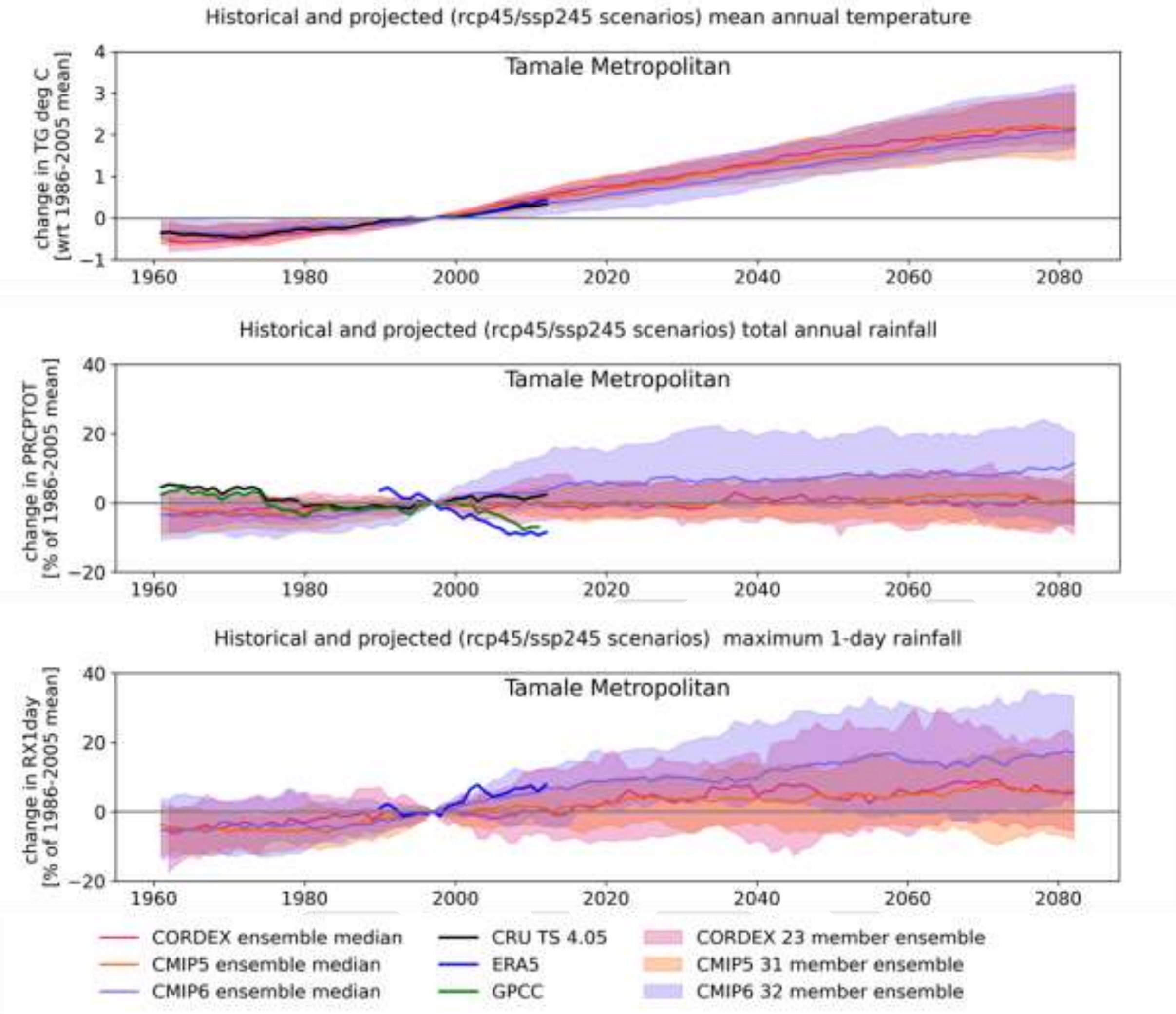
Figure 25 | Four climate zones defined for synthesizing climate change projections in Ghana

Individual plume plots showing the range of possible climate scenarios derived from both the CMIP5 and CMIP6 ensemble of climate models as well as the CORDEX dataset of downscaled climate scenarios (CMIP5 only) for Tamale are shown in, Figure 26, Figure 27 and Figure 28**.** These represent the combined global emission scenarios of SSP2-1.26, SSP2-45 and SSP5-8.5 respectively. The individual plume plots show the median and 10^{th} and 90^{th} percentile values for (1) change in average daily temperature, (2) change in mean annual precipitation, and (3) change in the maximum one-day rainfall out to 2100. The plots also show the observed historical climate data from multiple sources.



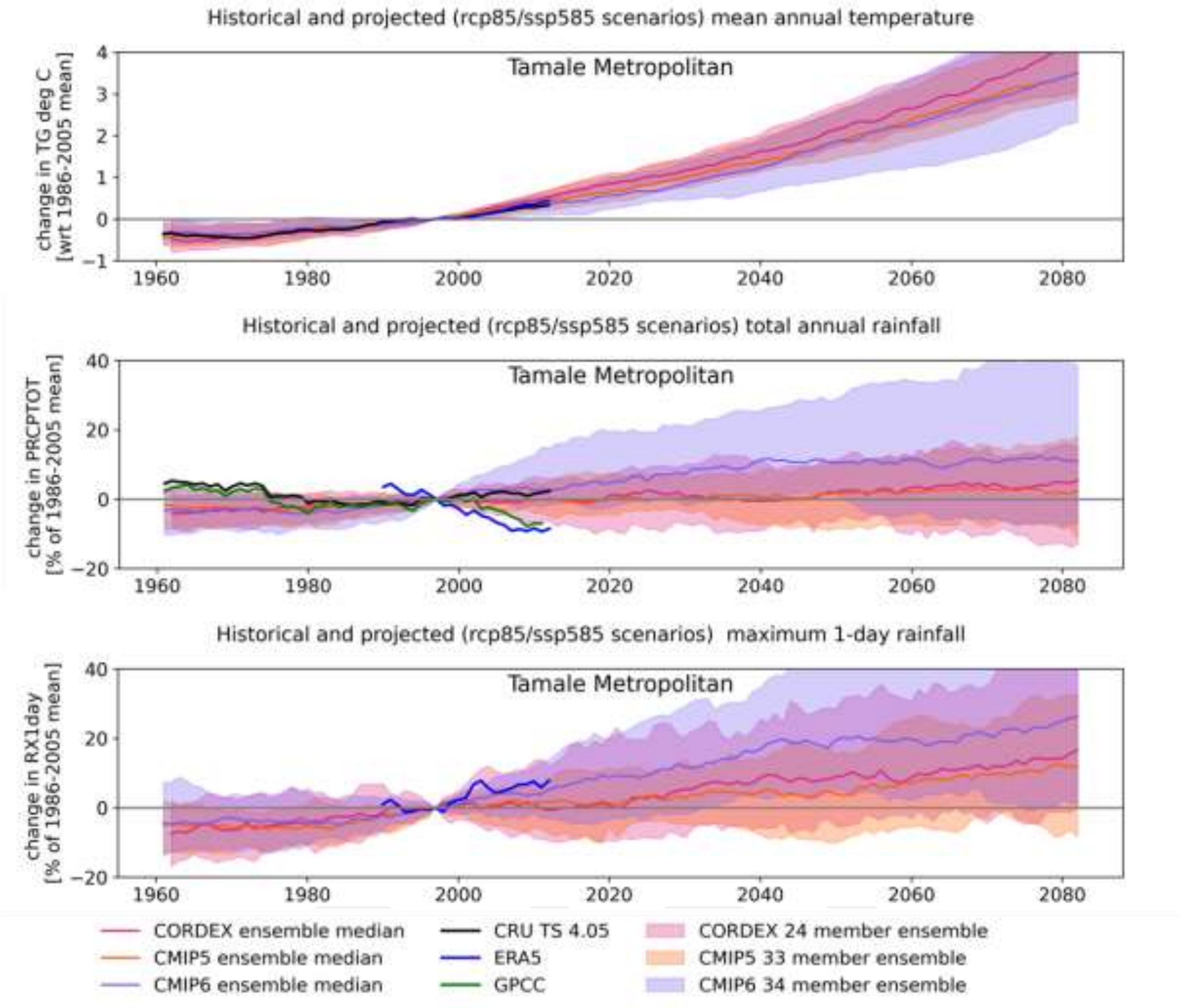
Note: All lines represent 20-year running averages calculated on annual values

Figure 26 | Plume plots illustrating the evolution of mean annual temperature, total annual rainfall and maximum 1-day rainfall, in Tamale Metropolitan MMDA in simulations of historical and future climate in three ensembles under rcp26/ssp126 scenarios



Note: All lines represent 20-year running averages calculated on annual values

Figure 27 | Plume plots illustrating the evolution of mean annual temperature, total annual rainfall and maximum 1-day rainfall, in Tamale Metropolitan MMDA in simulations of historical and future climate in three ensembles under rcp45/ssp245 scenarios



Note: All lines represent 20-year running averages calculated on annual values

Figure 28 | Plume plots illustrating the evolution of mean annual temperature, total annual rainfall and maximum 1-day rainfall, in Tamale Metropolitan MMDA in simulations of historical and future climate in three ensembles under rcp85/ssp585 scenarios

4.3.1 Temperature

In the future, there is a greater likelihood for more significant increases in **temperature** in the North Climate zone (and the Central) than in the other two climate zones identified for Ghana. Tamale MMDA will see **temperature** increases from 1.5 °C under RCP 2.6 to 3.5/4 °C under RCP 8.5, with RCP 4.5 suggesting a mid-point of about 2.0 °C, by the end of the century. As usual, RCP 8.5 represents a step change in temperature. However, the plume plots, particularly when incorporating CMIP 6 suggest an even greater temperature increase of another 0.5 °C.

In short, there is a **risk of significantly higher temperatures for Tamale even at lower GHG concentration scenarios.** This is further increased as a result of the inland location of Tamale.

4.3.2 Precipitation

Precipitation does not vary as much as other regions in Africa. There is a slightly greater chance of **small increases** in annual average precipitation compared to the base years. Typically, around 5% increase. There is also a relatively significant chance of **decreases** in precipitation to a similar degree. The extremes suggest that a change in precipitation is possible of up to +/-15/20%.

The plume plots suggest there is a relatively good match in the precipitation scenarios and the plume plots suggesting that the scenarios do a relatively good job of capturing the possible variation at RCP 2.6 but not RCP 4.5 or RCP 8.5 where there is chance of significant increases in rainfall possibly up to 20% increases, by the end of the century. The CMIP6 models suggest a much greater chance of wetting for Tamale and the northern parts of Ghana, although this does require further investigations.

4.3.3 Extreme Rainfall

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 this scenario the median value for the increase in maximum daily rainfall is around 20% by 2050, but could be as high as >40%. Heavy precipitation events become more likely in the future, especially under the high emission scenario. This will have a significant impact on the potential for increased flooding events in Tamale.

4.3.4 Summary

In general, the latest **CIMP 6 model results** suggest **greater climate sensitivity** and more the potential for more **significant "wetting"**, particularly over the Northern climate zone, but **further analysis is required** to clarify these results. Temperature is expected to increase significantly for Tamale with the greatest increases in temperature as a result of the higher global emission scenarios.

The overall messages about future climate in Ghana emerging from the analyses are as follows:

- **strong confidence** message of **increases in air temperatures** manifested in all scenarios and all of the four climate zones identified for Ghana. Those increases amount to **0.5 to 1.5** °**C**, **1.5 to 2.5** °**C** and **2.5 to 4.5** °**C** above historical mean at the end of 21st century under **RCP26/SSP126**, **RCP45/SSP245** and **RCP85/SSP585** respectively.
- **moderate to low confidence** message of **weak changes** (comparable to or only slightly stronger than the level of variability simulated for the past) in the overall **"wetness"** of the climate **without a clearly defined direction** of future changes in total annual rainfall, independently of emission scenario. That **low confidence** is partly caused by the lack of consistency in historical rainfall trends between observational data and model simulations.

4.4 Future Climate Change Scenarios for Tamale

As part of the Climate Scenarios Analysis Report for Ghana (See separate report), individual climate scenarios were identified for each of the four regions of Ghana based on using Self Organising Maps (SOMs). Based on the results of the SOMs analysis, representative climate scenarios have been identified for each of the four climate zones in Ghana under three global emission scenarios: RCP 2.6, 4.5 and 8.5. Out of the possible 64 representative pathways, 16 have been identified that represent multiple future scenarios and across the different zones. The likelihood of each of these pathways has been determined based on the SOMs analysis. In addition, an Upper Extreme (UE) and Lower Extreme (LE) pathway have also been identified. For each representative pathway, a single representative climate model/scenario combination has bene identified from the CORDEX dataset which can then be used to provide additional information on specific climate variables for further study.

The expected change in critical climate variables for each of the selected climate scenarios and models for the different emission scenarios is shown in Table 5. The expected likelihood of the scenarios for each of the regions, including the Northern Region are shown in the following tables.

Table 5 | Change in critical climate variables for Tamale Metropolitan relative to the base period for the representative climate models representing the different future climate scenarios.

Climate variable	Baseline 1960-2000	2030-2040						*2050-2060*						2070-2080					
		A	B	C	D	LE	UE	*A*	*B*	*C*	*D*	*LE*	*UE*	A	B	C	D	LE	UE
RCP 2.6																			
TG	30.75	2%	3%	3%	3%	3%	3%	1%	5%	4%	4%	3%	4%	3%	5%	2%	2%	4%	4%
TXx	36.31	1%	3%	3%	3%	3%	2%	*1%*	*4%*	*4%*	*4%*	*3%*	*4%*	2%	5%	2%	2%	4%	4%
SU30	29.06	-1%	5%	7%	7%	10%	2%	*-1%*	*7%*	*7%*	*7%*	*12%*	*5%*	1%	7%	4%	4%	11%	4%
PRCPTOT	86.95	-2%	7%	-6%	-6%	-3%	9%	*-4%*	*8%*	*0%*	*0%*	*-6%*	*12%*	-6%	4%	8%	8%	-7%	6%
Rx1day	12.86	-36%	140%	-7%	-7%	-39%	56%	*-22%*	*141%*	*37%*	*37%*	*-44%*	*179%*	-17%	114%	224%	224%	-25%	115%
RCP 4.5																			
TG	30.75	3%	3%	3%	3%	6%	3%	5%	5%	5%	6%	7%	6%	7%	6%	6%	6%	7%	6%
TXx	36.31	3%	3%	3%	3%	6%	3%	*3%*	*4%*	*4%*	*6%*	*8%*	*6%*	6%	5%	5%	6%	7%	6%
SU30	29.06	6%	1%	1%	11%	21%	11%	*8%*	*2%*	*2%*	*18%*	*24%*	*18%*	10%	3%	3%	18%	24%	18%
PRCPTOT	86.95	-1%	-1%	-1%	-13%	-21%	-13%	*-1%*	*-8%*	*-8%*	*-16%*	*-14%*	*-16%*	-5%	0%	0%	-9%	-15%	-9%
Rx1day	12.86	4%	-43%	-43%	-166%	-60%	-166%	*6%*	*25%*	*25%*	*-80%*	*-13%*	*-80%*	-44%	1%	1%	60%	3%	60%
RCP 8.5																			
TG	30.75	3%	4%	4%	4%	5%	3%	4%	7%	7%	7%	9%	4%	8%	11%	9%	10%	14%	8%
TXx	36.31	2%	3%	3%	3%	4%	2%	3%	6%	6%	5%	9%	3%	7%	10%	8%	8%	14%	7%
SU30	29.06	0%	12%	2%	8%	7%	0%	*-1%*	*16%*	*6%*	*10%*	*12%*	*-1%*	1%	20%	8%	15%	15%	1%
PRCPTOT	86.95	-1%	-7%	28%	6%	27%	-1%	*7%*	*-5%*	*35%*	*22%*	*8%*	*7%*	0%	-3%	11%	6%	-8%	0%
Rx1day	12.86	100%	-81%	398%	78%	288%	100%	*108%*	*60%*	*380%*	*120%*	*219%*	*108%*	20%	22%	234%	70%	30%	20%

TG - Daily Mean Temperature; TXx - Maximum temperature; SU30 - Hot days with a maximum above 30ºC (SU30), PRCPTOT - Total Annual Precipitation; Rx1day - Maximum 1-day total precipitation

Table 6 | Results of joint pathways analysis across the four climate zones under RCP2.6

	Likelihood of Individual Scenarios				Expected Temperature (ºC) and Rainfall (ratio) Impacts.		
Scenario	**North**	**Central**	**Southwest**	**Coastal**	**2035**	**2055**	**2075**
A26	1 35%	1 30%	2 30%	1 35%	0.5/1.05	0.5/1.05	0.5/1.05
B26	2 25%	3 25%	3 20%	3 20%	1.5/1.05	1.5/1.05	2.0/1.05
C26	3 25%	2 30%	1 40%	4 15%	1.0/1.00	1.0/1.00	1.0/1.00
D26	4 15%	4 15%	4 10%	2 30%	1.0/0.95	1.5/0.95	1.0/0.95
UE A26	✓	✓	✗	✗	0.5/1.15	1.0/1.15	1.5/1.10
UE B26	✗	✗	✓	✓	1.0/1.10	1.5/1.10	1.5/1.05
LE A26	✓	✓	✓	✓	1.0/0.95	1.0/0.95	1.5/0.90

Table 7 | Joint pathways across the four climate zones under RCP4.5

	Likelihood of Individual Scenarios				Expected Temperature (ºC) and Rainfall (ratio) Impacts.		
Scenario	**North**	**Central**	**Southwest**	**Coastal**	**2035**	**2055**	**2075**
A45	1 50%	1 50%	2 40%	✗	1.0/1.00	1.5/1.00	2.5/1.00
B45	✗	✗	✗	2 40%	1.0/1.00	1.5/1.05	1.5/1.05
C45	2 40%	2 30%	1 45%	1 45%	1.0/0.95	1.5/0.95	2.0/0.90
D45	3 10%	3 20%	3 15%	3 15%	1.0/1.10	1.5/1.10	1.5/1.10
UE A45	✓	✓	✓	✓	1.0/1.15	1.0/1.15	2.0/1.15
LE A45	✓	✓	✓	✓	1.0/0.90	2.0/0.90	1.5/0.85

Table 8 | Joint pathways across the four zones under RCP8.5

	Likelihood of Individual Scenario				Expected Temperature (ºC) and Rainfall (ratio) Impacts.		
Scenario	**North**	**Central**	**Southwest**	**Coastal**	**2035**	**2055**	**2075**
A85	1 40%	1 40%	1 30%	3 30%	1.0/1.05	2.0/1.05	3.5/1.05
B85	2 35%	4 10%	3 25%	2 30%	1.5/0.95	2.5/0.95	4.5/0.90
C85	✗	2+3 50%	4 15%	1 40%	1.5/1.00	2.5/1.00	3.5/1.00
D85	3 25%	✗	2 30%	✗	1.5/1.10	2.0/1.10	3.5/1.15
UE A85	✓	✓	✓	✓	1.0/1.10	2.0/1.15	3.5/1.20
LE A85	✓	✓	✓	✓	1.0/0.90	3.5/0.90	5.0/0.85

4.5 Potential Climate Change Impacts

The potential impact of climate change on the priority risk domains for Tamale are described here.

4.5.1 Water Resources

Climate change is expected to contribute to a reduction in runoff for the northern parts of Ghana and including the area around Tamale Metro. This is largely due increased variability in rainfall and higher temperatures. Even with a potential increase in the likelihood of wetter climate scenarios for the northern region of Ghana, higher temperatures and associated increases in evaporation will result in an overall reduction in runoff except during periods of very high flow which will causing flooding.

More variable rainfall on its own will also contribute to an overall reduction in the availability of surface water (and potentially also groundwater) particularly if there is limited available storage capacity.

Severe degradation of the river through land clearing and unsustainable agricultural practices, sand mining, overgrazing, fuelwood harvesting and charcoal production, driven by population growth and a changing climate, is not only threatening water supply but also biological diversity in the White Volta basin (Awotwi, Yeboah & Kumi, 2014; Nsor, Ashiagbor & Danquah, 2019; Abu & Peprah, 2020; Tahiru, Doke & Baatuuwie, 2020; Arends, 2021). As a result of vegetation clearing for agriculture and settlements, and sand mining in the river channel and floodplain, water is becoming contaminated with sediments and pollutants and dry season water flows are decreasing (Kumordzi, 2020). Recent studies have demonstrated the sensitivity of river flows and water quality of the White Volta River to changes in land cover and land use in the basin (Awotwi et al., 2014; Tahiru et al., 2020).

It has been found that land cover transformation (involving the loss of natural vegetation) corresponded to a decrease in surface water and base flow (Awotwi et al., 2014), as well as an increase in the levels of turbidity and ammonia over a period of ten years (2007-2017); (Tahiru et al., 2020). The diminishing water quality significantly increases water treatment costs and the decreasing dry season flows has an impact on the quantity of water available for abstraction. Increased protection of the vegetation and soils of the Nawuni catchment is essential to ensuring water security and avoiding elevated water treatment costs (Anchor Environmental Consultants, South Africa, 2022).

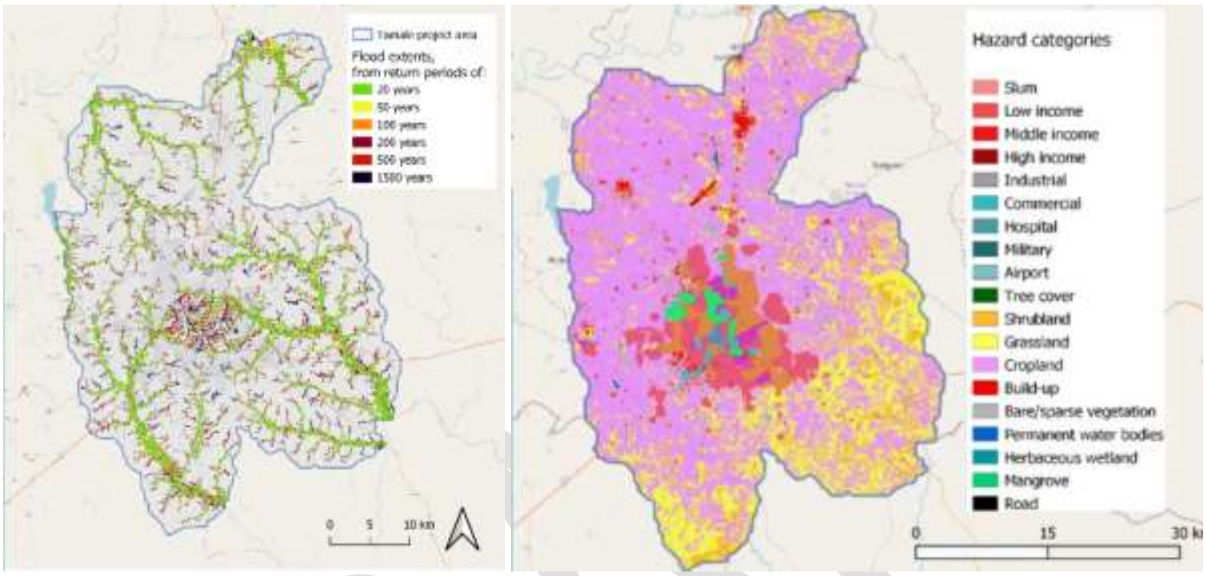
In 2022 a study carried out by Anchor Environmental Consultants, South Africa, was commissioned by Catholic Relief Services (CRS) in partnership with The Nature Conservancy (TNC) to develop a business case for the investment in proposed nature-based solutions for the Tamale Water Fund, as well as to engage with key stakeholders to get their support for the prioritisation of investments.

4.5.2 Flooding

Floods are dominated by two aspects: the presence of excessive water and the topographical characteristics of the area. The phenomenon of urban floods is caused by the effects of deficient or improper land use planning. Many urban areas facing the challenges of increased urbanization coupled with increasing populations, and high demands for land do not properly enforce legislations aimed at militating against floods. Understanding flood risk requires knowledge of the different types of floods, their probabilities of occurrence, how they can be modelled and mapped, what the required data are for producing hazard maps and the possible data sources for these (Jha, et al., 2012).

The natural topographic characteristics of Tamale city, being relatively flat, built upon a raised area with the rest of the city lower lying, combined with the hydro-meteorological conditions of the region are causing factors for the urban floods in Tamale. However, these are exacerbated by the rapid ‘unplanned’ urbanization resulting in the encroachment on natural drainage systems and drains.

A high-level assessment of the flood hazards, damage and risks in Tamale using a flood risk mapping and modelling approach was done in 2022 to improve the evidence-based information on urban flooding, to support the planning and implementation of solutions to alleviate the flood risk. The project area for this project was determined by assessing the extent of the built-up urban area and selecting the river basins to include those urban areas, which resulted in a bigger area than the Tamale Metropolis MMDA. This study defined flood risk as “*a combination of the probability (likelihood or chance) of a flood event (or flood hazard) happening and the consequences (impact) if it occurs*” (Triple Line Consulting Limited, 2022). The flood risk assessment was done combining flood hazard information for different return periods, land-use data (Figure 29), and flood damage curves (showing to what extent a maximum damage is reached depending on the flood depth) for each land-use type, and maximum damage values for each land-use type. These were then combined to determine an Average Expected Damage (AED) function for Tamale (Table 9). The flood hazard maps were also cross-checked against the presence of streams and drains that could be identified from satellite images. From these it was concluded that in general the hazard maps represent the position of streams and drains, but with some deviations. This is especially the case in Tamale and likely caused by limitations in the accuracy of the elevation defined for the Tamale region. Tamale is relatively flat deviating plus or minus 15-20 metres across the project area at an average slope of 1 degree.



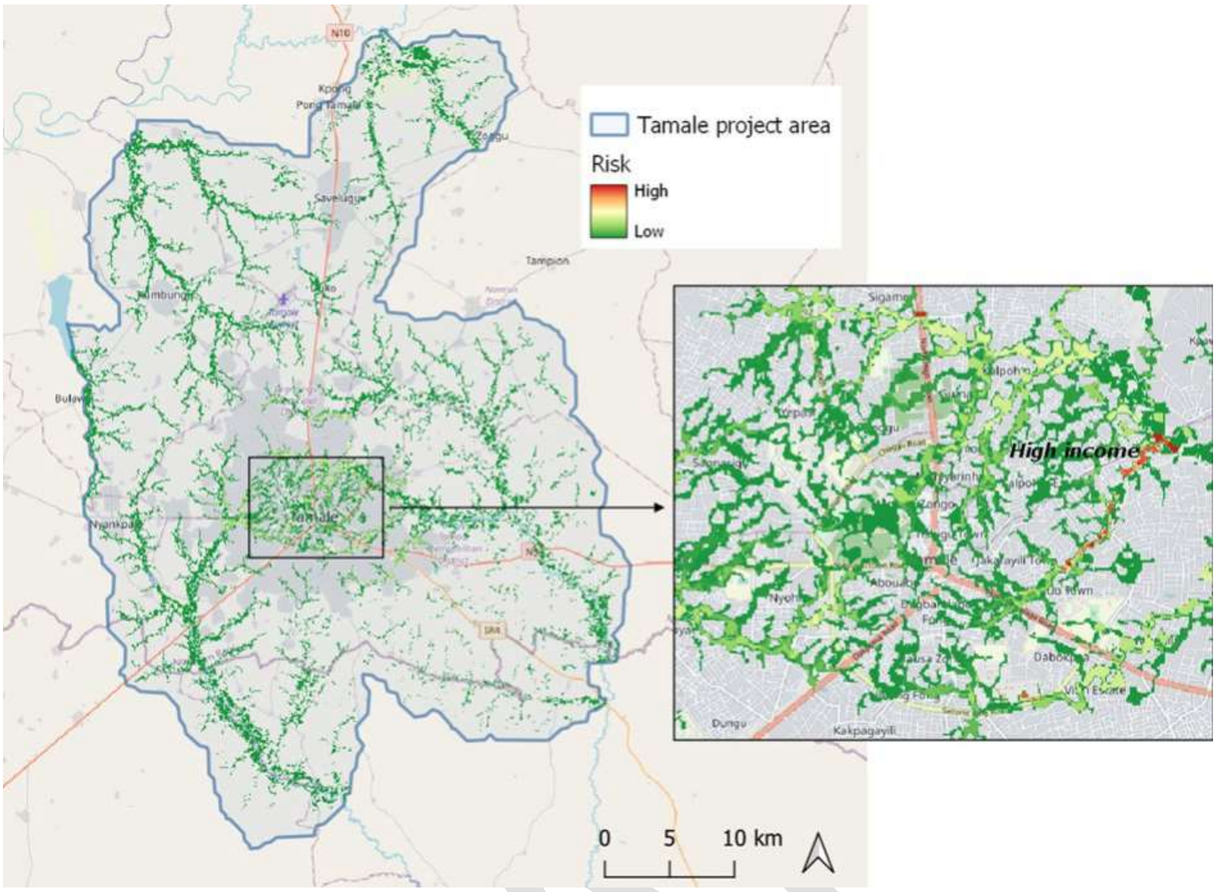
Source: (Triple Line Consulting Limited, 2022)

Figure 29 | Flood hazard and land-use maps for the Flood Risk Mapping and Modelling study area in Tamale

Table 9 | Flood damage and risk for Tamale for various return periods of flood

Damage caused by fluvial flooding Tamale (USD millions)													
Return period	Slum	Low income	Middle income	High income	Industrial	Commercial	Hospital	Military	Airport	Cropland	Build-up	Roads	Total
T20	-	274.4	228.1	56.8	-	3.2	-	-	-	31.8	1.7	2.6	599
T50	-	387.1	321.1	81.1	-	21.9	-	-	-	38.7	2.5	3.2	856
T100	-	504.7	390.8	109.6	-	53.9	-	-	-	44.7	3.2	4.0	1,111
T200	-	609.7	475.8	155.3	-	95.0	-	-	-	51.2	4.1	5.0	1,396
T500	-	812.1	638.3	233.4	-	205.3	1.6	-	-	62.0	6.2	6.8	1,966
T1500	-	1,153.5	906.6	342.2	-	318.1	2.7	-	-	80.4	10.1	10.1	2,824
AED	-	21.4	17.3	4.9	-	2.1	0.0	-	-	2.0	0.1	0.2	48
AED % of total	-	45%	36%	10%	0%	4%	0%	0%	0%	4%	0%	0%	100%

The maps below present the spatial representation of the flood hazard areas for Tamale. From this it can be concluded that in Tamale increased flood risk occurs across the entire project area. High risk areas in Tamale are mainly mixed-income residential areas inside these original floodplains, possible better described as flood paths. These areas should be prioritised when developing flood mitigation measures. However, as indicated, risks calculated for Tamale are likely overestimated. To address these inaccuracies the flood hazard model data and land-use data should be further improved. Further analysis at a finer scale of resolution is currently being done for a single catchment in Tamale.



Source: (Triple Line Consulting Limited, 2022)

Figure 30 | Flood risk map of Tamale MMDA

To calculate the future risk the return periods of rainfall events were recalculated (assuming similar effect on the likelihood of flood events) assuming that the daily maximum rainfall will have increased by 10%. This resulted in shorter return periods in the future as shown in Table 10. These changes in the probability of each level of flooding event where then used to determine a future AED. The study concluded that "a 10% increase in the maximum daily rainfall (due to climate change impacts) leads to a 92% increasing the Annual Expected Damage (AED). The environmental and social impacts of flooding would need to be assessed, and avoided costs calculated to provide a more comprehensive estimated of the potential total avoided cost of inaction" (Triple Line Consulting Limited, 2022).

Table 10 | Effect of climate change on flood return periods

Return period current situation	Return period future situation
T = 50	T = 20
T = 20	T = 10
T = 10	T = 6
T = 5	T = 4

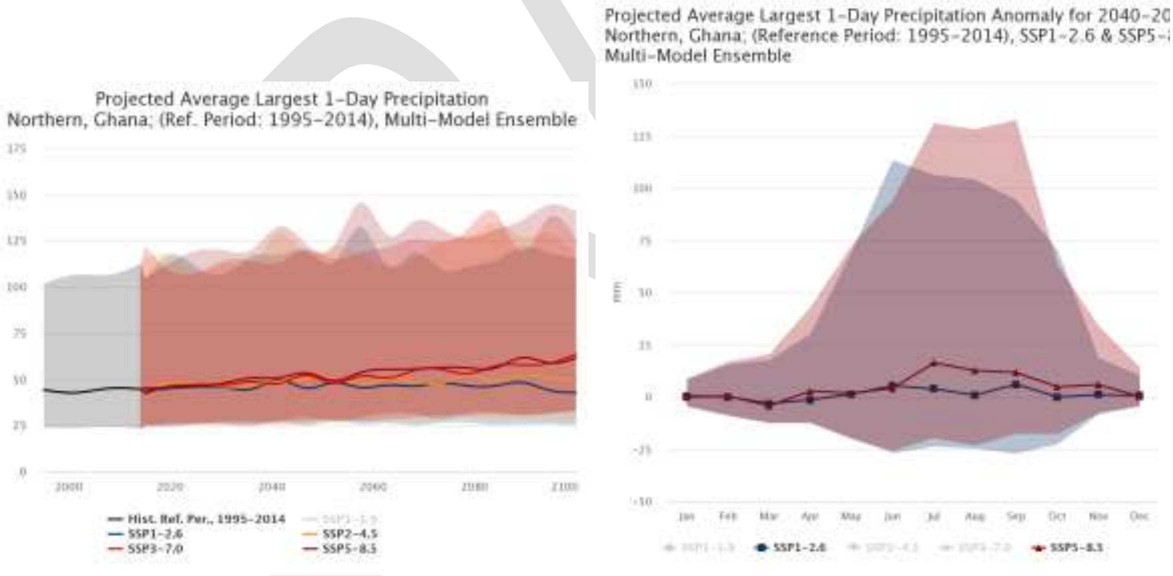
Source: (Triple Line Consulting Limited, 2022)

Table 11 | Climate change impact on flood damage and risk in Tamale for various return periods of flood

Damage caused by fluvial flooding Tamale (USD millions)													
Return period	**Low income**	**Middle income**	**High income**	**Industrial**	**Commercial**	**Hospital**	**Military**	**Airport**	**Crops**	**Built-up**	**Roads**	**Total**
T20	274	228	57	-	3	-	-	-	32	2	3	596
T50	387	321	81	-	22	-	-	-	39	2	3	852
T100	505	391	110	-	54	-	-	-	45	3	4	1,107
T200	610	476	155	-	95	-	-	-	51	4	5	1,391
T500	812	638	233	-	205	2	-	-	62	6	7	1,959
T1500	1,154	907	342	-	318	3	-	-	80	10	10	2,814
AED	41	33	9	0	4	0	0	0	4	0	0	92
AED % of total	20%	34%	6%	0%	19%	0%	0%	0%	18%	1%	1%	1

Source: (Triple Line Consulting Limited, 2022)

The expected change in the maximum daily rainfall under the different global emission scenarios for the Northern Region in Ghana from the CMIP6 ensemble is shown in (Figure 31) shows a significant increase under SSP3-7.0 and SSP5-8.5, but not under SSP2-4.5 and SSP1-2.5. The greatest impact is likely to be in July with the median values showing an increase of around 28% in the average maximum daily rainfall but with a range from -34% to +226% by mid-century (i.e. centred on 2050).



Source: Climate Change Knowledge Portal

Figure 31 | Expected change in the Maximum Daily Rainfall for the Northern Region in Ghana.

In terms of the expect change in the frequency of extreme events, probabilistic analysis of the maximum daily rainfall suggests that the on average the current 1 in 10 year and 1 in 100-year events could become up to 2.32 and 3.58 times more likely under SSP5-8.5 by 2050. The worst-case scenario (i.e. 90th percentile under SSP5-85) indicates that the 1 in 100 year event (current AEP = 1%) could become up to thirteen times more likely in any year by 2050. This indicates a significant increase in the risk associated with extreme rainfall events and flooding due to climate change.

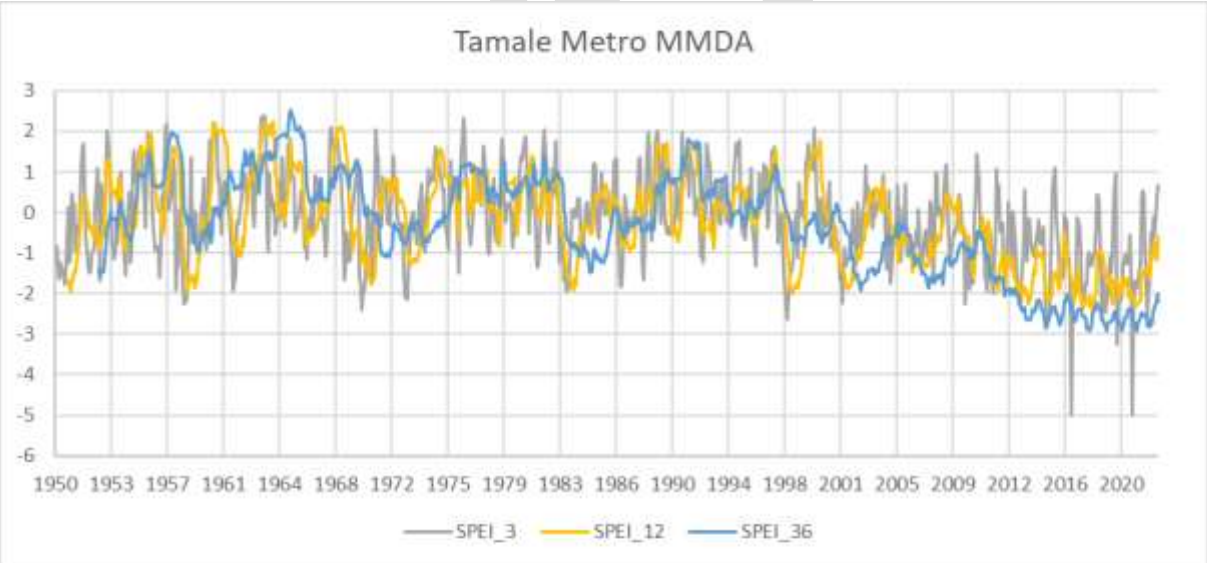
Table 12 | Expected change in Annual Exceedance Probability for Design Rainfall events for the Northern Region in Ghana by 2050 under different global emission scenarios.

Change in Annual Exceedance Probability, 2035-2064 (centre 2050) (change factor for occurrence/ year)						
Event	**10-yr**			**100-yr**		
	10th	**median**	**90th**	**10th**	**median**	**90th**
SSP1-1.9	0.82	1.55	2.32	0.67	1.95	3.58
SSP1-2.6	0.9	1.56	2.48	0.78	1.93	4.22
SSP2-4.5	0.95	1.8	3.06	0.96	2.47	5.77
SSP3-7.0	1	1.87	3.27	0.91	2.65	6.41
SSP5-8.5	1	2.32	5.15	0.99	3.58	13.05

Source: Climate Change Knowledge Portal

4.5.3 Drought

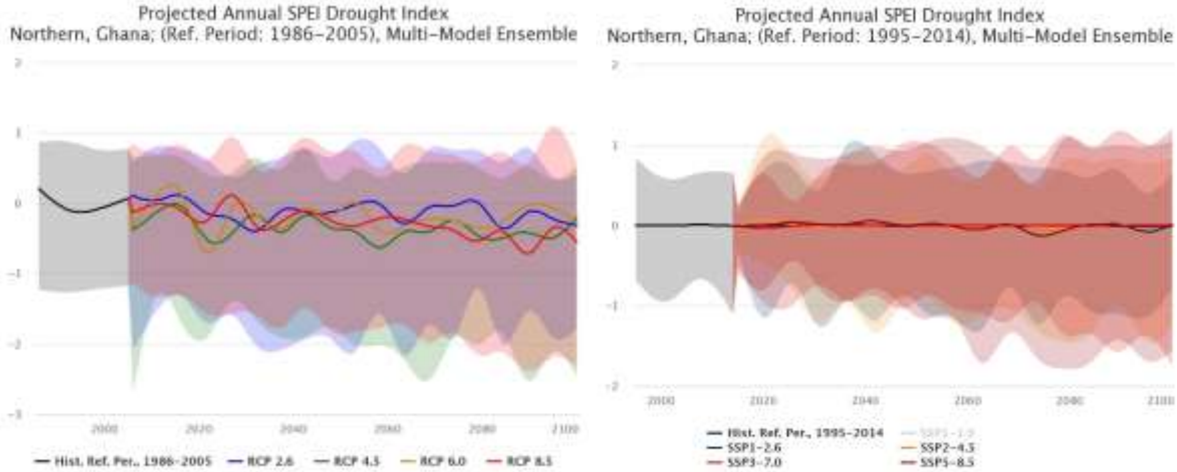
Tamale already experiences significant periods of drought. The trend in the Standardised Precipitation and Evaporation Index (SPEI), which is a commonly used indicator of drought, shows a significant increase in drying (Figure 32). This is indicated by the negative trend in the SPEI. In particular, the cumulative 3-year (36 month) SPEI shows the increasing nature of droughts. The annual SPEI trend is much more variable, but also has been consistently low since around 2009. The seasonal (3 – month) SPEI trends shows significant increase in the variability with both very dry as well as very wet periods.



Source: Data retrieved from ***https://spei.csic.es/database.html#p5***

Figure 32 | Observed trends in the SPEI in Tamale Metropolitan District, 1950-2010

Previous global climate models (i.e. CMIP5) tended to show a continued decrease in SPEI indicating a continued increasing risk for drought for the Northern Region of Tamale (9, left). The more recent global climate models (CMIP6), however suggest that there will be no significant increase in the risk of drought as indicated by SPEI (Figure 33, right). This is primarily as a result of the expected increase in precipitation indicated in the latest models as well as slightly lower increasing in temperate which would result in slightly less increase in potential evaporation. It is important to note, however, that there is a general decrease lower bounds of the ensemble (i.e. the lowest 10th percentile), which would suggest that there is still likely to be an increased risk of more regular and more extreme droughts in the region. There is also likely to be increased variability in both wet and dry periods.



Source: World Bank Climate Change Knowledge Portal

Figure 33 | Comparison of expected impacts of climate change on annual Standard Precipitation and Evaporation Index (SPEI) for the Northern Region of Ghana based on the CMIP5 (left) and CMIP6 (right) full ensemble of climate models for all future emission scenarios.

4.5.4 Wildfires

Wildfires have been identified as a problem in the catchment areas around Tamale because both the intensity and frequency of fires have increased in recent years. Wildfires are started mainly from human activities such as honey tapping and group hunting, but they are more likely to occur on hot days. Hunters start fires to flush small mammals and rodents and the local communities are apathetic about wildfires. As a result, the majority of seedlings from natural regeneration do not survive the dry season, as shown by studies on the woodland structure in the Red Volta Valley (Adjewodah et al. 2006). Most of the plants (73%-82%) are less than 5cm in diameter, thus the late dry season wildfires cause high casualties among this sapling group and prevent their succession to adult trees by the end of February every year. Wildfires also affect rivers, especially when they burn the moist gallery forests where most trees are not fire-adapted compared to savanna woodland species.

The risk of wildfires is affected by increasing number of hot and windy days as well as an accumulation of fuel load and an increased potential for them being started either by people, or as a result of natural events such as lightening. The future climate change scenarios for Tamale suggest that both the average daily temperatures and the number of hot days will significantly increase which is likely to contribute to an increasing risk of wildfires, particularly with an increasing risk of ignition.

4.5.5 Water Security and Supply

Neary half of the water used in Ghana originates from three international rivers (Volta, Bia, Tano), which flow into the country from outside of Ghana's borders, putting the country at risk of **water insecurity** and political tensions should water availability decline. Currently, tensions already exist between Ghana and Burkina Faso due to Burkina Faso's decision to withdraw its water from the Volta Basin, reducing water levels and impacting hydropower generation in Ghana[10].

The Volta Basin flows could be reduced by as much as 24% by mid-century and by as much as 45% by end of the century due to reduced rainfall and increased evaporation (USAID, Climate Change Risk Profile – Ghana (Fact Sheet), 2017). Clean water and sanitation are a challenge for some areas and communities in Ghana, where approximately 25% of the population lacks access to clean water.

Declining rainfall, increased levels of drought and rising temperatures in addition to increased pressures from a growing population, urbanization, and industrialization are likely to further compound this issue.

[10] Republic of Ghana (2015). Ghana's Third National Communication to the UNFCCC. URL: https://unfccc.int/resource/docs/natc/ghanc3.pdf

The reduced quantity and quality of water will be a significant challenge for human consumption as well as use in the agriculture, industry, and hydropower sectors.

Rising sea levels are already increasing salinization in coastal water sources and wells[11].

Poor areas in the country (especially the northern part) disproportionally suffer from droughts, floods and soil erosion that are adversely affecting agricultural production; newer challenges in flood management due to urbanization; and flooding exacerbated by poor land use and limited mitigation infrastructure [12&13]. Rainfall and evaporation changes also impact rates of surface water infiltration and recharge rates for groundwater, which, when coupled with low-water storage capacity, increases the country's vulnerability to unreliable rainfall patterns. This has the potential for further decreased reliability of groundwater and surface water sources during droughts or prolonged dry seasons.

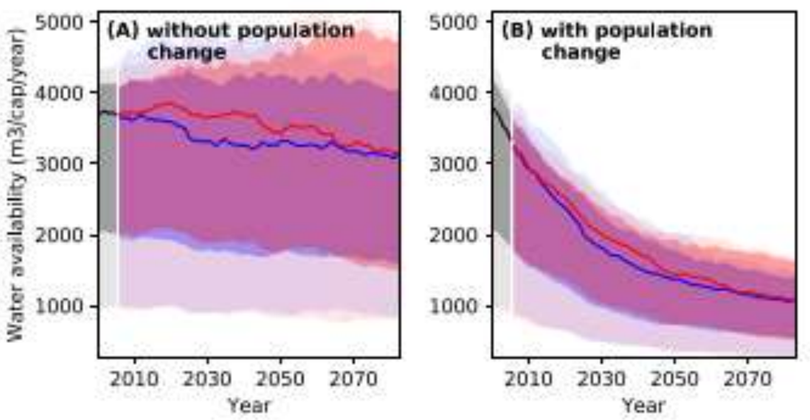
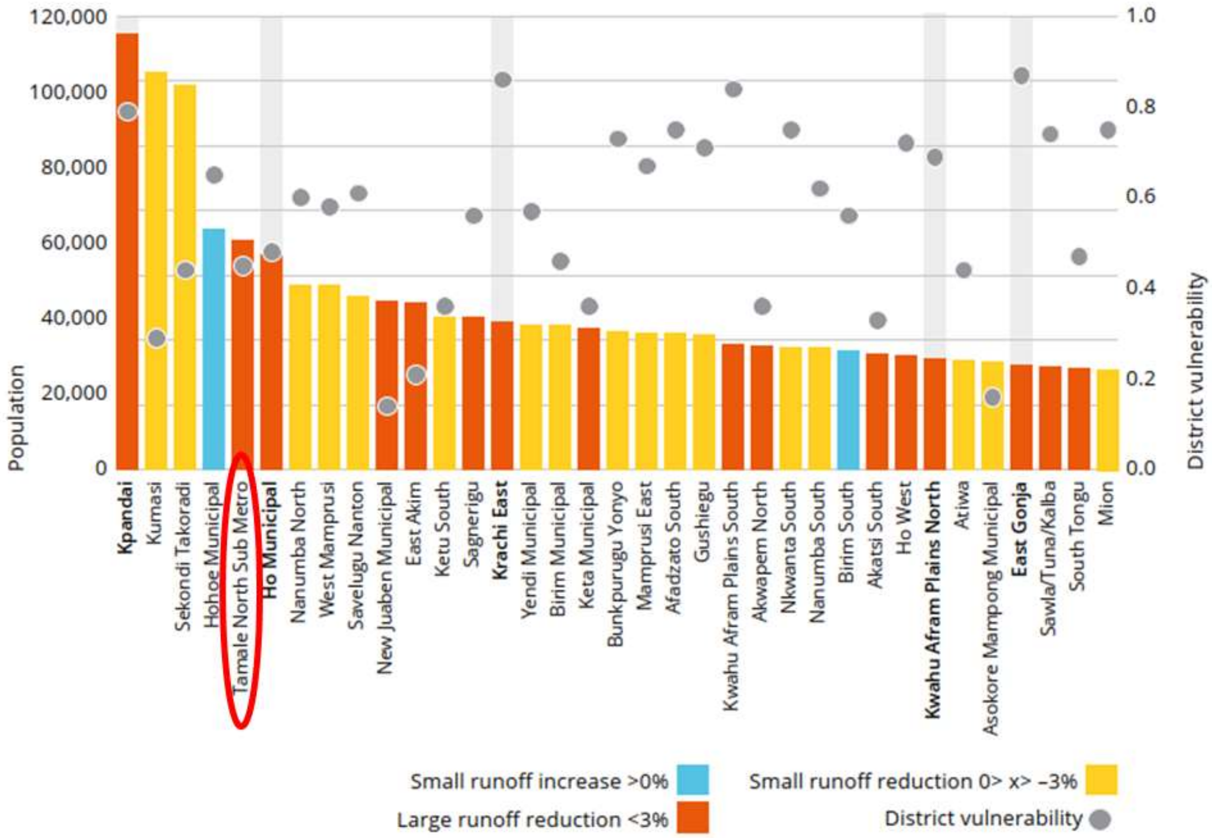


Figure 34 | Projected water availability from rainfall per capita and year with national population constant at year 2000 level (A) and changing according to SSP2 projections (B) for different GHG emission scenarios relative to the year 2000 for Ghana

As part of the national level climate change risk assessment for infrastructure, the climate change risk for water supply to Tamale was considered to be very high as a result of an expected reduction in local surface water runoff. These results were based on the original CMIP5 climate scenarios, while the more recent CMIP6 climate models suggest a potential increase in precipitation. Increasing precipitation does not necessarily result in increasing water availability as increasing temperatures will also lead to greater evaporation and losses, but it may be that the latest climate scenarios could result in less of an impact on surface water runoff. This is however likely to also be much more variable and as a result could still contribute to significant increasing water scarcity, particularly as a result of a lack of storage and also increasing risks due to flooding and catchment degradation and sand mining.

[11] Republic of Ghana (2015). Ghana's Third National Communication to the UNFCCC. URL: https://unfccc.int/resource/docs/natc/ghanc3.pdf
[12] Yeleliere, E. et al (2018). "Review of Ghana's water resources: the quality and management with particular focus on freshwater resources". Applied Water Science. https://doi.org/10.1007/s13201-018-0736-4
[13] Obuobie, E. et al (2012) "Assessment of vulnerability of river basins in Ghana to water stress conditions under climate change". Journal of Water and Climate Change, 03.4. DOI: https://doi.org/10.2166/wcc.2012.030



Source: (Ghana: Roadmap for resilient infrastructure in a changing climate, 2022)

Figure 35 | Climate change risk for water supply infrastructure – exposure to flooding, drought and reduced runoff due to climate change for selected MMDAs

4.5.6 Crop and Livestock Productivity

Agriculture is a key sector for Ghana's economy, household livelihoods and food security. The sector employs more than half the population on a formal and informal basis, and accounts for almost 20% of GDP and almost half of export earnings. The sector is the main source of livelihood for the majority of the country's poorest households. Two-thirds of non-oil manufacturing depends on agriculture for raw materials, and accounts for a major share of all economic activities and livelihoods among smallholder farmers. Ghana produces variety of crops in various climatic zones which range from dry savanna to wet forest and which run in east west bands across the country. Ghana's agriculture sector is made up of crops, livestock, fisheries and forestry. The crops sub-sector includes industrial crops (e.g. cocoa, rubber, oil palm, coconut, cotton), starchy and cereal staples (e.g. cassava, yam, maize, rice, plantain), and fruits and vegetables (e.g. pineapple, banana, cashew, citrus, mango).

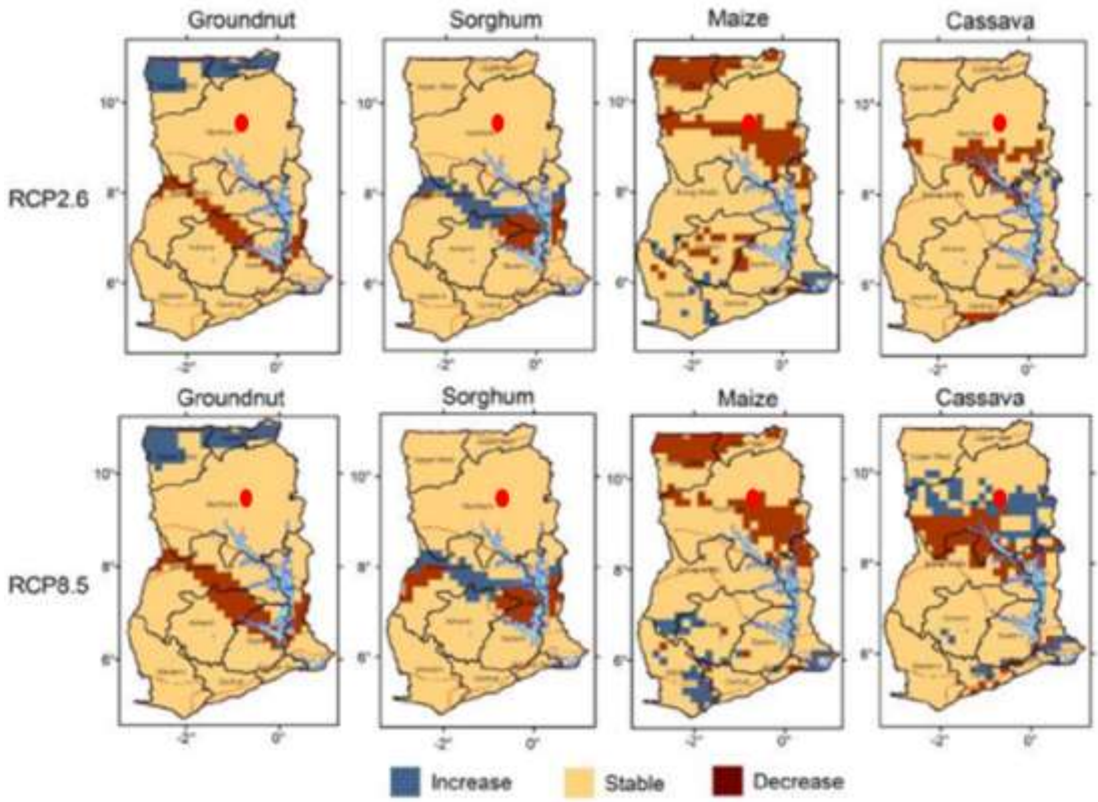
Rising temperatures are projected to lower yields in major staple crops (cassava, yams, plantains, maize and rice). Cassava yields, for example, are projected to fall by 29.6% by 2080 and maize yields by 7% by 2050. Cases of total crop failure are projected to occur approximately once every five years in Ghana's northern region due to delayed or diminished rainfall. Cocoa, a major cash crop and the country's second leading foreign exchange earner, is sensitive to rising temperatures as well as drought. Suitable areas for cocoa production, mainly along the coast, are also decreasing due to temperature increase, floods, soil salinization and continued coastal erosion.

Yield losses may additionally become more severe as interannual rainfall variability increases and the length of growing seasons shorten. Rising temperatures are likely to increase presence of pests and diseases leading potentially to crop failure and reduced yields, especially for cassava, a key food staple. Reduced rainfall will shorten growing seasons and the desertification of agricultural land brought about by unsustainable farming practices, such as limited crop rotation and poor soil management, will further inhibit production[14].

Animal production is an important part of agriculture in Ghana, as it plays a vital role in rural livelihoods of small-scale farmers for meeting needs such as food and generates income. Cattle, pig, poultry, goat, and sheep are some of the predominant livestock produced in Ghana. Although the livestock production index in Ghana in 2019, indicated an increase from the preceding year, climate variability and change are a threat, especially through negative impacts on the major fodder sources, such as rangelands and crop residues. The adverse effects of climate change on livestock farming and how to overcome such effects is a situation that requires critical attention.

Crop and Livestock Productivity in Tamale are highly vulnerable to the effects of climate variability and change, because of its excessive reliance on rainfed agriculture, and extreme poverty. As a result, the sector is characterized by low productivity levels. Erratic precipitation patterns have severe consequences for productivity as only 2% of the country's irrigation potential is in use. In addition to the direct impact of droughts, discussed in a previous section, climate change will likely have an impact on overall crop productivity. A recent study on the potential impacts of climate change on crop productivity across Ghana shows the impact that this will have including for Tamale (Figure).

Based on the results from this study, it is likely that maize will be the most severely impacted crop type in the region of Tamale with an expected decrease in crop productivity under both RCP2.6 and RCP 8.5. This analysis suggests a potential for increased productivity for Casava under RCP8.5. The most recent climate models (CMIP6) suggest a possible increase in rainfall for Tamale and the Northern Region of Ghana, which could potentially improve crop productivity for some crop types in the area, however this is likely to be accompanied by increased variability in rainfall and greater risk of flooding.



Source: (Murken, et al., 2019)

Figure 36 | Modelled change in crop suitability for selected crops in Ghana under different scenarios

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[14] IFPRI (2012). Ghana – Strategy Support Program, climate change, agriculture, and food crop production in Ghana. URL: http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/127134/filename/127345.pdf

Table 13 | Expected Change in Crop Suitability by 2050 (Tamale)

Crop Type	RCP 2.6	RCP 8.5
Groundnut	Stable	Stable
Sorghum	Stable	Stable
Maize	Decrease	Decrease
Cassava	Stable	Increase

4.5.7 Human Health

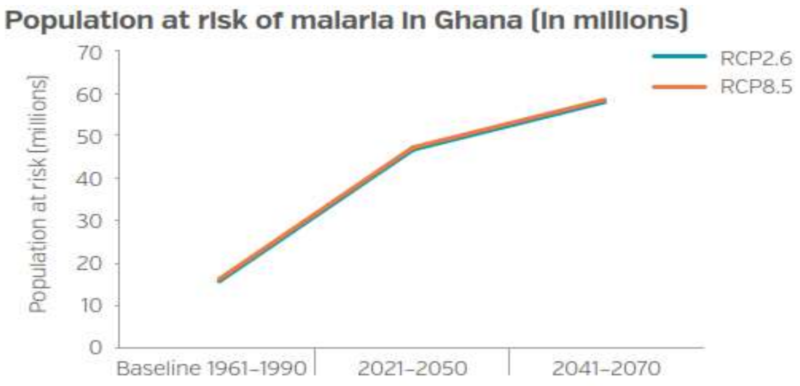
Ghana is highly vulnerable to the negative health implications of climate change. Changes in key climate hazards are expected to impact food and water security, human settlements, infrastructure, and ecosystems and increase the prevalence and geographic extent of vector and waterborne diseases. Increased disease prevalence will be immensely significant in densely populated urban areas, such as Tamale, where temporary settlements lack access to clean water and sanitation.

Flash Floods which have recently become more common in Tamale, commonly lead to cholera outbreaks across the country. Malaria remains a significant challenge and is likely to increase as temperatures rise and flooding becomes more common, particularly in coastal and urban zones.

The impacts of climate change on health, further exacerbate existing health disparities and disproportionately affect vulnerable communities such as low-income and marginalized populations by compounding the existing burden of disease and barriers to accessing health services, often at the times when they are most needed. Flooding also damages critical health infrastructure like hospitals.

Access to improved sanitation is low overall (20% of urban and 9% of rural populations). Flooding commonly leads to cholera outbreaks across the country. Malaria remains a significant challenge and is likely to increase as temperatures rise and flooding becomes more common, particularly in coastal and urban zones (USAID, Climate Change Risk Profile – Ghana (Fact Sheet), 2017).

Climate and socio-economic factors affect the spread of some vector and water-borne diseases. Temperature, precipitation and humidity strongly influence the life cycles of the vectors and the infectious agents that carry and control the transmission of water-borne and vector-borne diseases. With climate changing the changes in precipitation patterns are eminent, and temperatures are expected to rise in Tamale. Warmer temperatures will increase the range and reproduction rates of disease-carrying organisms like mosquitos and ticks and thus increase the incidence of diseases like malaria and dengue fever. At the same time, changes in precipitation patterns can cause stagnant water to form, serving as a breeding ground for disease-carrying organisms. Population growth will also increase the population at risk in areas where malaria presence is static in the future. According to the study by World Health Organisation (WHO), under high (RCP8.5) and low (RCP 2.6) emissions scenarios, over 58 million people are projected to be at risk of malaria in Ghana. (WHO, 2015)



Source: (WHO, 2015)

Figure 37 | Population at risk of malaria in Ghana

The health of Tamale's population is expected to be aggravated by heat stress, other vector-borne diseases such as dengue fever and yellow fever, air pollution, communicable diseases such as HIV/AIDS, cholera and TB, and other respiratory disease. Higher temperatures, land and water scarcity, flooding, drought and displacement will all impact agricultural productivity and can contribute to breakdowns in food systems. This disproportionally affects those most vulnerable to hunger and can lead to food insecurity. Vulnerable groups risk further deterioration into a food and nutrition crises if exposed to extreme weather events Without considerable efforts made to improve climate resilience, the risk of hunger and malnutrition globally could increase by up to 20% by 2050.

In Ghana, the prevalence of child malnutrition in children under age five is 13.4%[15]. Under a high emissions scenario heat-related death in the elderly (65+ years) are projected to increase to 70 deaths per 100,000 by 2080 compared to the estimated baseline of approximately 2 deaths per 100,000 annually between 1961 and 1990[16] The annual distribution of days with a high-heat index provides insight into the health hazard of heat. The expected increase in the number of high heat index days (>35 deg C) for the Northern Region in Ghana under different climate scenarios is shown in Figure 38.

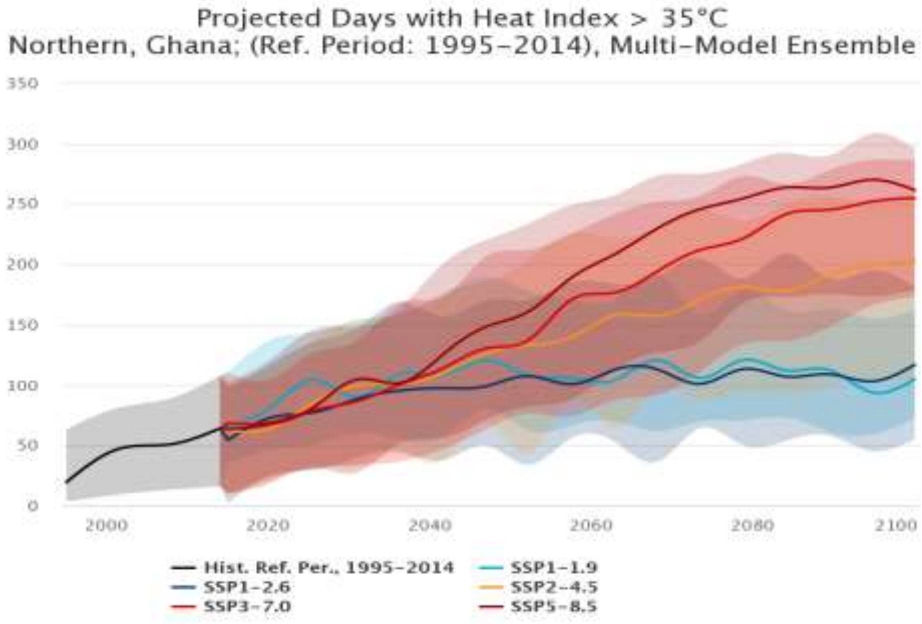


Figure 38: Expected increase in days with a High Heat Index for the Northern Region in Ghana

[15] WHO (2015). Climate and Health Country Profile – Ghana. URL: https://apps.who.int/iris/bitstream/handle/10665/208862/WHO_FWC_PHE_EPE_15.08_eng.pdf?sequence=1

[16] WHO (2015). Climate and Health Country Profile – Ghana. URL: https://apps.who.int/iris/bitstream/handle/10665/208862/WHO_FWC_PHE_EPE_15.08_eng.pdf?sequence=1

5 Climate Change Risk Assessment

5.1 Identify Critical Climate Related Hazards

The climate analysis and baseline research (presented in previous chapters) revealed that Tamale is already affected by several climate extremes, such as unpredictable and erratic rainfall (floods and droughts) and temperature extremes and that these are likely to increase into the future.

Through a multi-stakeholder workshop, the climate hazards common to the Tamale were validated by engaging with stakeholders to determine climate hazards through their perceptions. Table 14 presents 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.

Table 14 | Climate change hazards identified during the Tamale stakeholder workshop (29-Nov-2022)

Systems and Assets Exposed to climate hazard	Climate Hazard	Climate risk and potential impacts
Damage to water treatment plant.	Extreme Rainfall	Heavy precipitation can lead to damage to the water treatment plant.
	Prolonged Drought	Droughts and changing precipitation patterns can affect the availability and the quality of the water for communities and businesses using both local sources and regional sources.
	Floods	Heavy precipitation can lead to flooding and damage to the water treatment plant. This is added to by releases made from the upstream Bagre dam when the dam exceeds its maximum level. Floodwaters also carry large amounts of sediments that affects the water quality and operation of the treatment plant. Increased sediment loads also raise the bed level and increase the flood risk. Catchment degradation and sand mining also increase sediment.
Water Supply Systems and Infrastructure	Extreme Rainfall, Flooding and Storms	Extreme weather events, such as storms and floods can cause damage to water supply infrastructure and disrupt operations.
	Drought	Droughts and changing precipitation patterns can affect the availability and the quality of the water for communities and businesses using both local sources and regional water sources.
Water Resources	Higher temperatures and evaporation	Rising temperatures can lead to increased evaporation and lower surface and groundwater levels for both local and regional sources.
	Extreme Rainfall	Heavy rainfall events can lead to surface water runoff and erosion.
	Drought	Prolonged dry periods can lead to lower river and stream flows.
	Flooding	Flooding causes erosion, and increased sediment loads in rivers leading to the contamination of water resources.
Communities along riverbanks	Flooding	Fluvial flooding can damage homes and other forms of property around the riverbanks, leading to financial losses for communities and disrupting people's livelihoods. Also damage to crop lands.
Urban flooding and storm water management.	Frequent and intense storms	Changes in precipitation patterns can lead to more frequent and intense storms, which can overwhelm the capacity of stormwater systems and increase the risk of urban flooding.
Damage to road infrastructure.	Flooding	Heavy precipitation and increased frequency of floods can cause washouts, landslides, and erosion to rural roads, making them impassable and difficult to access.
	Storms	Storms can damage or destroy roads, bridges, and other infrastructure, causing disruptions to transportation and access to essential services.
	High Temperatures	High temperatures can cause roads to expand and contract, leading to cracking, potholes, and other types of damage.

Systems and Assets Exposed to climate hazard	Climate Hazard	Climate risk and potential impacts
Agriculture	Rising temperatures and more variable precipitation.	Rising temperatures, more extreme weather events, and changing precipitation patterns all have adverse effects on crop yields and livestock health. Crops fail due to floods, water logging, drought, extreme heat, and storms. Potential change in crop suitability.
	Changing precipitation patterns (more frequent dry spells and floods)	Heavy precipitation and increased frequency of floods can cause waterlogging and damage crops while dry spells and prolonged drought lead to water shortage and crop failure
	Storms	Increased number of storms and lead to crop failure.
	Pests	Increasing temperatures and precipitation (i.e. more flooding) are likely to increase the risk of infestation of pest and diseases leading to crop failure and reduced livestock production.
	Hotter Temperatures	Hotter temperatures will reduce livestock productivity.
Health systems	Bushfires	Hotter temperatures can lead to more bushfires that will contribute to poor air quality and increased exposure to pollutants, which can exacerbate respiratory and cardiovascular illnesses.
	Changes in temperature and precipitation	Changes in temperature and precipitation can alter the distribution and abundance of malaria-carrying mosquitos, leading to a potential for increased risk of malaria.
	Flooding and heavy precipitation.	Flooding and heavy precipitation can increase the risk of waterborne diseases such as cholera, typhoid, and diarrhoea. Flooding can also damage critical health infrastructure and limit access to hospitals.
	Climate extremes	Floods, storms, and wildfires can lead to displacement, loss of property, and trauma, which can contribute to mental health issues such as anxiety and depression as well a direct physical impacts.

5.2 Impact Story Lines for Priority Risk Domains

In order to better understand the climate change related hazards, vulnerability and exposure for 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:

- Risk 1: Lack of clean and safe water for the community, livelihoods, and business.
- Risk 2: Flooding of critical infrastructure, crop lands, buildings, and settlements.
- Risk 3: Increase in occurrence and spread of diseases
- Risk 4: Decline in agriculture production
- Risk 5: Loss of livelihoods

5.2.1 Risk 1: Water Security and Supply

Climate change is expected to exacerbate water scarcity. Rising temperatures and changing precipitation patterns can lead to droughts, and altered river flows, which can decrease the availability of fresh water for human and ecosystem needs. In Tamale, there is a risk of significantly higher temperatures under all emission scenarios, even at lower GHG concentration scenarios. Precipitation projections are statistically insignificant under lower emission scenarios. However, under RCP 8.5, precipitation will significantly increase. The temperature increases and the possible change in precipitation patterns will bring unprecedented impacts on water resources and worsen water scarcity.

Climate change can also increase the frequency and severity of extreme weather events, such as floods and storms, damaging the water treatment and water supply infrastructure and contaminating water supplies. Increased flooding also leads to increased costs for the treatment of water for drinking.

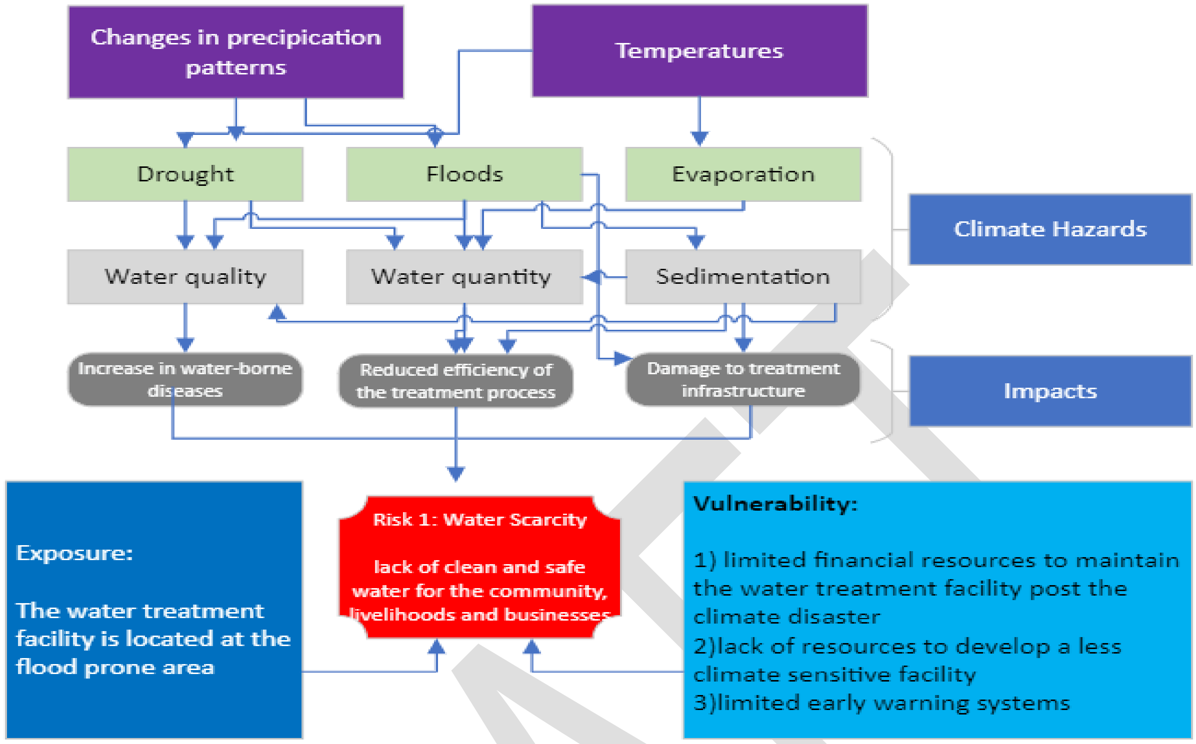


Figure 39 | Water Treatment Plant Impact Chain Diagram

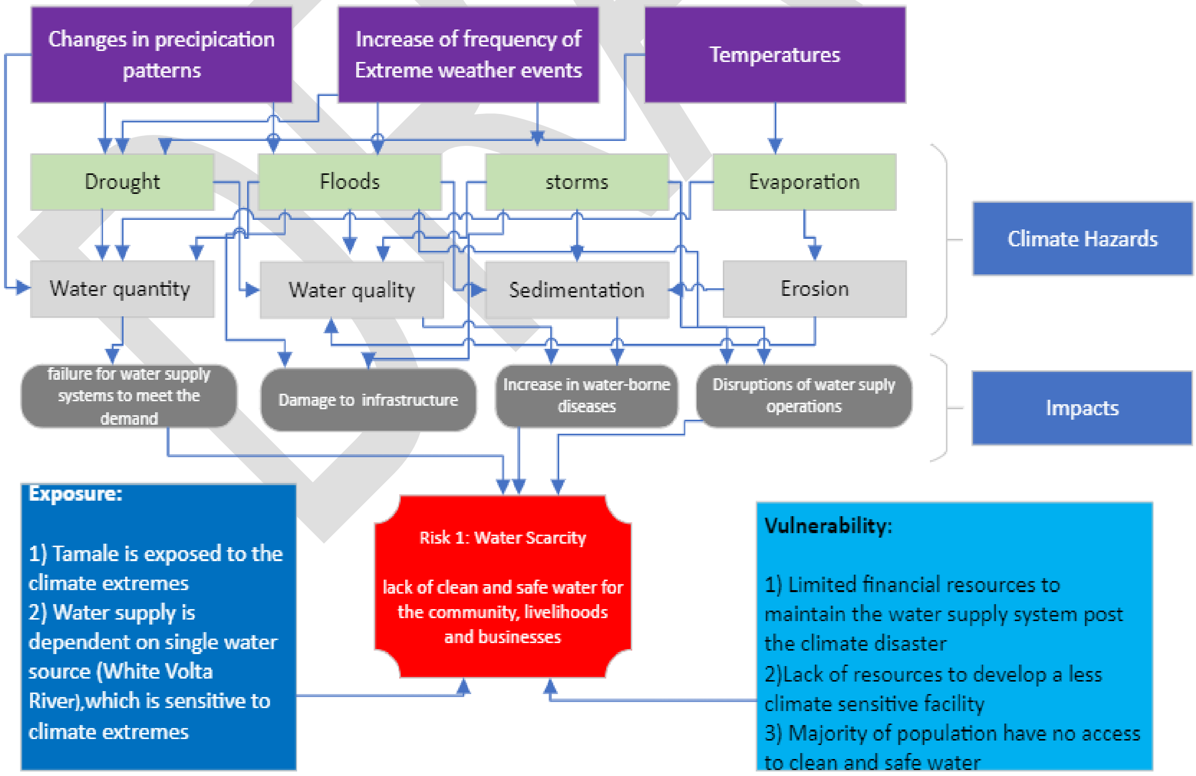


Figure 40 | Water Security Impact Chain Diagram

5.2.2 Risk 2: Flooding

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, storm surges, and changes in land use, causes fluvial 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. The floods also have long-term impacts on the soil quality, affecting agriculture and livestock.

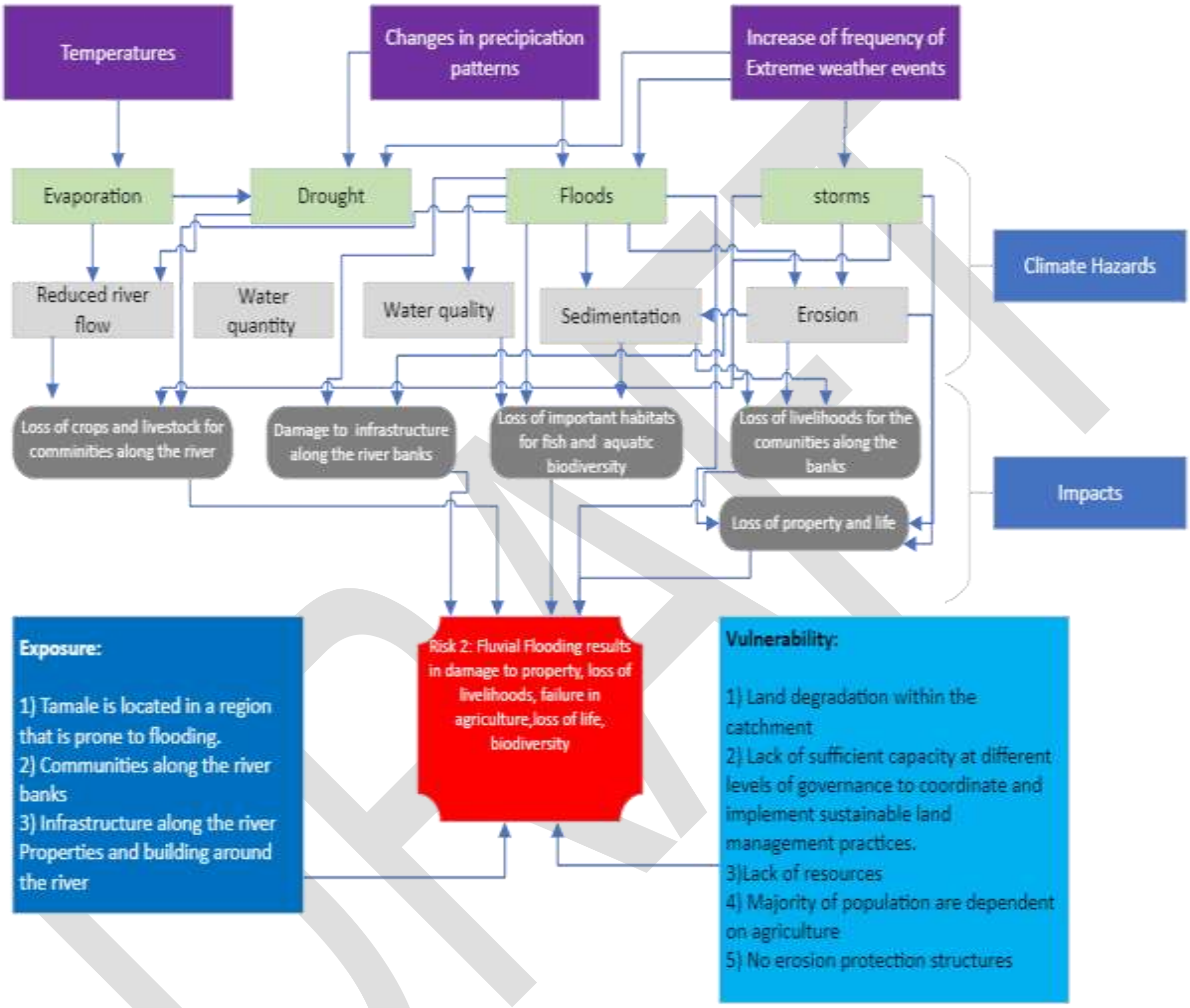


Figure 41 | Flooding Impact Chain Diagram

5.2.3 Risk 3: Community Health

The factors contributing to an increased risk to human health are shown in Figure 42. Climate change impacts are far-reaching and detrimental to human health, affecting mental and physical health. Tamale is particularly vulnerable to climate hazards such as heatwaves, bushfires, floods and drought, affecting the community health through some of the following climate impacts: increased heat stress and stroke, increase in vector- and water-borne diseases, increased respiratory problems and psychological challenges due to the displacement of communities. The spread of climate-related diseases, injuries and loss of life are becoming common due to climate hazards. The conditions are exacerbated by underlying vulnerabilities such as high poverty levels, limited access to health facilities, and a population with already existing health disparities.

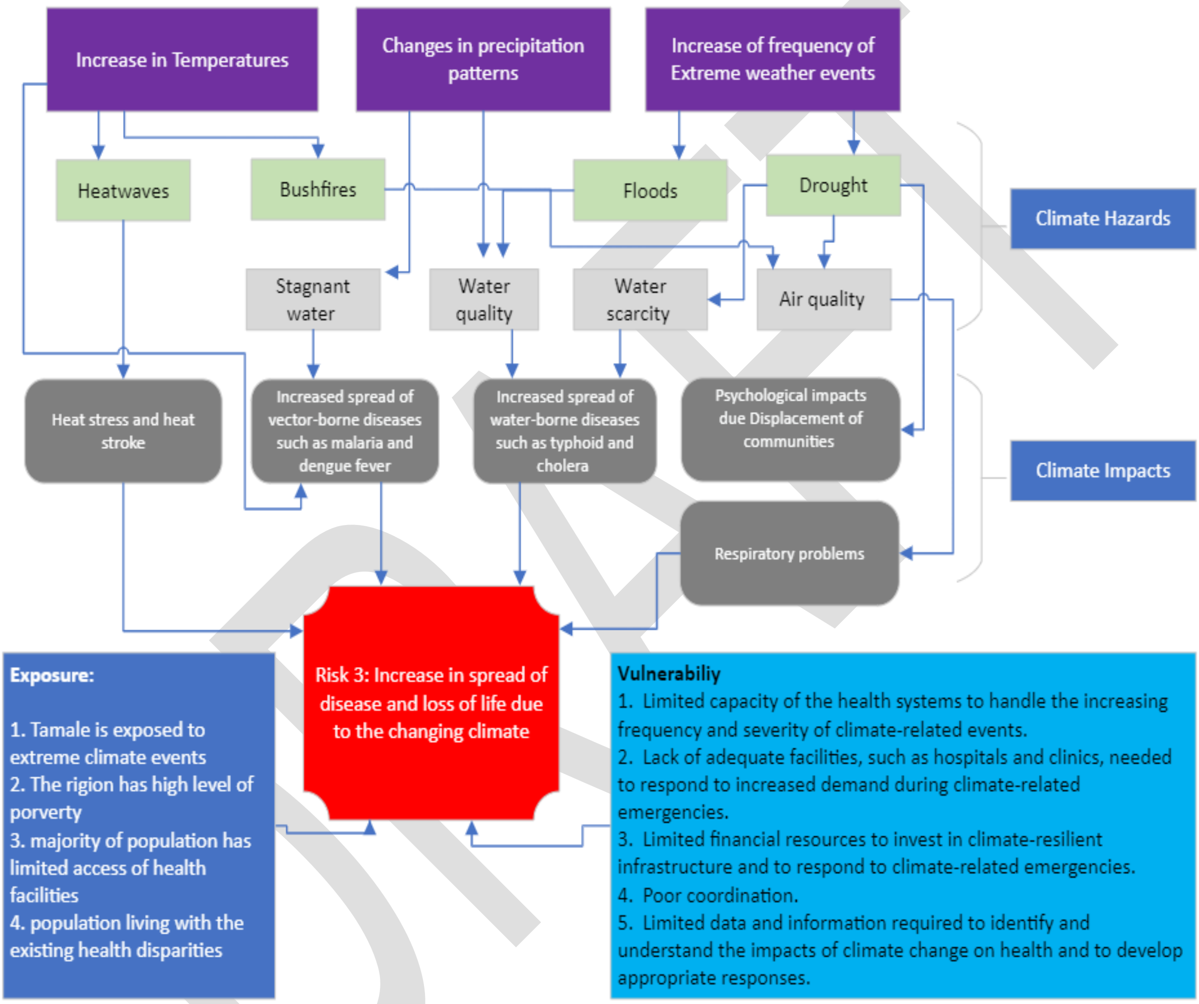


Figure 42 | Health system Impact Chain Diagram

5.2.4 Risk 4: Decline in agriculture production

The factors contributing to the decline in agriculture production are shown in Figure 43. The changes in climate have detrimental impacts on agriculture production due to an increase in climate hazards manifesting through drought, floods, heatwaves, and storms. Such hazards directly increase exposure of smallholder farmers to climate impacts of reduced irrigation water resulting; in crop failure and loss of livestock, which in-turn increases poverty levels. The impacts are worsened by factors such as lack of access to information and technology (climate-smart agriculture), lack of access to weather forecasts, and weak institutional capacity to support the farmers, as well as catchment degradation.

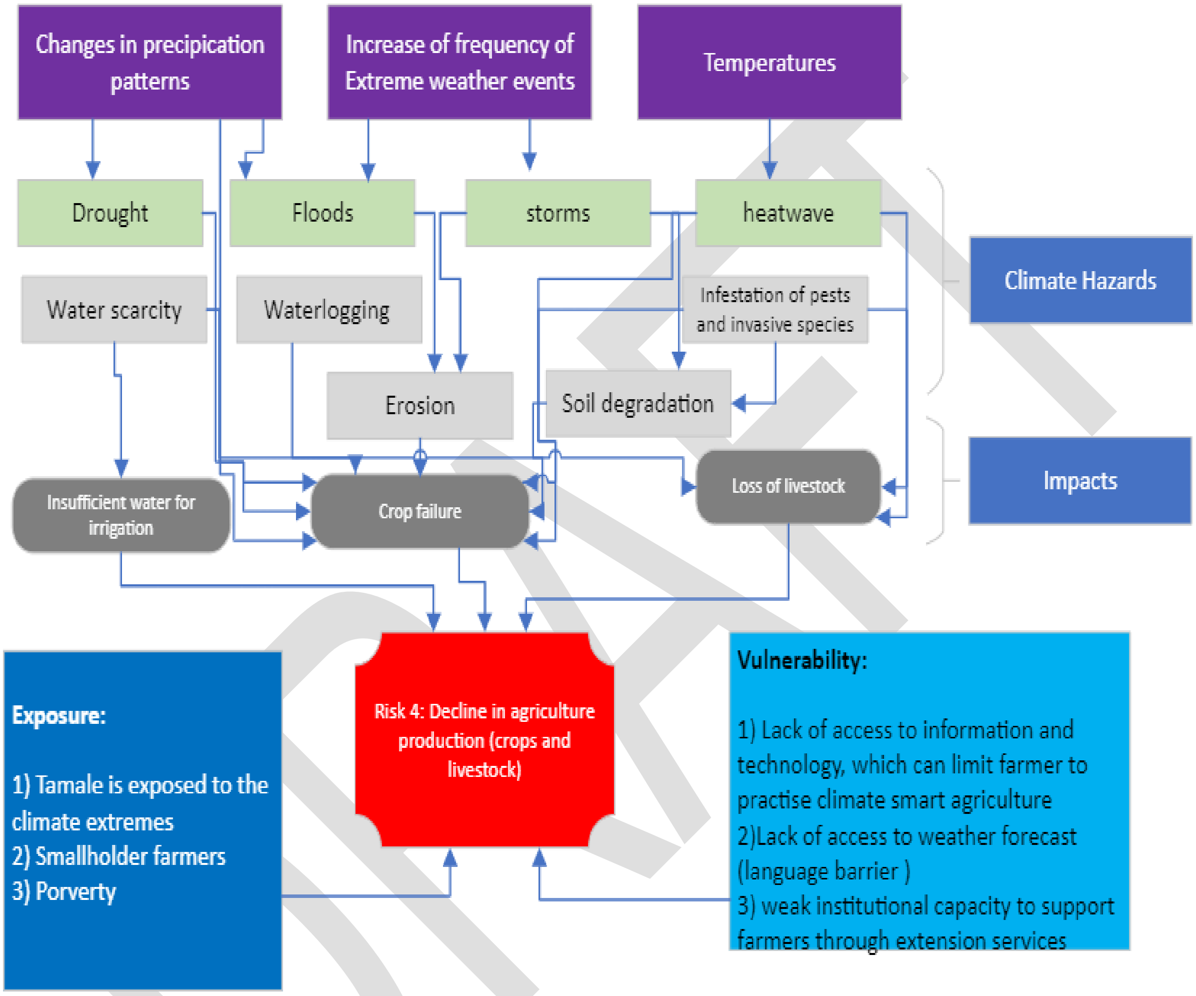


Figure 43: Agriculture Impact Chain Diagram

5.2.5 Risk 5: Loss of Livelihoods

The factors contributing to an increased risk to Livelihoods are shown in Figure 44. Livelihoods in Tamale are affected by the climate hazards; flooding, heavy rainfall, drought, increased temperature, and evaporation which increases the exposure (to climate impacts) of small-scale farmers and fishers, the unemployed, poverty-stricken communities, and those living within the flood-prone areas, such as along the riverbanks. In the region, climate change impacts will be experienced through; decreased water quality and quantity, high rates of land degradation, erosion and sedimentation, which affects livelihoods by reducing water available for farming and domestic uses, increasing water- and vector-borne disease, damaging infrastructure and disrupting services along the riverbanks, loss of arable and habitable land, which in turn affects the socio-economic activities in the region, lastly, there will be an increase in injuries and loss of life. These impacts will increase the vulnerability of the communities dependent on climate-sensitive livelihoods and lack of resources to improve their adaptive capacity.

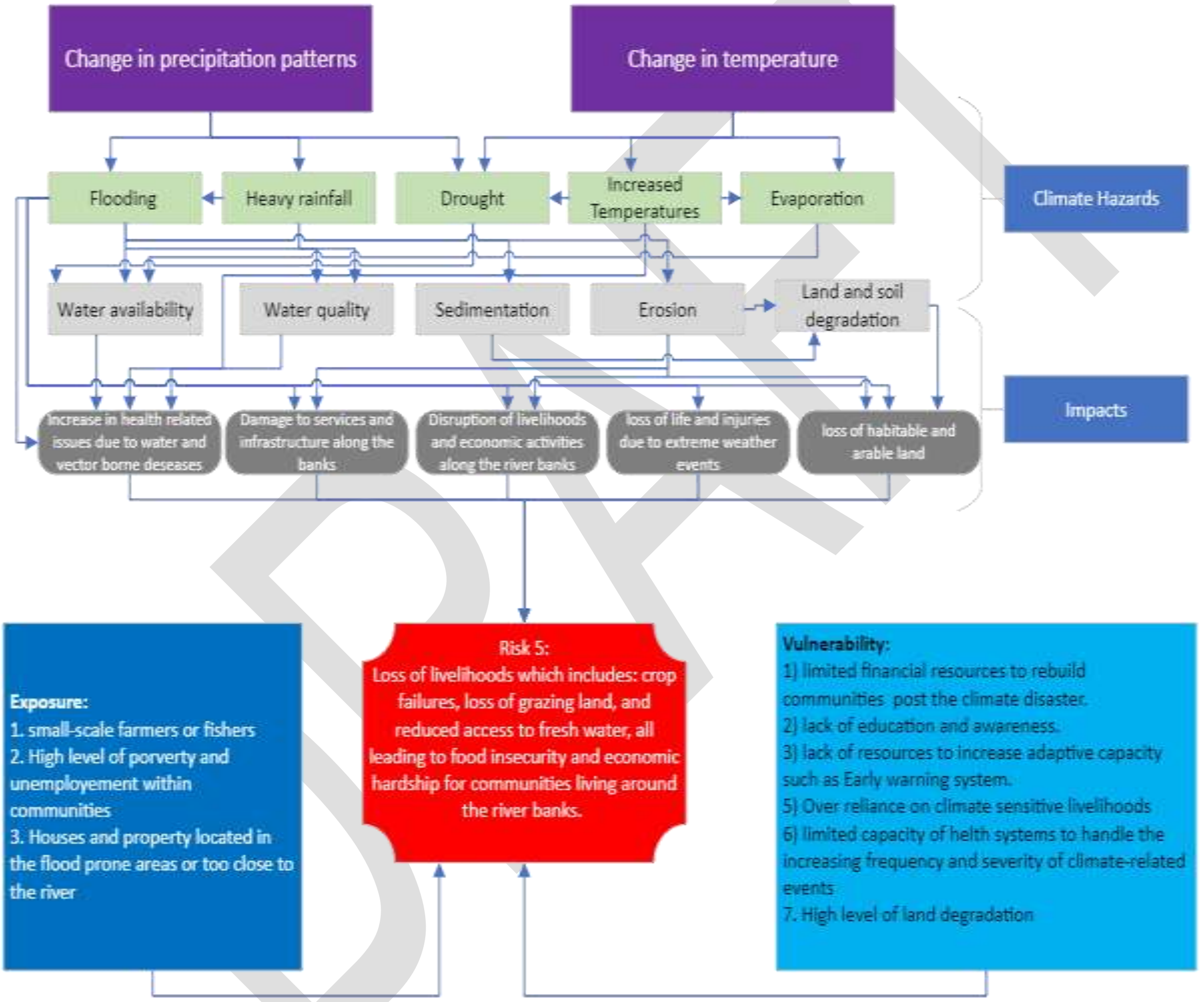


Figure 44 | Loss of Livelihoods Impact Chain Diagram

5.3 Risk Assessment Methodology

To assess key climate risks to the communities, a high-level, qualitative risk assessment was undertaken based on the understanding of risk as provided in the IPCC 2014 WG II report. In this study, the risk is defined as a function of hazard, exposure and vulnerability and assessed as probable harm that can be caused to a biophysical or socio-economic system by an anticipated threat. The approach to risk assessment involved collating and analysing information from the stakeholders' consultations and literature, considering the three elements that result in risk: exposure (E), hazard (H) and vulnerability (V).

Risk= f(H,E,V)

The assessment involved:

- Hazard identification and characterisation.
- Exposure characterisation
- Assessing the systems' vulnerability.

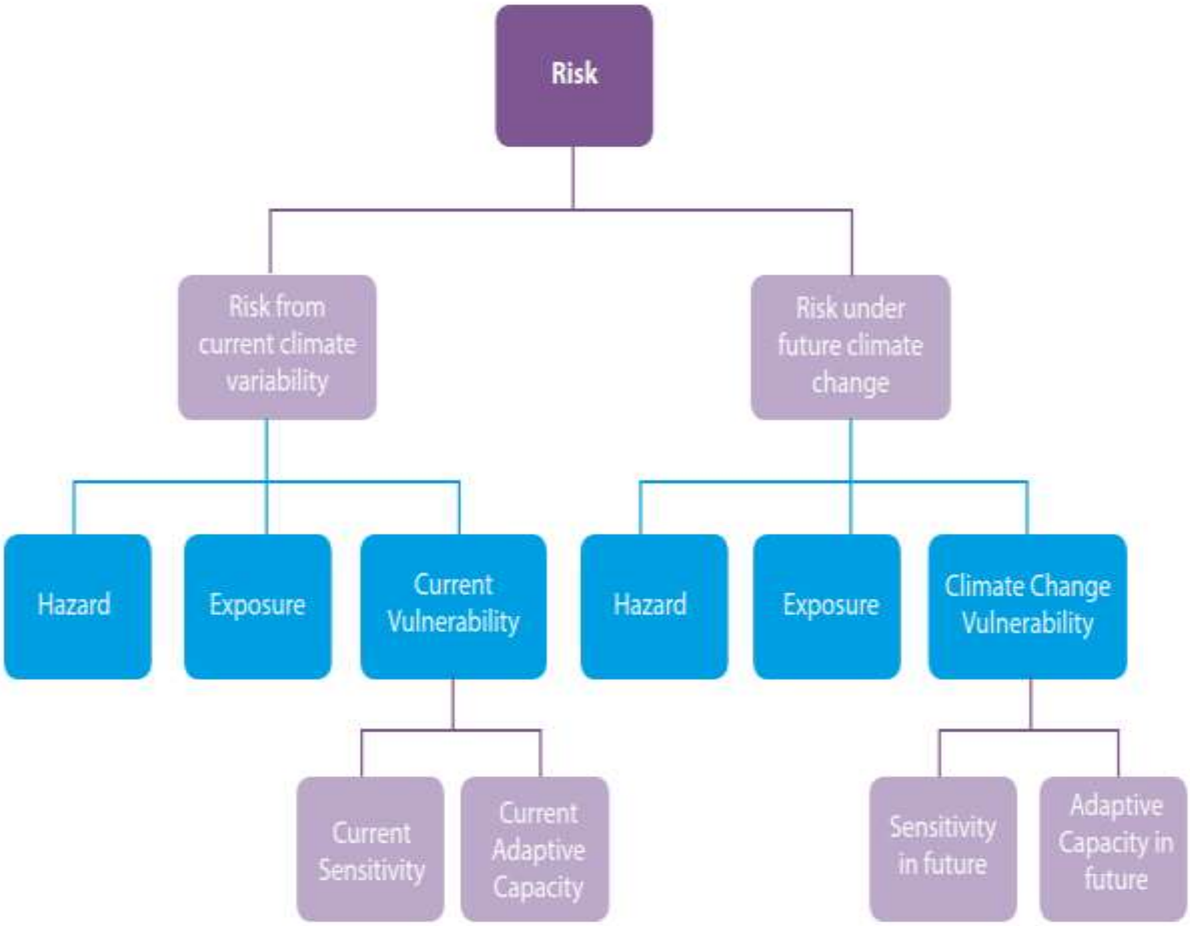


Figure 45 | Climate change risk assessment variables

5.3.1 Determining the Magnitude of the Hazard

The level of hazard is determined either directly from individual climate change parameters such a temperature and precipitation, or from derived variables such as changes in drought frequency, extreme rainfall events, mean annual runoff, impact on water supply, heat stress, or crop productivity.

The severity of potential impact is then characterised in terms of thresholds such as in Table 15.

Table 15 | Climate hazard thresholds to characterise the severity of potential impacts

Climate Hazard	Climate change parameter used	VL	L	M	H
Temperatures	Change in Mean Temperatures	< 0ºC	<+ 1ºC	1<x<1.5	1.5<
Precipitation	Change in Mean Annual Rainfall	>100	50	0	-50>x
Droughts	Change in SPEI	2	1	0%	-1
Floods	Change in extreme rainfall	-10%	-5%	0%	5%
Wildfires	Change in extreme temperatures	0%	10%	50%	100%
Winds/Storms	Change in maximum daily wind speed	TBD	TBD	TBD	TBD
Water Availability	Change in mean annual runoff	TBD	TBD	TBD	TBD
Agriculture	Change in crop suitability	TBD	TBD	TBD	TBD
Livestock	Change in heat index (HI)/max temperature	0%	10%	50%	100%
Human Health	Change in heat index (HI)/max temperature	0%	10%	50%	100%

Some of the values for the above variables can be derived directly from climate risk maps (for example changes in mean annual temperature or precipitation) or from derived hazard maps such as are shown below in terms of drought hazard and water resource availability (Figure 33) and crop suitability for primary crops grown in Ghana under different climate change scenarios

Table 16 | Criteria for determining the magnitude of the hazard

Exposure	Description
Very Low	The hazard is expected to have minimal impact and unlikely to cause significant disruptions.
Low	The hazard is expected to have a low impact and may cause some minor disruptions or inconvenience, and yet can be easily managed.
Medium	The hazard is expected to have a moderate impact and may cause significant disruptions or inconvenience but can be managed with adequate preparation and response.
High	The hazard is expected to have a high impact and may cause widespread disruptions or significant harm, requiring a significant effort to manage.
Very High	The hazard is expected to have a very high impact and may cause catastrophic damage or widespread harm, requiring an immediate and large-scale response.

5.3.2 Defining Exposure and Vulnerability

5.3.2.1 Determining the Level of Exposure

The exposure critical hazards such as increasing flood risk can be supported by hazard mapping, as mentioned above with regards to flood hazard mapping study for Tamale and also the Ghana: Roadmap for resilient infrastructure in a changing climate report. These maps can be used to determine the exposure for people or infrastructure. The results of these analysis showed that the people or assets exposure to flood risk does not necessarily significantly increase with different climate scenarios, but the frequency and magnitude of these might change which is driven primarily by changes in extreme rainfall events.

Exposure was analysed by evaluating the history of past and recent weather events in the Tamale. Where there was not enough secondary data to establish the exposure, information gathered during the stakeholder engagement was used to complement the quantitative indicators such as the estimate of the number of people or buildings located in flood prone areas.

Table 17 | Criteria for assessing exposure

Exposure	Description
Very Low	In the past, the study area, or areas nearby, have rarely experienced extreme weather events (less than one event every 50 years).
Low	Exposure is almost unlikely. In the past, the study area, or areas nearby, have sporadically experienced extreme weather events (1 every 20-50 years).
Medium	Exposure is possible to occur. In the past, the study area, or areas nearby, have experienced extreme weather events (1 every 10-20 years).
High	Exposure is likely to occur. The study area, or areas nearby, have regularly experienced extreme weather events (1 every 5-10 years).
Very High	The exposure is almost certain. Hazard manifestation is common (1 every 1-5 years).

5.3.3 Assessing the Systems' Vulnerability

Vulnerability is conceptualised as an integral part of a system or assets that is a function of its current lack of adaptive capacity to overcome the adverse impact of a climate hazard and its sensitivity.

Tamale is renowned for its agricultural production and highly sensitive to the climatic events. Due to its location in the Sahel region of Ghana, which experiences high temperatures, little rainfall, and high evaporation, Tamale is vulnerable to climate risks. Various factors, including economic, social, human, and political resources, influence Tamale's vulnerability.

Tamale's adaptive capacity is limited by a lack of financial and technical resources, a lack of awareness and knowledge about climate change, and a lack of effective governance and institutions.

Tamale has a relatively small economy, with agriculture and trade being a mainstay of the economy. The city's economy needs to be developed more to enable the necessary investments in climate adaptation measures. Nonetheless, Tamale has a strong sense of community, and people tend to rely on traditional social support systems. However, the city needs strengthen the capacity of the existing social systems and institutions to facilitate collective action to address climate change risks.

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.

The vulnerability of a natural ecosystem or socioeconomic system was assessed as a function of its sensitivity to such a hazard and its lack of adaptive capacity to overcome such sensitivity. In this assessment, high vulnerability is expressed as a situation where the system that is exposed to climate risks has high sensitivity and low the adaptive capacity

Vulnerability is expressed as: ***Vulnerability= Sensitivity-Adaptive Capacity***

Table 18, and Table 19 present the criteria to assess sensitivity and adaptive capacity respectively. Table 20 presents the matrix used to assess and categorise the level of vulnerability for each system or assets.

Table 18 | Criteria to access sensitivity

Sensitivity	Description
Very Low	Extreme weather events and climate change related hazards may marginally affect the study area and there are no assets critically affected.
Low	Extreme weather events (strong winds, floods, extreme temperatures, droughts, sea level rise, coastal erosion etc.) relatively more resistant population, the consequence is classified as minor.
Medium	Extreme weather events cause moderate damage to local goods and services (eg increased incidences of dengue, diarrhoea, malaria or other vector -borne diseases affect the health of the local community and put greater pressure on sanitation and agricultural goods; or a moderate drought may lead to some loss of household income, but may not require external assistance).
High	Extreme weather events affect assets, reducing the capacity of local services to respond, causing damage to local communities (eg floods that lead to the interruption of water supply affecting communities and irrigation pump failures, reducing the productivity of agricultural productions, can have a major impact on a weak local community that has no other alternatives and cannot withstand seasonal shocks of this type).
Very High	Extreme weather events lead to the failure or destruction of local goods and services, communities have to be relocated for at least several months, etc. This is a very high potential impact that could seriously affect local communities and the consequence is considered to be catastrophic.

Table 19 | Criteria to access adaptive capacity

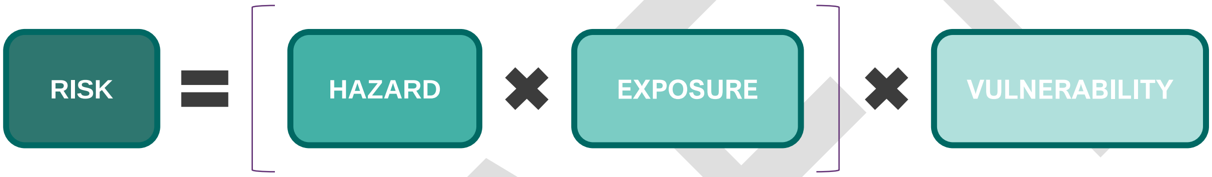
Adaptive capacity	Description
Very high	Existence of good knowledge, institutions that function perfectly and sufficient means and technologies to avoid or reduce the exposure and/or sensitivity of the identified climate risks. Local communities have a good understanding of climate change and its effects/impacts and adopt initiatives to increase their resilience in the short, medium and long term. Existence of action strategies for climate change at the study area level.
High	Existence of alternative resources and capacities to diversify the local economy. Local populations have access to resilient infrastructure (built and natural/ecosystem services) that support means of production and livelihoods. Existence of technical capacity, strategies, a risk and disaster prevention plan, an action plan for climate change, etc.
Medium	Existence of a national/regional action plan for climate change etc., but no local climate action plan, including the participation of local communities. There is a moderate capacity to reduce sensitivity to identified climate risks and some adaptation measures are implemented at the community level to mitigate risks in the short and medium term. Existence of basic energy services, water supply to communities, etc. to address the potential impacts resulting from climate change.
Low	Lack of a legal, institutional and operational framework at the local level to mitigate climate risks and their effects on local ecosystems and livelihoods. Restricted access to resilient infrastructure (built and natural/ecosystem services) that support means of production and livelihood against the effects of variability and climate change.
Very Low	Lack of basic energy services, water supply to communities, etc. to address the potential impacts of climate change. Lack of knowledge and perception about the phenomenon of climate change and its effects on natural ecosystems and local livelihoods. Very limited and vulnerable means of survival and no alternative means.

Table 20 | Vulnerability Matrix

Vulnerability		**Sensitivity**				
		Very Low	Low	Medium	High	Very High
Adaptive capacity	Very High	Low	Low	Low	Medium	Medium
	High	Low	Low	Medium	Medium	High
	Medium	Low	Medium	Medium	High	High
	Very Low	Medium	Medium	High	High	Extreme
	Low	Medium	High	High	Extreme	Extreme

5.3.4 Evaluating Priority Risk Domains

Finally, the final risk evaluation involved combining the results that reflect the situation of the different components that comprise it. The assessment of potential risk that climate change will have on natural and human systems was done through the matrix of hazard, exposure and vulnerability.



This potential risk assessment matrix makes it possible to rank exposure and vulnerability to climate change. The final risk assessment matrix helps to identify the priorities and systems and sectors at risk (Fall, Correa, & Sarr, 2011).

Table 21 presents the matrix used to rank the potential risks of the hazards associated with climate change on natural and human systems, based on exposure to identified climate hazards and the vulnerability of key natural systems, socio-economic sectors and local livelihoods.

Table 21 | Risk Matrix

Risk		**Hazard x Exposure**			
		Low	Medium	High	Extreme
Vulnerability	Low	Low	Low	Medium	High
	Medium	Low	Medium	High	High
	High	Medium	High	High	Extreme
	Extreme	High	High	Extreme	Extreme

5.4 Climate Change Risk Assessment Results

The risk assessment was intrinsically participatory and based on the approach elaborated under 5.3 and conceptual framework presented figure 45. Understanding the risks at a local level requires an integrative approach that looks at both the physical climate hazards and social dimensions of vulnerability. The stakeholders were engaged to identify the assets and systems exposed to climate hazards and shared their perspectives and experiences of the climate events that had adversely affected their systems of interests and challenges that they had to face as a result of such events.

The engagement sessions revealed that the population seems to be more interested and aware of climate change issues and prepared for disasters as the following actions are already being implemented:

- There are Disaster volunteer groups in every community that have been trained on what to do in the event of a disaster. They have a communication protocol to follow. However, there has been a challenge of recruiting volunteers because they don't receive payment, but the Department is addressing this with a new initiative.
- There is an effective health communication system.
- Forestry personnel collaborate well with the fringe communities who have got communication protocols.
- Fringe community members have been trained in basic firefighting skills
- There is an active movement to use digital technologies to address hazards. Apps have been developed in the following fields:
- Forestry: to report fires and also illegal cutting.
- Fisheries: to report illegal fishing and catching of mammals (this is a project whose data will feed directly back into government for policy making purposes)
- The data collected for marine mammals is included in CETA-BASE
- People with disabilities are always included into engagements and have a good working relationship with government officials.

During the workshop there was a suggestion that an improvement can be made on the reporting of Ghana Meteorological Agency (GMet) weather information to communities. This is only reported on television or can be accessed on smart phones. There are challenges met with disseminating the information further, but this would be good information to have disseminated further as it could assist with early warning to communities of flooding, heat waves, etc.

The discussions led to the results presented in the Table 22 and Table 23 below. In addition to that, the outputs of climate models were used to inform future climate risk assessment, where different scenarios were considered.

Residual climate risk assessment results for different assets and risk domains are presented in Table 24 below, ranking current, future and residual from Low to the extreme. According to the assessment, climate risk mitigation measures (adaptation) can reduce some elements of risk, such as sensitivity, and enhance adaptive capacity. Reducing risk requires modifying current policies and programs and implementing policies that explicitly consider climate variability and climate change. The proposed Adaptation measures focus more on reducing the sensitivity and enhancing the capacity hence building a more resilient system.

Tamale is located in a region vulnerable to climate and weather extremes, including high summer temperatures, floods, droughts and Bushfires. Climate change projections for Tamale under RCP 8.5 suggests increasing average and maximum temperatures and heatwave events, increased rate of evaporation, and higher risk of wildfires. However, there is disagreement amongst climate models on future changes to seasonal and annual precipitation levels and intensity, suggesting a high level of uncertainty, with some models projecting increases and others decreases.

Based on the analysis of current and future climate risks and qualitative considerations of the sensitivity, exposure and vulnerability, this CCRA has identified several critical climate-related risks for Tamale (see Table 25) should climate-related hazards occur. The Identified risk under the current and future conditions are rated high to extreme, but with the suggested risk mitigations measures, the level of risk is expected to reduce.

Table 22 | Assessment of current climate change risks

Asset	Hazard Description	H	E	HxE	AC	S	V	Comment- Impacts	CCR
Damage to water treatment plant	Precipitation increase and flooding- Excess water due to the spillage of the Bagre dam. The in-take dam risk exceeds its maximum level. Increased sedimentation also affects the treatment plant negatively.	High	High	High	Medium	Very High	High	1) water supply was affected, 2) water quality (PH from the farm and sedimentation) affecting the health of the communities (cholera outbreak)	**High**
Water supply system.	1) Water scarcity when supply is affected by drought or rains coming later than usual. 2) Damage to water supply infrastructure due to floods and storms, leading to water unavailability. 3) Failure to meet water supply demands during the drought seasons	High	Medium	High	Medium	High	High	1) Water scarcity has led to an increased risk of waterborne diseases in Tamale, as water quality was affected, which in turn affected the health of communities (i.e. cholera outbreaks). 2. Rate of evaporation has increased exacerbating water scarcity issues.	**High**
Water Resources.	Flooding, riverbanks erosion	Medium	Medium	Medium	Low	High	High	1) Damage to infrastructure: fluvial flooding has damaged bridges, and other forms of infrastructure, which is costly to repair and disrupted lives of the communities, livelihoods, and transportation 2) In some cases, people were forced to leave their homes due to flash floods, leading to homelessness and other social disruptions.	**High**
Communities living along riverbanks	Fluvial flooding	High	High	High	Very low	High	Extreme	1) fluvial flooding has damaged infrastructure and property around the riverbanks, leading to financial losses for individuals and communities and disrupting people's livelihoods.	**Extreme**
Urban storm water management	Flash floods have become the common phenomenon over the past 4 years, it was reported that residents were trapped in flood waters after 3 hours downpour in 30-8-21 in Tamale	High	High	High	Low	High	High	Flooding has damaged roads, bridges, and other forms of infrastructure, which can be costly to repair, affecting general population, women and children, people with special needs	**High**
Road infrastructure	Urban flooding, river flooding, poor road infrastructure, Flooding of roads and bridges and waterlogging significantly impact accessibility.	High	High	High	Low	High	High	Flooding can damage roads, bridges, and other forms of infrastructure, which can be costly to repair and disrupt transportation and communication. Children, People with Disability and the older population get to be affected the most	**High**
Agricultural land- crop productivity.	Heavy precipitation is causing water logging, patterns and distribution of rainfall has changed, and decreased. dry spells have become more frequent	High	High	High	Low	High	High	Decline in agricultural production due to water logging, causing food insecurity and affecting the most vulnerable groups within the society	**High**
Fisheries - rivers	Farms become submerged under water and sedimentation has increased	Medium	Medium	Medium	Very low	Very High	Extreme	Decline in fish production, affecting livelihoods	**High**
Health Systems	Increased numbers of stagnant water bodies and temperatures have resulted in an increased reports of malaria in Tamale. One health government official reported that over the past season they have required double the amount of medication to cover the increased number of cases as well as repeat cases of malaria.	Very High	Very high	Extreme	Low	Very High	Extreme	Increase in temperatures and numbers of stagnant water bodies has resulted in an increased reports of malaria affecting children more than any group within the communities.	**Extreme**
Agricultural (Crops and Livestock)	1) 2017 outbreak of army worm- due to increase in minimum temperatures and precipitation, 2) overall increase of pests and diseases in crops and livestock	High	High	High	Very low	Very High	Extreme	Agriculture production had been affected by the army worm and other pests and invasive species outbreak in Tamale, leading to food insecurity and loss of livelihoods	**Extreme**
Forestry	1) Bushfires are reported to have been particularly bad over the past 10 years with 1 in every 3 plantations being burnt (stakeholders). 2) Deforestation	Medium	Medium	Medium	Medium	High	High	1) Deforestation leads to the severe impact of gusts/ strong winds on settlements because there are no trees to buffer 2) Bushfires threaten the human life and had resulted in injuries to people who were caught in the path of the fire.	**High**
Human Health	Increased cases of Malaria during the rainy season. Air pollution due to Bushfires, causing respiratory diseases.	Medium	High	High	Low	High	High	Malaria and respiratory diseases have increased affecting people with chronic illnesses and children.	**High**
Education	Heavy rainfall can make roads unpassable and fear of flooding and safety of school children during heavy rain	High	High	High	Low	High	High	Disruption of education programmes due to heavy rains	**High**
Settlements	Strong winds: Deforestation has removed natural buffers and communities have reported increased winds that destroy their property, together with more dust and respiratory/health issues.	Medium	High	High	Very low	High	Extreme	Loss of property, leaving people homeless and affecting livelihood and businesses	**Extreme**

H: Hazard Score **E: Exposure** **AC: Adaptive Capacity** **S: SensitivityVulnerability** **HxE: Hazard x Exposure** **CCR: Climate** Change **Risk**

Table 23 | Assessment of future climate change risks

Asset	Hazard Description	H	E	HxE	AC	S	V	Comment- Impacts	CCR
Water treatment plant	There is a possible trend, although not significant, towards increased return values for the wettest years, indicating the prospects of increased **flood risks.**	Very high	Very high	Extreme	Low	High	High	1) water supply was affected, 2) water quality (PH from the farm and sedimentation) affecting the health of the communities (cholera outbreak)	Extreme
Water supply systems	Precipitation is highly variable however the CMIP 6 projections projected wetter conditions over Tamale, and yet there is high confidence that temperatures are expected to increase under both CMIP5 and CMIP6 projections. Increase in temperature will likely increase the rate of evaporation and therefore affect water availability and lead to **water scarcity.** Climate change will also intensify the magnitude and the frequency of extreme weather event.	Very high	High	Extreme	Low	High	High	1) Water scarcity can lead to an increased risk of waterborne diseases, as people may resort to using unsafe water sources if clean sources are unavailable. 2) Water scarcity can also lead to conflicts over access to water, as different groups may compete for limited supplies. This can lead to social and political tensions within communities. 3) water scarcity can have economic impacts, as it can lead to a decline in agricultural productivity.	Extreme
Water sources, rivers	The expected changes of precipitation patterns will likely lead to **fluvial flooding**. While there are no clear trends in return values for the driest annual events, suggesting limited change in drought occurrences and magnitudes, the precipitation patterns when combined with an increasing trend in average annual temperatures, could result in an increasing **risk of drought.**	High	High	High	Low	Moderate	High	1) Damage to infrastructure: fluvial flooding can damage bridges, and other forms of infrastructure, which can be costly to repair and disrupt transportation and communication. 2) Erosion can undermine the foundations of buildings and other structures, making them more susceptible to collapse. 3) In some cases, people may be forced to leave their homes due to erosion, leading to homelessness and other social disruption. 4) Erosion can negatively impact the environment by destroying habitats and disrupting ecosystems.	High
Communities along riverbanks	The expected changes in precipitation and temperatures may lead to **floods, drought and storms.**	High	Very high	Extreme	Very Low	High	Extreme	1) fluvial flooding can damage homes and other forms of property around the riverbanks, leading to financial losses for individuals and communities and disrupting people's livelihoods. 2)The damage caused by flooding can have significant economic impacts, including losses in agriculture, industry, and other sectors.	Extreme
Urban storm water management	There is a possible trend, although not statistically significant, towards increased return values for the wettest years, thus indicating the prospects of increased flood risks.	Very high	Very high	Extreme	Very Low	High	Extreme	Flooding can damage roads, bridges, and other forms of infrastructure, which can be costly to repair	Extreme
Road infrastructure	There is a possible trend, although not statistically significant, towards increased return values for the wettest years, thus indicating the prospects of increased **flood risks.**	Very high	Very high	Extreme	Very Low	Medium	High	Damage to infrastructure: Flooding can damage roads, bridges, and other forms of infrastructure, which can be costly to repair and disrupt transportation and communication. Children, People with Disability and the older population get to be affected the most	Extreme
Agricultural land- crops	Precipitation patterns may change, floods, drought events and extreme weather events may increase in future	Very high	High	Extreme	Very Low	High	Extreme	Decline in agricultural production due to water logging	Extreme
Fisheries- along rivers.	Projected wetter conditions in Tamale and lead to the increased risk of **fluvial flooding**	High	Very high	Extreme	Very Low	High	Extreme	Decline in fish production	Extreme
Health systems	The projected wetter conditions (on average) and increase in temperatures are likely to increase risk of vector-borne and water-borne diseases. Increasing flood risks could damage critical infrastructure and limit access to hospitals and other health care facilities.	Very high	Very high	Extreme	Low	High	High	Increase in temperatures and numbers of stagnant water bodies will result in increased reports of malaria.	Extreme
Agricultural	The expected changes in precipitation and temperatures may lead to floods, drought and storms affecting food production and leading to food insecurity. Water Scarcity risk may also increase and thus affect irrigation	Very high	High	Extreme	Low	Medium	High	1) Pests can cause significant damage to crops and other plants, reducing yields and potentially leading to crop failures. 2) Pest infestations can result in economic losses for farmers and industries that rely on agricultural production. 3) Pests can also negatively impact the environment by reducing biodiversity and disrupting ecosystems. 4) Some pests, such as ticks and mosquitoes, can transmit diseases to humans, negatively impacting public health.	Extreme
Forestry	Temperatures are expected to increase in future leading to increased risk of **Bushfires**	High	High	High	Low	Medium	High	1) Removal of trees can disrupt the local ecosystem, leading to changes in the water cycle, soil erosion, and habitat loss for plants and animals. 2) Removal of trees contributes to the greenhouse effect and warming of the planet. 3) Deforestation leads to the severe impact of gusts/ strong winds on settlements because there are no trees to buffer 4)Bushfires can pose a threat to human life and can result in injuries to people who are caught in the path of the fire. 5) Bushfires can cause damage to homes, businesses, and other property.	High
Human Health	Temperatures are expected to increase in future leading to increased risk of **Bushfires that may cause respiratory related health issues**	High	Very high	Extreme	Low	Very high	Extreme	1) Bushfires may cause respiratory related health issues. 2) Bushfires burn away critical medicinal plants.	Extreme
Education	Precipitation and extreme rainfall events may increase in future leading to floods	High	High	High	Very Low	Medium	High	Disruption of education programmes due to heavy rains	High
Settlements	Increase in extreme events such as storms and heavy precipitation and strong winds, may lead to floods and damage of properties	High	High	High	Very Low	Very high	Extreme		Extreme

H: Hazard Score **E: Exposure** **AC: Adaptive Capacity** **S: SensitivityVulnerability** **HxE: Hazard x Exposure** **CCR: Climate** Change **Risk**

Table 24 | Assessment of Future Residual Risk after implementation of adaptation measures

Asset	**Adaptation Measures**	**Residual Risk assessment**				
		Residual Adaptive capacity	Sensitivity	Exposure	Vulnerability	Residual Risk
Water treatment plant	1) Develop and strengthen early warning systems for Floods, droughts, and water scarcity 2) Upgrade treatment plant and processes to handle changing climate related risk 3) Conduct a more detailed climate risk assessment on the infrastructure 4) Improve the resilience and capacity of infrastructure to cope with extreme weather events	Medium	High	Medium	High	High
Water supply systems	1) Develop and implement water conservation and management strategies 2) Develop and strengthen early warning systems for Floods, droughts, and water scarcity 3) Conduct a more detailed climate risk assessment on the infrastructure 4) Improve the resilience and capacity of infrastructure to cope with extreme weather events	Medium	High	Medium	High	High
Water sources, rivers	1) implement integrated catchment water conservation and management strategies 2) Develop and strengthen early warning systems for Floods, droughts, and water scarcity	Medium	Low	Medium	Medium	Medium
Communities living along riverbanks	1) Diversify livelihood sources and income streams to reduce the sensitivity of climate risk 2) Promote climate-resilient crops and agricultural practices 3) Promote the development of alternative livelihoods 4) Strengthen social safety nets and support systems 5) Enhance capacity building and training in climate-resilient practices 6) Foster community-based natural resource management	Medium	Low	Medium	Medium	Medium
Urban storm water management	1) Upgrade storm management systems	High	Moderate	Medium	Medium	Medium
Road infrastructure	1)Improve the drainage systems to handle increased rainfall 2) Use of porous pavements to reduce runoff and improve water quality 3) Retrofit bridges and culverts to improve resilience to extreme weather events 4) Implement early warning systems for natural disasters 5) Integrate climate change considerations into road design and planning processes	High	Moderate	High	Medium	High
Agricultural land- crops	1) Promote climate-resilient crops and agricultural practices 2) Enhance capacity building and training in climate-resilient practices 3) Improve access to climate information and knowledge on climate change impacts 4) Develop insurance schemes and risk mitigation tools for agriculture sector 5) Enhance the governance of climate-sensitive resources	Medium	High	Low	High	Medium
Fisheries - along the rivers	1) Diversify livelihood sources and income streams to reduce the sensitivity of communities to climate risk 2) Promote the development of alternative livelihoods 3) Enhance capacity building and training in climate-resilient practices 4) Foster community-based natural resource management	Medium	High	Medium	High	High
Health Systems	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	Medium	High	Medium	High	High
Agricultural (Crops and Livestock)	1) Promote climate-resilient crops and agricultural practices 2) Enhance capacity building and training in climate-resilient practices 3) Improve access to climate information and knowledge on climate change impacts 4) Develop insurance schemes and risk mitigation tools for agriculture sector 5) Enhance the governance of climate-sensitive resources	Medium	Medium	Medium	Medium	Medium
Forestry	1) implement REDD+ policies 2) Enhance capacity building and training in climate-resilient practices 3) Foster community-based natural resource management	High	Medium	Medium	Medium	Medium
Human Health	1) Develop insurance schemes and risk mitigation tools 2) Implement early warning systems for natural disasters	High	Medium	Medium	Medium	Medium
Education	1) Strengthen early warning system 2) Improve access to climate information	Medium	Low	Medium	Medium	Medium
Settlements	1) Strengthen early warning system 2) Improve access to climate information 3) Develop insurance schemes and risk mitigation tools	Medium	Medium	Medium	Medium	Medium

Table 25 | Climate change risk assessment results matrix and short narrative explaining the risk

Critical System	Risk description	Current Risk	Future Risk	Residual Risk
Water treatment plant	There is a possible trend, although not significant, towards increased return values for the wettest years, indicating the prospects of increased flood risks. The current water treatment plant is located close to the river and could be damaged due to floods.	High	Extreme	High
Water supply systems	Precipitation is highly variable however the CMIP 6 projections projected wetter conditions over Tamale, and yet there is high confidence that temperatures are expected to increase under both CMIP5 and CMIP6 projections. Increase in temperature will likely increase the rate of evaporation and therefore affect water availability and lead to water scarcity. Climate change will also intensify the magnitude and the frequency of extreme weather event and likely contribute to increase variability of rainfall.	High	Extreme	High
Water sources, rivers	The expected changes of precipitation patterns will likely lead to fluvial flooding. While there are no clear trends in return values for the driest annual events, suggesting limited change in drought occurrences and magnitudes, the precipitation patterns when combined with an increasing trend in average annual temperatures, could result in an increasing risk of drought.	High	High	Medium
Communities living along riverbanks	The expected changes in precipitation and temperatures may lead to floods, drought, and storms.	Extreme	Extreme	Medium
Urban storm water management	There is a possible trend, although not statistically significant, towards increased return values for the wettest years, thus indicating the prospects of increased flood risks.	High	Extreme	Medium
Road infrastructure	There is a possible trend, although not statistically significant, towards increased return values for the wettest years, thus indicating the prospects of increased flood risks.	High	Extreme	High
Agricultural land-crops	Precipitation patterns may change, floods, drought events and extreme weather events may increase in future	High	Extreme	Medium
Fisheries - along the rivers	Projected wetter conditions in Tamale could lead to the increased risk of fluvial flooding	High	Extreme	High
Health Systems	The projected wetter conditions and increase in temperatures are likely to increase risk of vector-borne and water-borne diseases	Extreme	Extreme	High
Agricultural (Crops and Livestock)	The expected changes in precipitation and temperatures may lead to floods, drought and storms affecting food production and leading to food insecurity. Water Scarcity risk may also increase and thus affect irrigation. Increasing temperatures will contribute to reduced productivity of livestock and reduced water availability and fodder affecting both crops and livestock.	Extreme	Extreme	Medium
Forestry	Temperatures are expected to increase in future leading to increased risk of Bushfires	High	High	Medium
Human Health	Temperatures are expected to increase leading to increased risk of Bushfires that may cause respiratory related health issues	High	Extreme	Medium
Education	Precipitation and extreme rainfall events may increase in future leading to floods	High	High	Medium

Critical System	Risk description	Current Risk	Future Risk	Residual Risk
Settlements	Increase in extreme events such as storms and heavy precipitation, may lead to floods and damage to properties.	Extreme	Extreme	Medium

6 Conclusion and Recommendations

6.1 Future Climate Change Scenarios for Tamale Metro

Future climate change projections show that there is a risk of significantly higher temperatures for Tamale MMDA 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. Precipitation projections, in contrast, carry large uncertainties. There is a slightly greater chance of small increases, typically, around 5%. in annual average precipitation 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 precipitation to a similar degree. By the end of the century, either an increase or decrease in mean annual precipitation appears possible, as the extremes suggest that a change in precipitation is possible of up to +/-15/20%. The latest CMIP 6 climate 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 precipitation by mid-century.

Heavy precipitation 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.

6.2 Priority Climate Related Hazards and Risks

For Tamale MMDA, eight first and second-order priority risk domains where identified that have a significant number of climate change hazards associated with them. These included the following:

- Water Resources (Surface water)
- Fluvial Flooding
- Droughts
- Fire Risk
- Water Security (water and sanitation)
- Agriculture – Crop Productivity
- Agriculture – Livestock Productivity
- Health (Heat Stress, Diseases, etc.)

Based on these priority risk domains, the following critical climate related issues/risks were identified by key stakeholders during a multi-stakeholder workshop held in Tamale on the 23rd November 2023.

- Precipitation patterns may change, floods, droughts, and extreme weather events may increase in the future, affecting food production (agriculture sector) and leading to food/water insecurity.
- The most prominent climate hazards for Tamale MMDA are extreme heat and inland flooding.
- The critical systems that were identified with high sensitivity and/or low adaptive capacity, as well as high exposure to extreme heat, include health and forest systems, since temperatures are expected to increase in future, leading to increased risk of bushfires that may cause respiratory related health issues. In addition, increases in temperature will likely increase the rate of evaporation and therefore affect water availability and lead to increased water scarcity.
- The water supply system (including the water treatment plant) which is a critical infrastructure, is highly exposed to inland flooding, and with a high sensitivity and low adaptive capacity, poses a risk not only to water scarcity, but also to the health sector since, this leads to an increased risk of waterborne diseases, as people may resort to using unsafe water sources if clean sources are

unavailable. Increasing water scarcity and damage to water infrastructure can also lead to conflicts over access to water, as different groups compete for limited supplies.

- Urban areas as well as the transport infrastructure, are also highly exposed to inland flooding, with a high sensitivity and/or low adaptive capacity. The damage caused by flooding can have significant economic impacts, including losses in agriculture, industry, and other sectors. Flooding also disrupts the access to crucial systems such as health and education, where people with disabilities, women children and the older population get to be affected the most.
- In many cases the communities most exposed and with limited adaptive capacity are those located in peri-urban or informal areas where there is also a lack of basic infrastructure.

6.3 Climate Change Risk Assessment Results

Based on the review of future climate scenarios and the engagement with key stakeholders, impact chain diagrams were developed for the priority hazards and risks identified above. These were then used to evaluate both the current and future level of risk as function of hazard, exposure, and adaptive capacity. For each of these priority risk domains, potential adaptation options were considered and their potential impact on reducing the overall climate related risks were determined as a residual risk.

Following the consideration of potential adaptation options, the critical systems with the highest residual risk, and therefore considered to be important for prioritising adaption responses where:

- Potential flood risk to the Water Treatment Plant (and other critical infrastructure) as well as the impacts of upstream catchment degradation and sand mining affecting water quality.
- Overall impact on water resource availability and water supply infrastructure.
- Damage to road infrastructure and disruptions due to increased urban flooding risk.
- Impact on Health Systems including damage to hospitals and access to health facilities.
- Impact on crop productivity and livestock health (mainly for surrounding areas).
- Impact on fisheries (rivers) due to more variable flows and higher sediment loads.

6.4 Potential Adaptation Options and Recommendations

The Ghanaian Government has been investing in integrating climate change objectives and priorities into sector-specific development plans in agriculture, transportation, and energy to mainstream climate change strategies and coordinate the strategic climate adaptation activities, in line with the country's socio-economic development objectives. In the Fourth National Communication, Ghana is particularly focused on increasing its resilience through the development of sustainable land use practices, climate-proof infrastructure, water security, energy security, sustainable forest management, and urban waste management. It is evident that there is a need to adapt to the future unpredictable climate. Investing in capacity building, and education on climate risks, as well the dissemination of information was found to be a crucial component for a successful climate change adaptation strategy for Tamale. Additional actions needed to address priority risks and vulnerabilities due to climate change were identified in various studies and risk assessments undertaken in the last decade.

Below is a non-exhaustive list of adaptation options from the various previous studies and policy documents consulted by the Project Team, which could improve the residual risk level for Tamale:

- General Adaptation Response Priority Projects for critical infrastructure, for Tamale MMDA
  - Energy Sector:
    - Resilient and green energy access in drought-prone districts
    - Capacity development and regulatory frameworks to support local renewable energy generation to enhance resilience of remote, vulnerable communities

    - Update energy sector design standards to incorporate climate adaptation risk
- Water Sector:
    - Water supply resilience through regional harvesting and storage solutions
    - Climate adaptation alignment across water ministries and planning mechanisms to ensure integrated water resource management
    - Proactive risk-informed asset management
- Transport Sector:
    - Supporting resilient design and construction of roads through research, capacity building, and the creation of a design manual
    - Climate-risk informed asset management system and operations and maintenance practices for roads
    - Airport flood resilience through elevation of runways and other vulnerable components
    - Bridges and underpasses to ensure community access to services
- Agriculture Sector:
    - Ensure affordability and financial sustainability of crop insurance products, such as Weather index insurance (this measure will mostly increase resilience of vulnerable communities to climate-related risks)
    - Invest in improved post-harvest management systems
    - Improve water management, and explore potential for irrigation upscaling
    - Facilitate setting up of rainwater harvesting structures for small-scale irrigation
    - Increase investment in local breeding of improved crop varieties and improve dissemination of improved seeds
- Urban planning:
    - Development of an overall drainage plan that is consistent with the Greater Tamale Structure Plan and identifies the low-lying areas and the locations of outfalls and main drains and considers future population and land-use
    - Develop, broadcast, and enforce zoning guidelines or other local regulations, to ensure encroachment on flood prone areas is avoided
- Cross-sectoral:
    - Upstream afforestation of the Volta River reservoir to build resilience to flood and drought
    - Centralised climate-risk data management system
    - Mainstream resilience through climate risk assessments and EPA permitting process and strengthen enforcement for all infrastructure projects
    - Gender mainstreaming in adaptation planning, implementation and management
    - Prioritise nature-based solutions in planning, design and operation of infrastructure

Underlying many of these proposed interventions is the need to support the transition of Tamale to becoming a more Water Sensitive City (see Figure 46) as this will help in addressing many of the existing climate related risks and help to improve liveability and productivity for Tamale. Key to supporting the transition to a Water Sensitive City or developing a strategy and identifying champions as well as putting in place the necessary information and tools to help with integrated urban planning.

Figure 46: Components of a Water Sensitive City

Several other initiatives are already underway, and must be supported, which will also help in improving climate resilience for Tamale. Some of these existing initiatives identified include:

- A more detailed flood risk analysis for priority catchments within Tamale Metro and plans to produce an updated stormwater master plan and to improve the existing drainage capacity.
- A study on the potential for establishing a Water Fund to improve catchment management and to reduce the impact of sand mining which are threatening water security for Tamale metro.
- Providing climate information and implementation of climate smart agriculture (CSA) in Ghana.

The success of interventions designed to mitigate against, or adapt to climate change, rests on a combination of factors that is often hard to fully assess at the time of designing an intervention. Given the complex and dynamic nature of climate change, and the various variables and unknowns that accompany the phenomenon, it is challenging to tell with certainty whether an activity or policy mechanism put in place to either adapt or mitigate would have the desired effect.

Although the risk of not intervening could potentially outweigh the implications associated with acting, there are potential consequences which could either increase vulnerability or put other factors at risk.

Such potential knock-on effects could include the following:

- An increase in the cost of service delivery, because of the implementation of green technologies
- No certainty about the extent to which extensive infrastructure upgrades (such as stormwater management upgrades) will be utilised, as extreme weather events are informed by projections and predictions
- High infrastructure spend could result in a shift/flow of budget away from sector departments who are responsible for social development, and livelihood support (i.e. potential overemphasis/strong preference toward infrastructure interventions)
- Potential increase in peak stormwater runoff flows because of stormwater management interventions designed to ensure adequate management of stormwater in extreme rainfall events

- Methods to decrease water demand (such as water restrictions, metering, and step tariffs) could result in low investor/developer confidence and a decline in tourism numbers
- Ground-water abstraction could result in the depletion of groundwater resources
- Low rate of groundwater recharge (lower natural infiltration) due to more aggressive stormwater management practices
- Potential proliferation of informal settlements linked to the fast-tracked formalisation of informal settlements (i.e. the phenomenon of “umping the queue”)
- Stringent by-laws might discourage investors and developers
- Lack of thorough understanding of climate change system dynamics and ways to respond appropriately at an institutional level might result in inappropriate implementation plans/activities
- Lack of understanding of the long-term effects/impacts of green infrastructure (i.e. such as those aimed at reducing localised temperature increases)

The process of enhancing adaptive capacity cuts across all adaptation activities regardless of the approach. There are generally considered to be five key components to assessing adaptive capacity that should be outlined within an adaptation policy framework, shown in Figure 47. These criteria should be considered when identifying priority actions for adapting to climate change in Tamale Metro.

Source: Modified from Berger et al. (2014)

Figure 47 | Outline Framework for Developing Adaptive Capacity

7 References

Adapting to Climate Change in Time Project partners. (2020). *Planning for adaptation to climate change. Guidelines for municipalities.* Climate-ADAPT; Life Project No LIFE08 ENV/IT/000436. Retrieved from https://base-adaptation.eu/sites/default/files/306-guidelinesversionefinale20.pdf

Adshead, D., Thacker, S., Fuldauer, L., Gall, S., Chow, N., Pant, R., . . . Agbesi, L. (2022). *Ghana: Roadmap for resilient infrastructure in a changing climate.* Accra, Ghana: Ministry of Environment, Science, Technology & Innovation. Retrieved from https://gca.org/wp-content/uploads/2022/03/Ghana_Roadmap-for-Resilient-Infrastructure-in-a-Changing-Climate.pdf

Alidu, A.-F. (2020). Determinants of Household Food Security of Tamale in the Northern Region of Ghana. *2nd Joint Seminar Agriculture, Resources, and Environtmental Economics (JSAREE).* Universiti Putra Malaysia. Malaysia. Retrieved from https://www.researchgate.net/publication/341381823_DETERMINANTS_OF_HOUSEHOLD_FOOD_SECURITY_OF_TAMALE_IN_THE_NORTHERN_REGION_OF_GHANA

Anchor Environmental Consultants, South Africa. (2022). *Development of a Business Case for the Tamale Water Fund.* Catholic Relief Services (CRS) in partnership with The Nature Conservancy (TNC).

Beguería, S., Latorre, B., Reig, F., & Vicente-Serrano, S. M. (2022). *SPEI Global Drought Monitor*. Retrieved from SPEI, The Standardised Precipitation-Evapotranspiration Index: https://spei.csic.es/map/maps.html

Berger, R., Ensor, J., Wilson, K., Phukan, I., & Dasgupta, S. (2014). Adaptive capacity. *Community-Based Adaptation to Climate Change: Scaling it up*, pp. pp. 22–35. doi:https://doi.org/10.4324/9780203105061

Cardona, O., Aalst, M. v., Birkmann, J., Fordham, M., McGregor, G., Perez, R., . . . Sinh, B. (2012). Determinants of risk: exposure and vulnerability. *In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation(A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC))*, 65-108. (C. Field, V. Barros, T. Stocker, D. D. D. Qin, K. Ebi, M. Mastrandrea, . . . P. Midgley, Eds.) Cambridge, UK, and New York, NY, USA: Cambridge University Press. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap2_FINAL-1.pdf

Choudhary, V., Christienson, G., D'Alessandro, S. P., & Josserand, H. P. (2016). *Ghana agricultural sector risk assessment (English).* Washington, D.C.: The World Bank Group. Retrieved from http://documents.worldbank.org/curated/en/412431468198000868/Ghana-agricultural-sector-risk-assessment

CRIDF. (2015, November 6). *Final Resiliency Screening and Climate Change Risk Assessment Guidelines.* Climate Resilient Infrastructure Development Facility (CRIDF). Retrieved July 2021, from https://cridf.net/RC/wp-content/uploads/2018/04/Extlib22.pdf

Damba, O. T., Abarike, M. A., Nabilse, C. K., & & Akudugu, M. A. (2019). Urban Poverty Analysis in Tamale, Ghana. *UDS International Journal of Development, 6*(2), 79–96. doi:https://doi.org/10.47740/377.UDSIJD6i

Fall, B., Correa, J. B., & Sarr, S. (2011). *Guide Methodologique Pour L'Evaluation de la Vulnérabilité au Changement Climatique au Niveau Communautaire (Zones Côtières).* Consultant report by Environnement-Développement du Tiers Monde (ENDA). Dakar, Senegal: USAID/COMFISH project.

Field, C., Barros, V., Mach, K., Mastrandrea, M., Aalst, M. v., Adger, W., . . . Yohe, G. (2014). Technical summary. In C. Field, V. Barros, D. Dokken, K. Mach, M. Mastrandrea, T. Bilir, . . . L.L.White (Eds.), *Climate Change 2014: Impacts,Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 35-94). Cambridge, United Kingdom and New York, NY, USA,: Cambridge University Press. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-TS_FINAL.pdf

Fugu, M. (2022, 03 25). Effect of illegal sand winning: Shutdown of Dalun water treatment plant imminent. *Graphic Online*. Retrieved from https://www.graphic.com.gh/news/general-news/effect-of-illegal-sand-winning-shutdown-of-dalun-water-treatment-plant-imminent.html

Fuseini, I. (2016). Urban governance and spatial planning for sustainable urban development in Tamale, Ghana. *Dissertation presented for the degree of Doctor of Philosophy in the Faculty of Arts and Social Sciences at Stellenbosch University*. South Africa: Stellenbosch University. Retrieved from https://core.ac.uk/download/pdf/188224726.pdf

Global Facility for Disaster Reduction and Recovery (GFDRR) . (2022). *Think Hazard Ghana*. Retrieved from ThinkHazard! : https://thinkhazard.org/en/report/94-ghana

He, C., Breuning-Madsen, H., & Awadzi, T. W. (2007). Mineralogy of dust deposited during the Harmattan season in Ghana. *Geografisk Tidsskrift, 107*(1), 9-15. doi:10.1080/00167223.2007.10801371
IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* (V. Masson-Delmotte, P. Zhai, A. Pirani, S. Connors, C. Péan, S. Berger, . . . B. Zhou, Eds.) Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. doi:https://dx.doi.org/10.1017/9781009157896
Jha, A., Lamond, J., Proverbs, D., Bhattacharya-Mis, N., Lopez, A., Papachristodoulou, N., . . . Century, R. B. (2012). *Cities and Flooding: A guide to integrated urban flood risk management for the 21st.* The World Bank, GFDRR. Retrieved from https://www.researchgate.net/publication/272793713_Cities_and_Flooding_A_guide_to_integrated_urban_flood_risk_management_for_the_21st_Century
Karg, H., Hologa, R., Schlesinger, J., Drescher, A., Kranjac-Berisavljevic, G., & Glaser, R. (2019). Classifying and Mapping Periurban Areas of Rapidly Growing Medium-Sized Sub-Saharan African Cities: A Multi-Method Approach Applied to Tamale, Ghana. *Land, 8*(3), 40. doi:https://doi.org/10.3390/land8030040
LDC Expert Group. (2012). *NATIONAL ADAPTATION PLANS: Technical guidelines for the national adaptation plan process.* Bonn, Germany: United Nations Climate Change Secretariat.
Martin, S. (2012). *No-regret low-regret and win-win adaptation actions.* climateXchange.
McSweeney, C., New, M., & Lizcano, G. (2012). *UNDP climate change country profiles: Ghana.* Retrieved from https://www.geog.ox.ac.uk/research/climate/projects/undp-cp/
Menk, L., Terzi, S., Zebisch, M., Rome, E., Lückerath, D., Milde, K., & & Kienberger, S. (2022). Climate Change Impact Chains: A Review of Applications, Challenges, and Opportunities for Climate Risk and Vulnerability Assessments. *Weather, Climate, and Society*, 619-636. doi:https://doi.org/10.1175/wcas-d-21-0014.1
Ministry of Foreign Affairs of the Netherlands. (2019). *Climate Change Profile: Ghana.* The Hague: Ministry of Foreign Affairs of the Netherlands. Retrieved from https://reliefweb.int/report/ghana/climate-change-profile-ghana
Murken, L., Gornott, C., Aschenbrenner, P., Chemura, A., Hattermann, F., Koch, H., . . . Yalew, A. W. (2019). *Climate Risk Analysis for Identifying and Weighing Adaptation Strategies in Ghana's Agricultural Sector.* Potsdam, Germany: Potsdam Institute for Climate Impact Research (PIK) . Retrieved from https://www.adaptationcommunity.net/publications/climate-risk-analysis-for-identifying-and-weighing-adaptation-strategies-in-ghanas-agricultural-sector/
National Climate Change Adaptation Research Facility (NCCARF) . (n.d.). *CoastAdapt: Assess risks and impacts*. Retrieved from CoastAdapt: https://coastadapt.com.au/how-to-pages/how-to-conduct-a-climate-change-risk-assessment
Norman, B., Webb, B., Steffen, W., O'Donnell, T., Sloan, T., Weir, B., & Williams, J. (2014). *Climate Adaptation Sector Review: Informing the Future Direction for the ACT and Region.* Canberra: Canberra Urban and Regional Futures. Retrieved from https://www.researchgate.net/publication/268747271_Climate_Adaptation_Sector_Review_Informing_the_Future_Direction_for_the_ACT_and_Region
Pwamanng, J. A., Appah-Sampong, r. E., & Oppong-Boadi, K. (2020, mAY). Ghana's Fourth National Communication to the United Nations Framework Convention on Climate Change. (L. Mensah, Ed., & D. D. Benefoh, Compiler) Ghana: Environmental Protection Agency (EPA). Retrieved from https://unfccc.int/sites/default/files/resource/Gh_NC4.pdf
Ray, P. A., & Brown, C. M. (2015). *Confronting Climate Uncertainty in Water Resources Planning and Project Design: The Decision Tree Framework.* Washington, DC: The World Bank Group. doi:10.1596/978-1-4648-0477-9
SAL Consult Ltd. (2022). *Environmental and Social Impact Assessment (ESIA) for Tamale Metropolinan Area Sub-Projects - The Savannah Agriculture Value Chain Development Project (SADP).* Accra: Ministry of Food and Agriculture.
Sarwar, M. B., Holmes, R., Korboe, D., Afram, A., & Salomon, H. (2022). *Understanding vulnerability and exclusion in Ghana,.* London: ODI. Retrieved from https://cdn.odi.org/media/documents/V_and_E_study_Ghana_8.8.22.pdf
The World Bank Group. (2009). *Identifying Appropriate Adaptation Measures to Climate Change. Guidance Notes: Mainstreaming Adaptation to Climate Change in Agriculture and Natural Resources Management Projects.* Washington, USA: The World Bank Group.
The World Bank Group. (2021). Climate Risk Profile: Ghana. Retrieved from https://climateknowledgeportal.worldbank.org/sites/default/files/2021-06/15857-WB_Ghana%20Country%20Profile-WEB.pdf
The World Bank Group. (2021). *Ghana - Climatology*. Retrieved from Climate Change Knowledge Portal: https://climateknowledgeportal.worldbank.org/country/ghana/climate-data-historical

The World Bank Group. (2021). *Ghana - Mean Projections Expert*. Retrieved from Climate Change Knowledge Portal: https://climateknowledgeportal.worldbank.org/country/ghana/climate-data-projections

Triple Line Consulting Limited. (2022). *CIG Ghana: Flood risk mapping and modelling report .* IMC Worldwide.

UKCIP. (2011). *Identifying adaptation options (AdOpt).* Retrieved from UKCIP. Oxford: https://www.ukcip.org.uk/wp-content/PDFs/ID_Adapt_options.pdf

UKCIP. (2013a, Julho 30). *Local Climate Impacts Profile (LCLIP) spreadsheet*. Retrieved 2020, from https://www.ukcip.org.uk/wp-content/LCLIP/lclip-spreadsheet-macros-notenabled.xls

UKCIP. (2013b, Julho 30). *LCLIP Spreadsheet guidance notes*. Retrieved 2020, from https://www.ukcip.org.uk/wp-content/LCLIP/LCLIP-spreadsheet_notes.doc

UNDRR and CIMA . (2019). *Ghana Disaster Risk Profile.* Nairobi: United Nations Office for Disaster Risk Reduction (UNDRR) and CIMA Research Foundation. Retrieved from https://www.undrr.org/publication/disaster-risk-profile-ghana

UNEP, IEMP & IISD. (2018). *Adaptation, Livelihoods and Ecosystems Planning Tool: User Manual. Version 1.0.* Retrieved from https://www.iisd.org/system/files/publications/alive-tool-manual-web.pdf

USAID. (2017). Climate Change Risk Profile – Ghana (Fact Sheet). Retrieved from https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID_Climate%20Change%20Risk%20Profile%20-%20Ghana.pdf

USAID. (2019). Climate Risk Profile – West Africa (Fact sheet). Retrieved from https://www.climatelinks.org/sites/default/files/asset/document/West_Africa_CRP_Final.pdf

WHO. (2015). *Climate and health country profile- 2015 Ghana.* Geneva: WHO.

www.meteoblue.com. (2022). *Simulated historical climate & weather data for Tamale*. Retrieved from meteoblue: https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/tamale_ghana_2294877

Zebisch, M., Schneiderbauer, S., Fritzsche, K., Bubeck, P., Kienberger, S., Kahlenborn, W., . . . Below, T. (2021, February). The vulnerability sourcebook and climate impact chains – a standardised framework for a climate vulnerability and risk assessment. *International Journal of Climate Change Strategies and Management*, pp. ahead-of-print. doi:10.1108/IJCCSM-07-2019-0042

Appendix A | Stakeholder Engagement

A1 | Invitation and Stakeholders List - Tamale

Tel: (03720) 22294
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Website: http://www.epa.gov.gh

Environmental Protection Agency
P. O. Box TL 620
Tamale
Northern Region

EPA/NR/25/Vol.1

24th November, 2022

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Dear Sir/Madam,

INVITATION TO A ONE (1) DAY STAKEHOLDERS CONSULTATION MEETING ON THE NATIONAL ADAPTATION PLAN FOR CLIMATE CHANGE MITIGATION

The Environmental Protection Agency (EPA) under the auspices of the Ministry of Environment Science Technology and Innovation (MESTI), is coordinating the national Adaptation Planning (NAP) process with technical and financial support from the Climate Fund (GCF) through the United Nations Environment Programme (UNEP). The NAP Project seeks to build the resilience of local communities through effective climate change adaptation.

The project has identified Tamale and Sekondi-Takoradi for a compressive risk assessment for the dry land conditions and coastal zone, respectively. The assessment will inform the development of adaptation plans for the two metropolises. Stakeholder consultation is one of guiding principles of the NAP Process.

Against the backdrop of this principles, a team of personnel from UNEP is embarking on a stakeholder consultation mission in Tamale Metropolis of the Northern region.

The venue and time for the stakeholder engagement is as follows;

Venue: Catholic Guest House, Tamale
Date: Tuesday 29th November, 2022.
Time: 8:30 am prompt

You are kindly required to nominate one (1) person from your outfit to participate in this very important stakeholder engagement meeting to be held in the Northern region

We apologies for the short notice

Counting on your usual cooperation.

Yours faithfully,

Abu Iddrisu
(Regional Director)
For: Executive Director

CLIMATE CHANGE ENGAGEMENT – STAKEHOLDERS – NORTHERN REGION: 28TH – 29TH NOVEMBER, 2022

1. The Hon. MCE - Tamale Metropolitan Assembly
2. The Regional Director - MoFA, Tamale – Northern Region
3. Regional Economic Planning Office - REPO. RCC – Tamale
4. The Regional Director - FSD, Tamale – Northern region
5. The Regional Director - Ghana National Fire Service
6. The Director - GDCA – Tamale –Northern region
7. The Head of Department - Department of Climate Change – UDS – Tamale
8. The Regional Director - Regional House of Chiefs, Tamale, N/R
9. The Director, - ACDEP Secretariate, Tamale , N/R
10. The Regional Director - Catholic Relief Service, Tamale, N/R
11. The Executive Director - Peasant Farmers Association, Tamale, N/R
12. The Regional Director - Irrigation Development Authority, Tamale, N/R
13. The Regional Director - Department of Gender, RCC, Tamale, N/R
14. The Regional Director - LUSPA, Tamale
15. The Regional Director - Lands Department, Tamale, N/R
16. The Regional Director - Ghana Productive Safety nets Project (GPSNP), Tamale.
17. The National Co-ordinator - GCAP Project Tamale, N/R
18. The Regional Director - GES, Tamale, N/R
19. The Regional Director - Community Development, Tamale, N/R
20. The Regional Director - National Population Council, Tamale, N/R.
21. The Regional Director - NADMO, Tamale, N/R
22. The Regional Director - Ministry of Health
23. The Regional Director - Zaam Tamale, N/R
24. The Regional Director - Plan Ghana, Tamale, N/R
25. The Regional Director - Action Aid (Ghana), Tamale, N/R
26. The Regional Director - CWSA, Tamale, N/R
27. The Regional Director - NORDA, Tamale, N/R
28. The Regional Director - Department of Women, Tamale, N/R
29. The Regional Director - GNA, Tamale, N/R
30. The Regional Director - RUMNET, Tamale, N/R
31. The Regional Director - NORSAC, Tamale, N/R
32. The Regional Director - WRI, Tamale, N/R
33. Dohinaa (Nomnaa) - Duunyin, Tamale, N/R
34. Abdul Rahman Lansah - (Kuko Naa) – Dolunaayilli, Tamale, N/R
35. Mac Mathia Chancellor - Opinion Leader, Tamale, N/R
36. Naa Abdul Latif (Sahanaa) Opinion Leader, Tamale, N/R
37. The Regional Director - GBC, Tamale N/R
38. The Regional Director - SEND Ghana, Tamale, N/R
39. The Regional Director - OXFAM, Tamale, N/R
40. The Regional Director - NCCE, Tamale, N/R
41. The Regional Director - Information Services Department, Tamale, N/R
42. The Regional Director - Ghana Water Company Limited, Tamale, N/R
43. The Regional Director - Fisheries Co-operation, Tamale, N/R
44. The Regional Director - Feeder Roads Department, Tamale, N/R.
45. The Regional Director - Environmental Protection Agency, Tamale, N/R

A2 | |Stakeholders List – Workshops held in Accra

7/December/2022

No.	Name	Institution
2.	Abena A. Adu	LUSPA
3.	Patience Agyekum	SYND
4.	Francisca Martey	GMET
5.	George Yorke	WaterAid
6.	Joy Hesse Ankomah	EPA-HSU
7.	Elliot Ansah	GSS
8.	Miriam Bafowaa opoku	DOR
9.	Antwi – B. Amoah	EPA
10.	Bob Manteaw	UG
11.	Eric Afornorpe	MLGDRD
12.	Evelyn Addor	Ecocare Ghana
13.	Carl Osei	GHS
14.	Joyce Gyeke	GBC
15.	David Aidoo	WaterAid
16.	Mumuni Abu	RIPS, UG
17.	Bernard Asante	VAL-Ghana
18.	Robert Mensah	MOF
19.	Foster A. Gyamfi	MOF
20.	Jonathan Gokah	Kasa Gh
21.	Joycelyn Smith	MOF
22.	Lydia Kukua Asamoah	GNA
23.	Isaac Kwabena Danso	EPA
24.	Kumi Sarfo Obed	EPA
25.	Marilyn Christian	EPA
26.	Emmanuel. A. Oduro	EPA

8/December/2022

No.	Name	Institution
27.	Abena A. Adu	LUSPA
28.	Patience Agyekum	SYND
29.	Francisca Martey	GMET
30.	George Yorke	WaterAid
31.	Joy Hesse Ankomah	EPA-HSU
32.	Elliot Ansah	GSS
33.	Miriam Bafowaa opoku	DOR
34.	Monique Cranna	ZUTARI
35.	Antwi – B. Amoah	EPA
36.	Bob Manteaw	UG
37.	Eric Afornorpe	MLGDRD
38.	Evelyn Addor	Ecocare Ghana
39.	Naa Adaku Palm	LUSPA
40.	Ishomon Foli	VALD- Ghana
41.	MaryJane Eunchill	PMU-NAP
42.	Joyce Gyeke	GBC
43.	Isabel Andam	SYND
44.	Solomon Yamoaa	YNREG
45.	Ali M. Katu	GAIP
46.	James Oppong Otoo	NADMO
47.	Angela Kwashie	UNCDF
48.	Robert Mensah	MOF
49.	Foster A. Gyamfi	MOF
50.	Jonathan Gokah	Kasa Gh
51.	Jocelyn Smith	MOF
52.	Lydia Kukua Asamoah	GNA
53.	Isaac Kwabena Danso	EPA
54.	Kumi Sarfo Obed	EPA
55.	Marilyn Christian	EPA
56.	Emmanuel. A. Oduro	EPA

In diversity there is beauty and there is strength.

MAYA ANGELOU

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