Adapting Together, Thriving Tomorrow

Climate Change Risk Assessment for Kumasi Metropolitan Assembly, Ghana

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

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Enhancing Multi-Sector Planning and Capacity for
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List of Abbreviations

Acronym	Expanded Form
AfDB	AfDB African Development Bank
CBOs	Community-Based Organizations
CCA	Climate Change Vulnerability
CCRA	Climate Change Risk Assessments
COP	Conference of Parties
CSOs	Civil Society Organizations
CWSA	Community Water and Sanitation Agency
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
FASDEP	Food and Agriculture Sector Development Policy
GCF	Green Climate Fund
GDP	Gross Domestic Product
GES	Ghana Education Service
GHG	Greenhouse gases
GHS	Ghana Health Service
GMet	Ghana Meteorological Agency
GSS	Ghana Statistical Service
GWCL	Ghana Water Company Limited
IPCC	Intergovernmental Panel on Climate Change
ISD	Information Services Department
IUNCN	International Union for Conservation of Nature
KMA	Kumasi Metropolitan Assembly
KNUST	Kwame Nkrumah University of Science and Technology
MCDM	Multicriteria Decision Making
MESTI	Ministry of Environment, Science, Technology and Innovation
MLGDRD	Ministry of Local Government, Decentralization and Rural Development
MMDAs	Metropolitan, Municipal, and District Assemblies
MoE	Ministry of Education
MoFA	Ministry of Food and Agriculture
MoH	Ministry of Health
MSWR	Ministry of Sanitation and Water Resources
MTDPs	Mid-Term Development Plans
MWH	Ministry of Works and Housing
NADMO	National Disaster Management Organization
NAP	National Adaptation Plan
NCCAS	National Climate Change Adaptation Strategy
NCCE	National Commission for Civic Education
NCCP	National Climate Change Policy
NCWSP	National Community Water and Sanitation Programme
NDCs	Nationally Determined Contributions
NGOs	Non-governmental Organizations
PPPs	Public-Private Partnerships

PFJ	Planting for Food and Jobs
SDGs	Sustainable Development Goals
SSPs	Shared Socio-Economic Pathways
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization
WRC	World Resources Commission

EXECUTIVE SUMMARY

Climate Change Rapid Risk Vulnerability for the Kumasi Metropolitan Assembly

This main goal of climate change rapid risk assessment is to assist local experts and stakeholders in systematically evaluating KMA vulnerability to climate change impacts, focusing on integrating hazard, exposure, and vulnerability. Applying the IPCC's climate change risk framework to the Kumasi Metropolitan Assembly, the report highlights the complex interplay of factors driving local climate risks.

The climate change rapid risk assessment adopted a structured participatory methdodlogacl approach involving a desk review, information synthesis, stakeholder consultation and final revision and validation. The assessment shows that KMA faces significant economic and physical vulnerabilities. The report suggests that KMA faces various challenges that affect its social vulnerability and adaptive capacity. Rapid urbanization and population growth put pressure on the existing infrastructure, services, and resources, and increase the exposure and sensitivity of the urban poor to hazards and shocks.

The report further recognizes that climate change affects different socioeconomic groups differently. It highlights how women and girls experience the greatest impacts of climate change, which amplifies existing gender inequalities and poses unique threats to their livelihoods, health, and safety. The key gender issues highlighted include.

- **Heat stress:** Women in the metropolis, especially pregnant women and girls, are more susceptible to heat-related illnesses due to biological differences and potential limitations on clothing choices.
- **Increased burden of waterborne diseases:** Women in Kumasi metropolis responsible for water collection face a higher risk of exposure to contaminated water sources due to changing rainfall patterns or flooding.
- **Mental health:** Women in the metropolis are disproportionately affected by climate change-induced stress due to concerns about family well-being, food security, and displacement.
- **Loss of crop yields:** Women farmers in the metropolis reliant on traditional crop varieties become less resilient to drought or erratic rainfall.
- **Limited access to climate-smart technologies:** Social norms limit women's access to training or resources for drought-resistant crops or water-saving irrigation techniques.
- **Food insecurity:** Women in the metropolis face a greater burden of ensuring household food security when climate change disrupts food production.
- **Increased flooding risk:** Women and girls living in flood-prone areas in the metropolis are more vulnerable due to limited mobility or difficulty reaching evacuation points.
- **Loss of shelter:** Women are responsible for rebuilding homes after disasters and face challenges accessing materials or financial support.

- **Gender-based violence:** Disasters that occur in the metropolis heighten the risk of violence against women and girls in overcrowded shelters or temporary housing.
- **Water scarcity:** Women responsible for water collection in the metropolis travel further distances or spend more time searching for water during droughts.
- **Sanitation challenges:** Limited water availability exacerbates sanitation issues, particularly for women and girls in the metropolis during menstruation or needing to use toilets at night.

Recommendations for *Kumasi Metropolitan Assembly*

- **Localized Action Plans:** KMA can develop a city-specific climate change adaptation plan based on the national framework, focusing on the city's unique vulnerabilities.
- **Gender-Specific Programmes:** Design programs that empower women in agriculture through access to drought-resistant crops, training, and financial resources. Partner with women's groups for community outreach and education.
- **Strengthen Early Warning Systems:** Implement robust weather forecasting and early warning systems to alert communities about floods and droughts, allowing them to prepare and mitigate impacts.

Adaptation Action Plan for the Kumasi Metropolitan Assembly

Following the identification of key vulnerabilities and climate risks in the KMA, a list of potential adaptation options was identified through a desk review literature search and interactions with key stakeholders. In total, 70 adaptation options were identified across the six sectors. An adaptation action plan was developed for the KMA to address the municipal's vulnerabilities and climate change risks while building its resilience towards the attainment of the sustainable development. Through stakeholder workshops with stakeholders drawn from priority sectors affecting the economy in KMA and adopti g a gendered apprach, the identified adaptation actions were prioritized to make informed decisions that lead to effective adaptation and avoid maladaptation. The adaptation actions were evaluated using a Multicriteria Decision Making (MCDM) Analysis. The action plan aligns with the unique socio-economic and environmental characteristics of the KMA. The adapatation action plan provides details on the objectives, key performance indicators, resources requirement and implementing agencies for each adaptation action across agriculture, water resources, energy, health, trade and gender sectors. The action plan also provides an estimaetsd cost for each adaotation action.

1 Introduction

1.1 Background

Climate change continues to dominate global environmental and development discourses because of the adverse impacts on socioeconomic development. These discussions have intensified over the past few decades, particularly through forums like the United Nations Framework Convention on Climate Change (UNFCCC) and the annual Conference of the Parties (COP) meetings. The Paris Agreement, adopted at COP 21 in 2015, marked a significant milestone, with countries committing to limit global warming to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C. These international commitments highlight the collective recognition of climate change as a critical global issue requiring concerted efforts (UNFCCC, 2015).

Sub-Saharan Africa (SSA) faces disproportionate effects of climate change even though it contributes negligibly to the total global emissions. The 6th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2021) suggests that climate change will continue to pose significant threats, including increased temperatures, changing precipitation patterns, and more extreme weather events.

Ghana, located in West Africa, is experiencing significant impacts of climate change (Asante & Amuakwa-Mensah, 2014). The country's climate has become increasingly unpredictable, with notable changes in rainfall patterns and rising temperatures. These changes pose substantial threats to economic sectors, particularly agriculture, water resources, energy, health, and infrastructure (Antwi-Agyei et al., 2012; Baffour-Ata et al., 2021). Addressing these threats requires effective and proactive adaptation planning, aimed at building resilience in these economic sectors. Adaptation involves adjusting practices, processes, and structures to minimize the adverse effects of climate change and take advantage of potential opportunities. For Ghana, this means integrating climate considerations into national and sectoral development plans, enhancing institutional capacities, and promoting community-based adaptation strategies.

Thus, effective climate adaptation in Ghana necessitates a thorough evaluation of risks and vulnerabilities across various sectors and regions. This knowledge should then be strategically applied to guide adaptation planning at both the national and local levels, particularly in critical climate-sensitive sectors. One critical framework guiding Ghana's adaptation efforts is the National Climate Change Policy (NCCP), which outlines the country's strategic direction in addressing climate change. The policy emphasizes resilience-building across sectors and highlights the importance of sustainable natural resource management, disaster risk reduction, and public awareness campaigns (Ministry of Environment, Science, Technology and Innovation [MESTI], 2021).

Ultimately, adaptation planning and resilience-building against climate impacts should be grounded in developing a deep understanding of climate impact manifestations, associated risks, and vulnerabilities in various sectors and regions (Owen, 2020; Eriksen et al., 2021). This knowledge should also underpin capacity-building processes that ensure effective climate adaptation governance, aimed at enhancing adaptive capacities across sectors, communities, and multiple levels (Yeleliere et al., 2023; Asibey et al., 2024). Ghana's National

Adaptation Planning (NAP) process addresses these needs by integrating climate adaptation imperatives into governance at different levels. Incorporating community-based knowledge and indigenous practices in the NAP process can further strengthen adaptation strategies, making them more effective and sustainable.

1.2 Aims and Objectives

The Government of Ghana, via the Environmental Protection Agency (EPA) and under the guidance of the Ministry of Environment, Science, Technology, and Innovation (MESTI), has secured a grant from the Green Climate Fund (GCF) for a three-year initiative aimed at bolstering the National Adaptation Plan (NAP) process in the country. The United Nations Environment Programme (UNEP) is partnering as the Delivery Partner, overseeing the project's implementation.

The NAP initiative aims to facilitate comprehensive, long-term adaptation planning and budgeting across various sectors in Ghana. It seeks to integrate climate change adaptation considerations into national development strategies and policies. To achieve this, the project will strengthen systems for collecting and sharing climate risk and vulnerability data and develop sustainable financing mechanisms for adaptation efforts. As part of this effort, the project will focus on generating climate change scenarios and risk assessments for Ghana using advanced techniques and data. These assessments will form the foundation for both national and regional climate change adaptation plans. Effective climate change risk assessments (CCRAs) are critical for understanding climate science, managing uncertainties, analyzing data through diverse methods, and conveying risk impacts in a clear and actionable manner for decision-makers and other stakeholders.

The outcomes of this work will support several national initiatives, including the updated NAP, and provide the climate rationale required to access international climate finance. This necessitates a thorough understanding of historical and current climate impacts, projections of future climate impacts with and without climate change, and distinguishing other concurrent changes within the assessment area. The ultimate goal is to create a detailed and transparent climate risk narrative for Ghana.

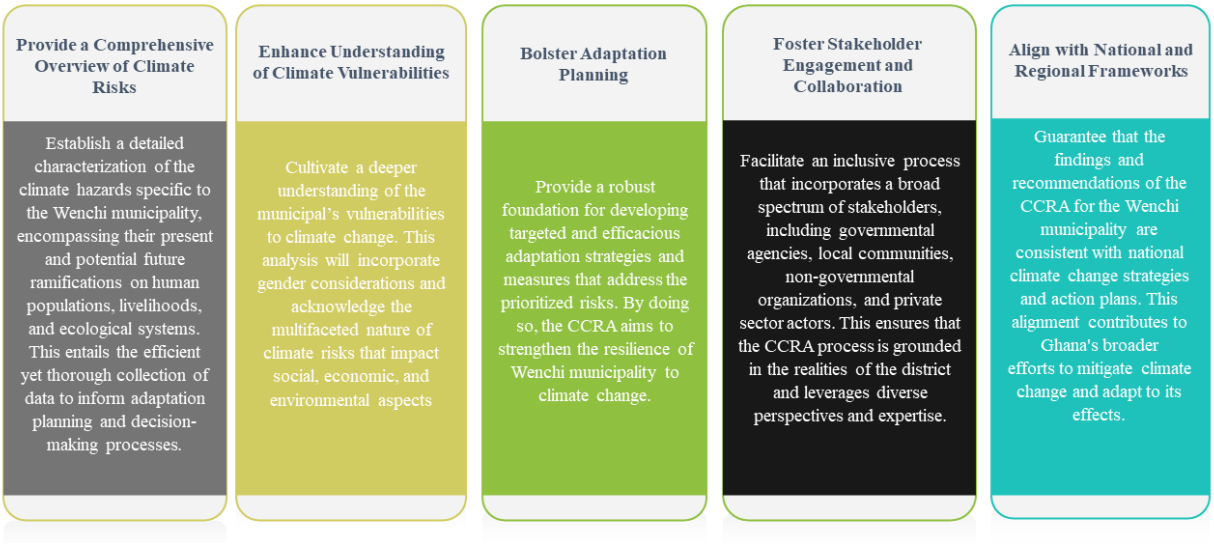
The overarching aim of this assignment is to develop a costed district adaptation plan and to build the capacity of the Kumasi Municipal Assembly for the mainstreaming of adaptation considerations in their Mid-Term Development Plan (MTDP) policies and plans. The assessment is guided by the following specific objectives:

- To conduct rapid climate risk assessment in the Kumasi Metropolitan Assembly.
- To develop costed adaptation plans for the Kumasi Metropolitan Assembly

1.3 Document Purpose

This report provides the CCRA for the Kumasi Metropolitan Assembly (KMA), for up to four first-order (biophysical) risk domains, and up to three second-order (economic sectors) risk domains, developed in collaboration with municipal stakeholders in Kumasi. The main goal of this document is to assist local experts and stakeholders in systematically evaluating the district's vulnerability to climate change impacts, focusing on integrating hazard, exposure, and vulnerability elements based on the Fifth Assessment Report (AR5) framework from the IPCC. Specifically, the CCRA endeavors to achieve the following goals:

Figure 1: A framework of the CCRA goals



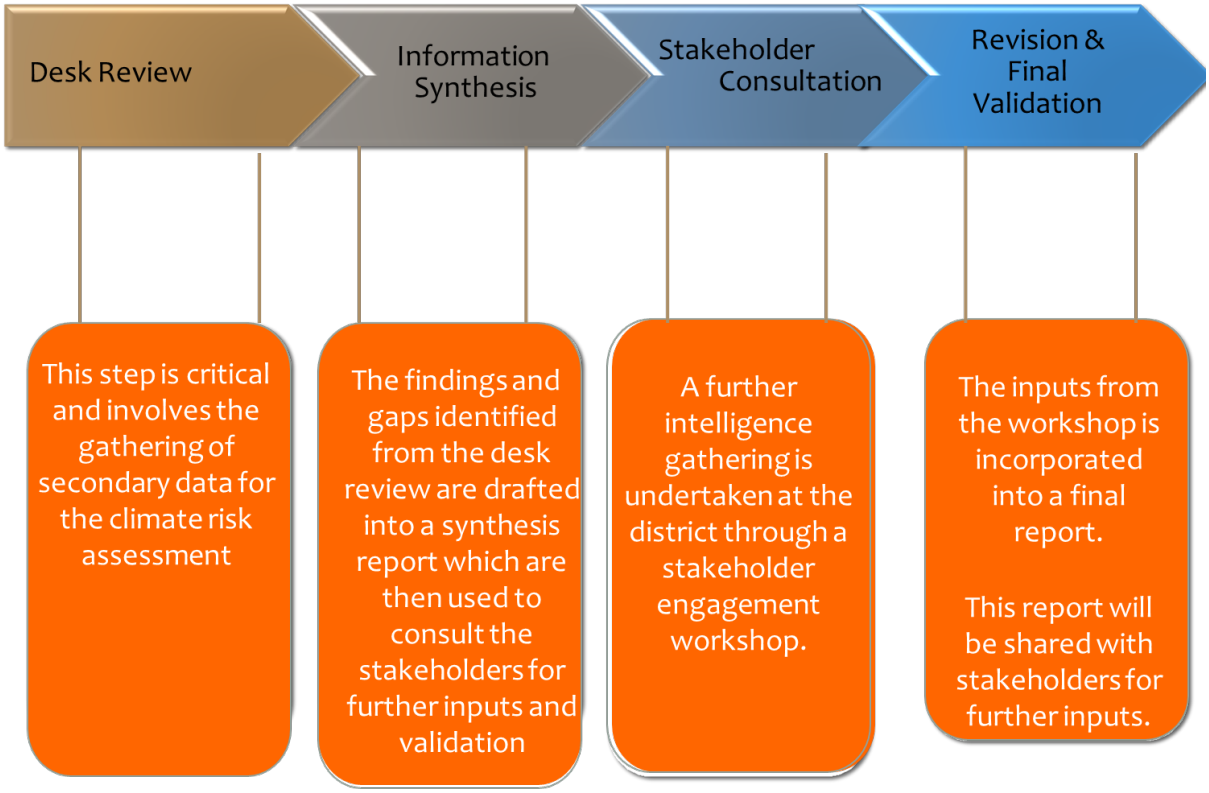
2

Approach and Methodology

2.1 Approach

The assessment method for this Climate Change Risk Assessment for the Kumasi Metropolitan Assembly is a structured, sequential procedure that comprises the following steps:

Figure 2: Overall work approach for the Climate Change Risk Assessment for the Kumasi Metropolitan Assembly



- **Desk Review**

  The desk review is the foundational step in the climate risk assessment process. This phase involves the critical task of gathering secondary data, which serves as the bedrock upon which the entire assessment is built. Secondary data refers to information that has already been collected, analyzed, and published by other sources. This could include academic research, government reports, climate models, historical climate data, and case studies from other regions or projects.

  The primary objective of the desk review was to compile a comprehensive dataset that provides a detailed understanding of the current state of climate risks. This step involves meticulous research and the synthesis of vast amounts of data to ensure a well-rounded perspective. Analysts must evaluate

the reliability and relevance of the sources, cross-referencing data to confirm accuracy and identify any discrepancies or gaps in the existing knowledge.

The gathered data provided insights into various climate-related factors such as temperature changes, precipitation patterns, sea level rise, and the frequency of extreme weather events. Understanding these elements is crucial for identifying vulnerabilities and potential impacts on the environment, economy, and communities. This initial phase sets the stage for more targeted and specific investigations in subsequent steps, ensuring that the assessment is grounded in robust and credible information.

- **Information Synthesis**

Following the desk review, the information synthesis step involved distilling the vast amount of collected data into a coherent and comprehensive synthesis report. This phase is crucial as it translates raw data into actionable insights, highlighting key findings, trends, and gaps identified during the desk review. The synthesis report serves multiple purposes. Firstly, it provides a summarized version of the extensive research conducted in the desk review, making the information more accessible and understandable for stakeholders.

Secondly, the synthesis report is a tool for engagement and can be used to consult with stakeholders, allowing them to provide inputs and validation. Stakeholders, including local communities, policymakers, scientists, and industry representatives, bring diverse perspectives and expertise, which are invaluable for refining the findings. Their feedback helps to ensure that the assessment is comprehensive and considers all relevant factors.

- **Stakeholder Consultation**

The stakeholder consultation step is pivotal in ensuring that the climate risk assessment is inclusive, participatory, and grounded in local realities. This phase involves engaging with a broad range of stakeholders through a district-level engagement workshop, aimed at gathering further intelligence and insights. Stakeholders typically include representatives from local governments, community organizations, businesses, academic institutions, and other relevant entities. Their involvement is crucial as they possess unique local knowledge, experience, and expertise that can enrich the assessment. Engaging stakeholders in a workshop setting fosters open dialogue, encouraging the sharing of perspectives and the identification of additional risks and opportunities.

During the consultation, the preliminary findings from the synthesis report are presented, and stakeholders are invited to provide feedback. This collaborative approach ensures that the assessment is not only scientifically sound but also socially and culturally relevant. Stakeholders can highlight local vulnerabilities, suggest mitigation strategies, and identify practical adaptation measures that may not have been apparent through secondary data alone.Furthermore, the consultation process builds trust and ownership among stakeholders. By actively involving them in the assessment, they are more likely to support and contribute to the implementation of the recommendations.

- **Revision and Final Validation**

This stage is about refining the assessment based on the inputs gathered during the stakeholder consultation and ensuring that the final report is accurate, comprehensive, and actionable. The inputs from the stakeholder workshop were meticulously reviewed and incorporated into the final report.

Once the revisions were made, the final report was validated by sharing the revised document with stakeholders for final review and approval. Their validation ensures that the report is not only technically sound but also aligned with the expectations and needs of the stakeholders. This step is crucial for building consensus and ensuring that the recommendations are feasible and supported by all involved parties.

The final report serves as a strategic tool for policymakers, planners, and other stakeholders, providing a clear roadmap for addressing climate risks. By incorporating stakeholder inputs and undergoing rigorous validation, the final report becomes a credible and authoritative guide for climate risk management, setting the stage for effective implementation and long-term resilience building.

2.2 Methodology

The methodology for this Climate Change Risk Assessment (CCRA) for the Kumasi Metropolitan Assembly, adapted from Norman et al. (2014), is a structured approach divided into three primary stages, each with its specific focus and activities (Figure 4):

Stage 1: Risk Identification

The first step in risk identification is establishing the context by defining the parameters that influence the climate risk management process in the Kumasi Metropolitan Assembly. This involved desk reviews to gather relevant information. These reviews involved examining existing documentation, reports, and data to gain a comprehensive understanding of the metropolitan's unique environmental and socio-economic attributes. Once the context was established, the next step was to identify relevant climate change-related risks. This involved recognizing and documenting potential risks that may arise due to climate change and could impact

the Metropolitan Assembly. These risks were varied and may have included physical risks (such as extreme weather events) and transitional risks (such as regulatory changes).

Stage 2: Risk Assessment

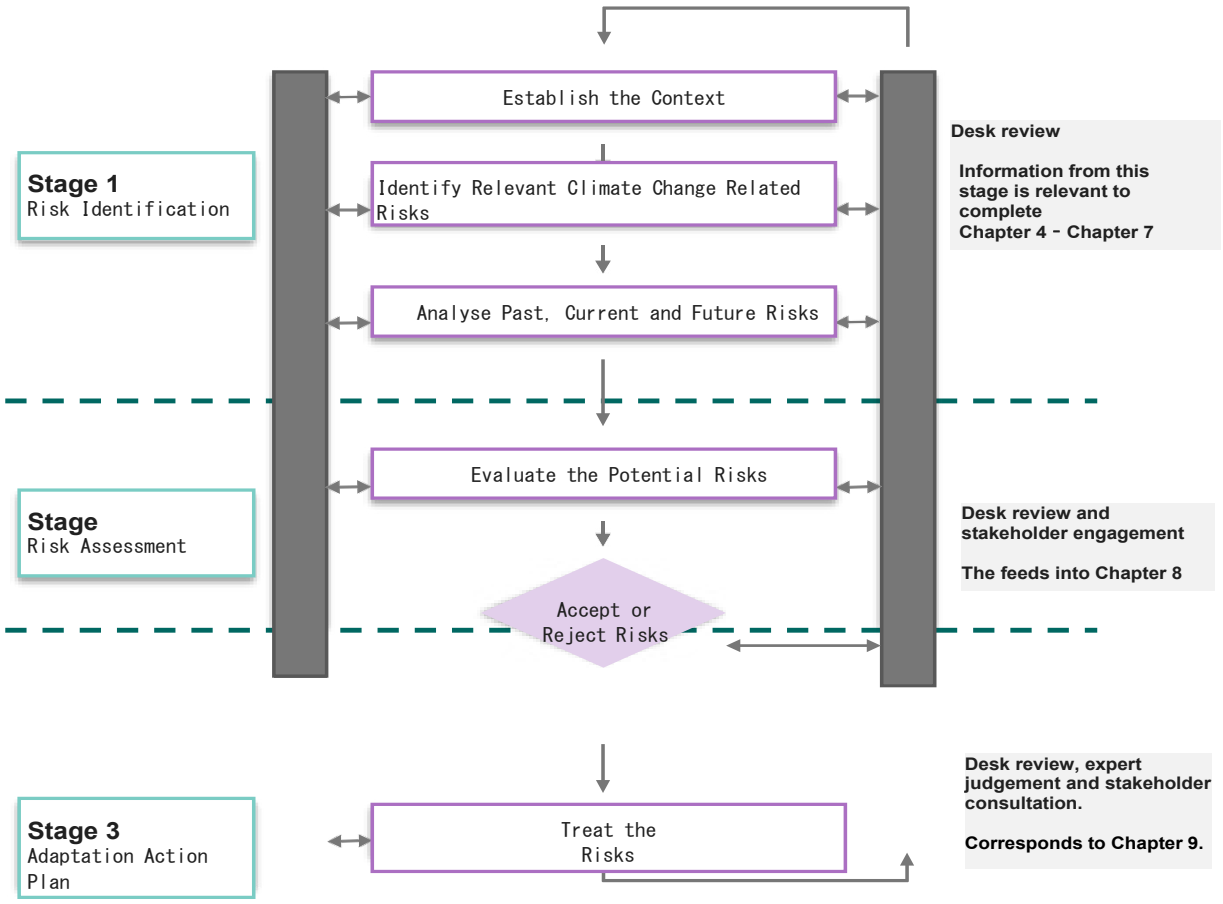
The second stage in climate change risk management is risk assessment, which involves analyzing the identified risks to evaluate their potential impacts and likelihood. This stage was essential for understanding the significance of identified risks and determining appropriate actions to address them. The risk assessment began with the analysis of past, current, and future risks. This involved evaluating how historical events and current trends can influence future risks. By examining past data, the team identified patterns and understood how similar risks may have impacted the Metropolitan Assembly in the past. The results of the risk evaluation feed into the risk management documentation, specifically Chapter 8. This documentation provides a detailed analysis of the potential risks, their impact, and likelihood. It serves as a critical input for decision-making regarding risk acceptance and treatment.

The results of this stage were meticulously documented in chapter 8 of the assessment, which examined and prioritized hazards based on their potential consequences and probability. Following the entire assessment, a decision point was reached at which risks were either approved for further action or denied based on preset criteria. These factors often included the severity of the impact, the financial costs of adaptation, and the metropolitan's ability to effectively manage the risks. This decision-making process was critical in determining the direction and focus of the subsequent Adaptation Action Plan.

Stage 3: Adaptation Action Plan

This final stage involved the formulation and implementation of an Adaptation Action Plan to address the identified risks. The objective of the adaptation action plan is to ensure that the Kumasi Metropolitan Assembly is resilient to the impacts of climate change and can continue to operate effectively in the face of the identified risks. The adaptation action plan corresponds to Chapter 9 of the risk management documentation. This chapter provides a detailed description of the adaptation strategies, their objectives, and the expected outcomes. It also includes a roadmap for implementation, outlining the steps and resources required to achieve the desired results. The methodology emphasizes a collaborative approach, incorporating diverse perspectives and expertise to shape the assessment and subsequent action plan. This process is crucial for creating a strong, contextually tailored strategy for climate change adaptation in the Kumasi Metropolitan Assembly.

Figure 3: General overview of the risk assessment process



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

3 Overview of Kumasi Metropolitan Assembly

This section provides a high-level overview of the Kumasi Metropolitan Assembly (KMA).

Figure 4: Aerial view of the Kumasi Metropolitan Assembly

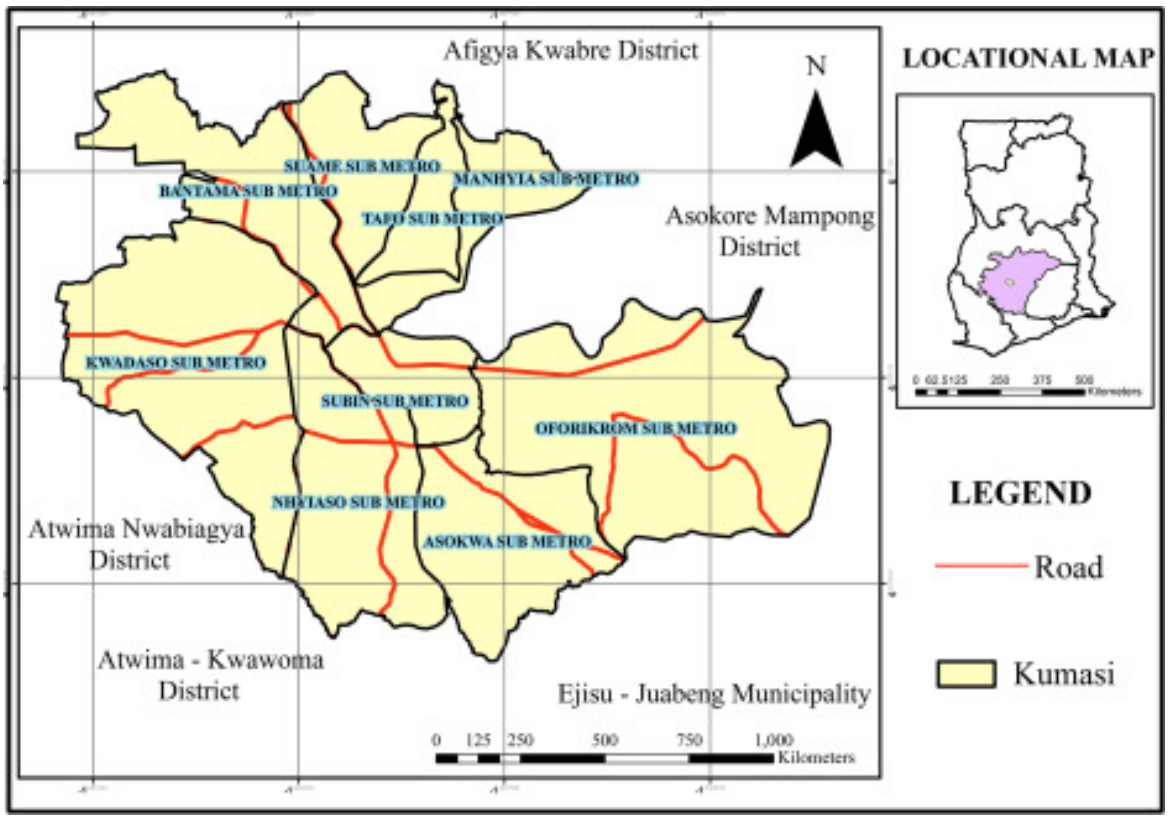
Source: AngelOnline (2020)

3.1 Profile of Kumasi Metropolitan Assembly

The Kumasi Metropolitan Assembly (KMA) is one of the 261 Metropolitan, Municipal and District Assemblies (MMDAs) in Ghana. It is part of the 43 MMDAs in the Ashanti Region, Ghana with Kumasi being its administrative capital. It is located between Latitude 6.35°N and 6.40° S and Longitude 1.30°W and 1.35° E and elevated 250 to 300 meters above sea level (Ghana Statistical Service [GSS], 2014). The Metropolis shares boundaries with Kwabre East and Afigya Kwabre Districts to the north, Atwima Kwanwoma, and Atwima Nwabiagya Districts to the west, Asokore Mampong and Ejisu-Juaben Municipality to the east and Bosomtwe District to the south. It is approximately 270 km north of the national capital, Accra (GSS, 2014). It has a surface area of approximately 214.3 square kilometers which is about 0.9% of the region's land area (GSS, 2014). However, it accommodates

about 36.2% of the region's population (GSS, 2014). According to the Ghana 2021 Population and Housing Census, KMA is made up of five constituencies namely Nhyiaeso, Subin, Manhyia South, Manhyia North, and Bantama (GSS, 2021).

Figure 5: Map of Kumasi Metropolitan Assembly showing major towns



Source: Amponsah et al., (2016)

3.2 Climate

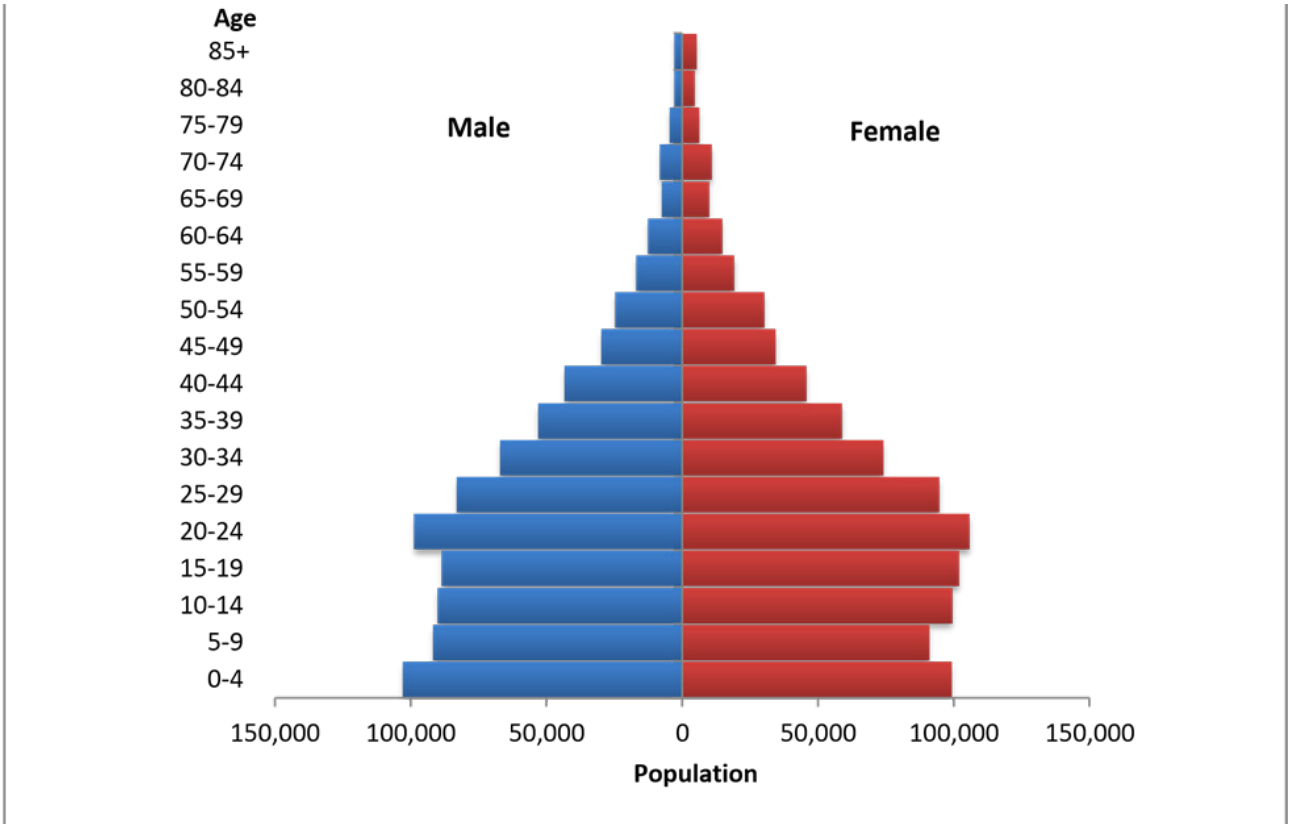
KMA falls within the wet sub-equatorial type. The average minimum temperature is about 21.5 and the maximum average temperature is about 30.7 (GSS, 2014). The average humidity is around 84.1% at sunrise and 60% at sunset. The moderate temperature and humidity and the double maxima rainfall regime (214.3 mm in June and 165.2 mm in September) have a direct effect on population growth and the environment as it has precipitated the influx of people from every part of the country and beyond its frontiers to the metropolis. This is chiefly because the climatic conditions are not harsh. Thus, Kumasi is the second most populous city in Ghana (World Population Review, 2023).

3.3 Population Size and Distribution

According to the Ghana 2021 Population and Housing Census, the total population of Kumasi Metropolis was 443,981 people, of which 51.9% were females and 48.1% were males (GSS, 2021). The population growth rate of Kumasi Metropolis between 2010 and 2021 was 1.9% per annum, which was lower than the national average of 2.1% (GSS, 2021). The population density of Kumasi Metropolis in 2021 was 6,542.6 people per square kilometer, which was higher than the national average of 149.1 people per square kilometer (GSS, 2021). The urbanization rate of Kumasi Metropolis in 2021 was 100%, which means that all of the population lived in urban areas (GSS, 2021). The age structure of Kumasi Metropolis in 2021 showed that 35.3% of the population were children (0-14 years), 60.4% were working age (15-64 years), and 4.3% were elderly (65

years and above). The age structure of KMA shows that it has a young and productive population, with a median age of 23.5 years (GSS, 2021). The sex ratio of KMA in 2021 was 92.8 males per 100 females.

Figure 6: Population pyramid of KMA



Source: Ghana Statistical Service, 2010 Population and Housing Census

3.4 Relief and Drainage

The Kumasi Metropolis lies within the plateau of the South–West physical region which ranges from 250 to 300 meters above sea level. The topography is undulating. The Metropolis is traversed by a major river (Owabi) and streams like Subin, Wiwi, Sisai, Aboabo, and Nsuben.

These water bodies, especially Owabi, serve as the main source of drinking water to residents

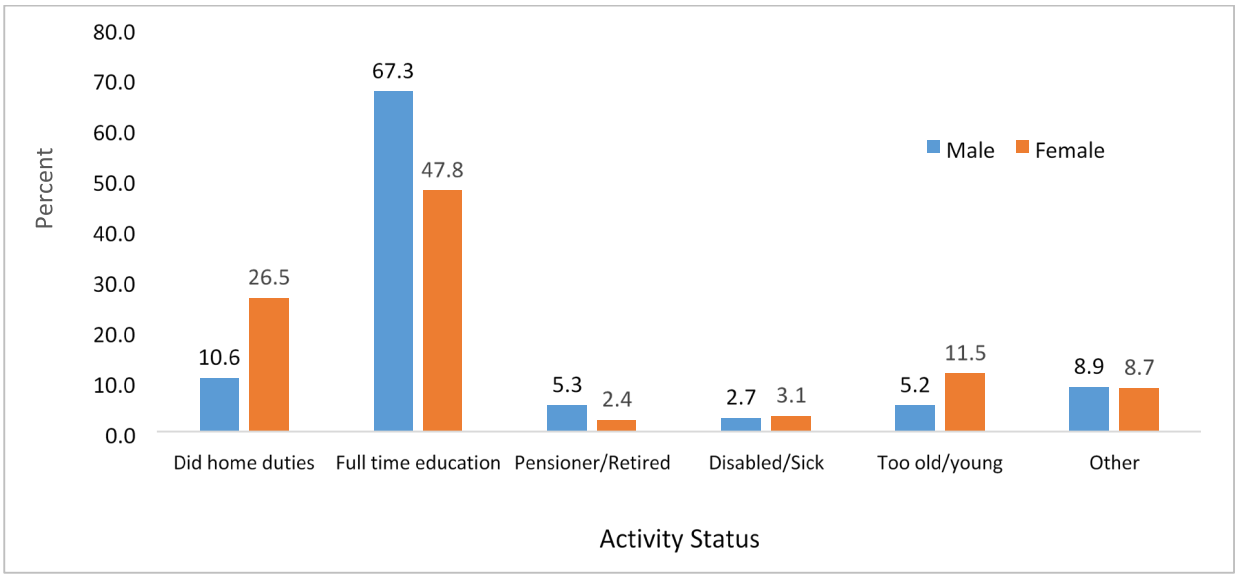
not only within the Metropolis but the region as a whole. Notwithstanding the critical role played by these water bodies in the socioeconomic well-being of residents, human activities have threatened the extinction of some of them. Building on water courses by estate developers and urban agricultural practices are some of the human activities that have polluted these water bodies. This may partly explain the frequent occurrence of flooding in the Metropolis.

3.5 Economic activities

About 66.5% of the population aged 15 years and older is economically active while 33.5% is economically not active (GSS, 2014). Of the economically active population, 91.4% is employed while 8.6% is unemployed. For those who are economically not active, a larger percentage of them are students (56.4%), 19.5% perform home duties and 2.9% are disabled or too sick to work. Nearly six out of ten (56.4%) of the unemployed persons are seeking work for the first time. Of the employed population, 38.9% are in service and sales work,

22.8% are in craft and related trades 10.3% are in elementary occupation and only 2.6% are skilled agricultural forestry and fishery workers. Females (55.1%) are more likely than males (22%) to be engaged in service and sales work whereas males (32.9%) are more likely than females (13.1%) to be engaged in craft and related trade. About 49.2% of the workforce is self-employed without employees with females and males proportion as 60.1% and 37.9% respectively (GSS, 2014).

Figure 7: Economically not active population by sex



Source: Ghana Statistical Service, 2010 Population and Housing Census

4

Climate Change Vulnerability of the Kumasi Metropolitan Assembly

4.1 Defining Climate Change Risk and Vulnerability

The Intergovernmental Panel on Climate Change (IPCC) provides a comprehensive framework for understanding climate change risk and vulnerability, crucial for developing effective adaptation and mitigation strategies. According to the IPCC, climate change risk is defined by the interaction of three primary components: hazard, exposure, and vulnerability. Hazards are the physical manifestations of climate change, such as extreme weather events, rising sea levels, and shifting temperature patterns. Exposure refers to the presence of people, assets, and ecosystems in places that could be adversely affected by these hazards. Vulnerability, a multifaceted concept, encompasses the susceptibility of these exposed elements to harm, influenced by social, economic, and environmental factors. The IPCC emphasizes that vulnerability is not static; it varies across different communities and over time, shaped by factors such as governance, socioeconomic conditions, and adaptive capacities. By dissecting these components, the IPCC highlights the complex and interconnected nature of climate change impacts, advocating for an integrated approach that addresses all aspects of risk to enhance resilience and reduce overall vulnerability. This nuanced understanding is critical for policymakers, enabling targeted actions that can safeguard both human and natural systems against the escalating threats of climate change.

The diagram below provided by the IPCC outlines a conceptual framework for understanding climate change risk, emphasizing the interplay between climate factors, socioeconomic processes, emissions, and land-use change. Applying this model to the Kumasi Metropolitan Assembly allows for a localized analysis of climate change impacts and the formulation of targeted strategies for adaptation.

In the context of the Kumasi metropolis, the climate components include natural variability and anthropogenic climate change. Kumasi, like many regions, experiences natural climate fluctuations that can lead to variability in rainfall, temperature, and seasonal patterns. However, human activities such as deforestation, agriculture, and urban development contribute significantly to climate change, exacerbating the frequency and intensity of extreme weather events such as floods, droughts, and heatwaves.

The **'Hazards'** represent these physical manifestations of climate change. For the Kumasi metropolis, key hazards include increased rainfall variability leading to flooding, prolonged dry spells causing drought, and temperature extremes affecting agricultural productivity. These hazards pose significant risks to the local population, infrastructure, and economy.

'Exposure' in Kumasi metropolis refers to the presence of people, properties, and ecosystems in areas prone to climate hazards. The metropolitan assembly must consider how densely populated areas, critical infrastructure like roads and schools, and vital agricultural lands are exposed to these risks. For instance, farming communities in low-lying areas may be particularly vulnerable to flooding, while those relying on rain-fed agriculture are at risk from droughts.

'Vulnerability' in Kumasi metropolis is shaped by social, economic, and environmental factors. High poverty levels, limited access to healthcare, and insufficient infrastructure can exacerbate the community's susceptibility to climate hazards. Additionally, the local capacity for adaptation, such as the availability of resources and technology for building resilient infrastructure or diversifying livelihoods, plays a critical role in determining vulnerability.

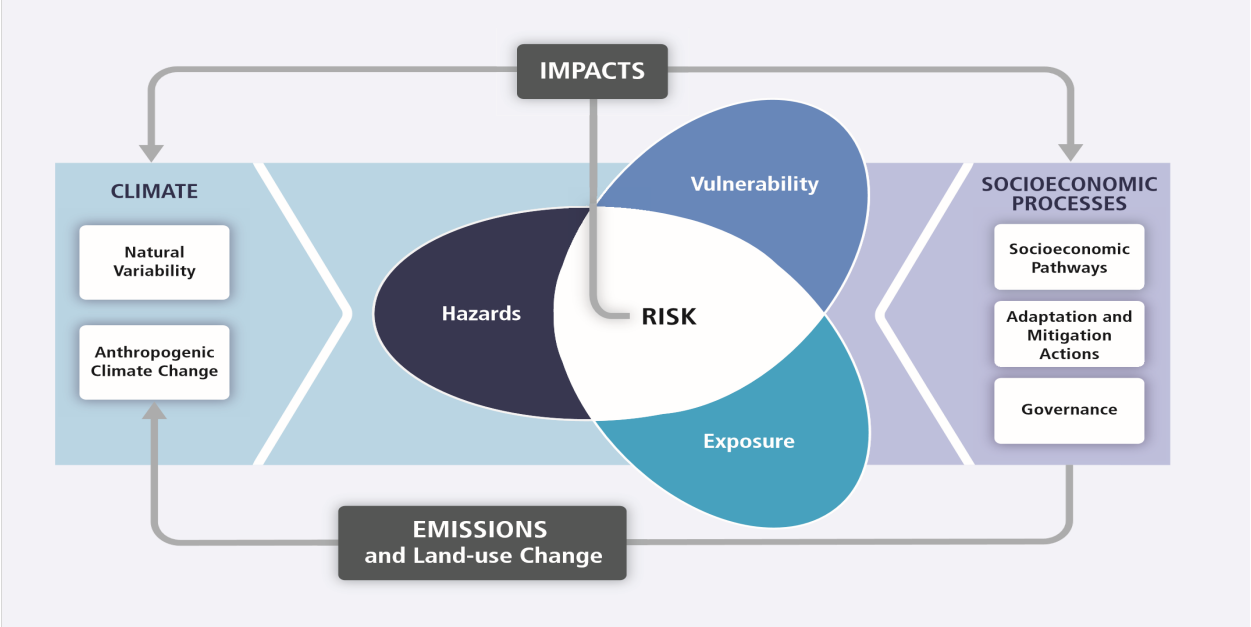
'Socioeconomic processes' further influence climate risk in the Kumasi metropolis. Socioeconomic pathways, including development trends and population growth, affect the scale and nature of exposure and vulnerability. Adaptation and mitigation actions taken by the metropolitan assembly, such as implementing early warning systems, constructing flood defenses, and promoting sustainable agricultural practices, are vital for reducing climate risks.

'Emissions and land-use change' are also pivotal in this framework. Local activities that increase greenhouse gas emissions, such as deforestation and fossil fuel use, contribute to global climate change. Conversely, land-use changes like reforestation and the adoption of sustainable farming practices can mitigate emissions and enhance local climate resilience.

The **'Risk'** is then a product of these hazards coming into contact with the exposed and vulnerable systems within the district. It represents the likelihood of experiencing adverse consequences, which can range from threats to human life and well-being to damage to property and infrastructure, and degradation of the environment and biodiversity.

The **'Impacts'** of climate change are felt across the natural and human systems in the district. They are influenced by the intersection of climate risk with 'Socio-economic Processes' such as development pathways, adaptive practices, and the efficacy of governance structures in place to manage and respond to these risks. Applying the IPCC's climate change risk framework to the Kumasi Metropolitan Assembly highlights the complex interplay of factors driving local climate risks. By understanding the specific hazards, exposure, and vulnerabilities in Kumasi, and addressing these through targeted socioeconomic processes and land-use practices, the metropolis can develop comprehensive strategies to enhance resilience and protect its communities from the adverse impacts of climate change.

Figure 8: Illustration of the risk assessment framework for evaluating climate change risks

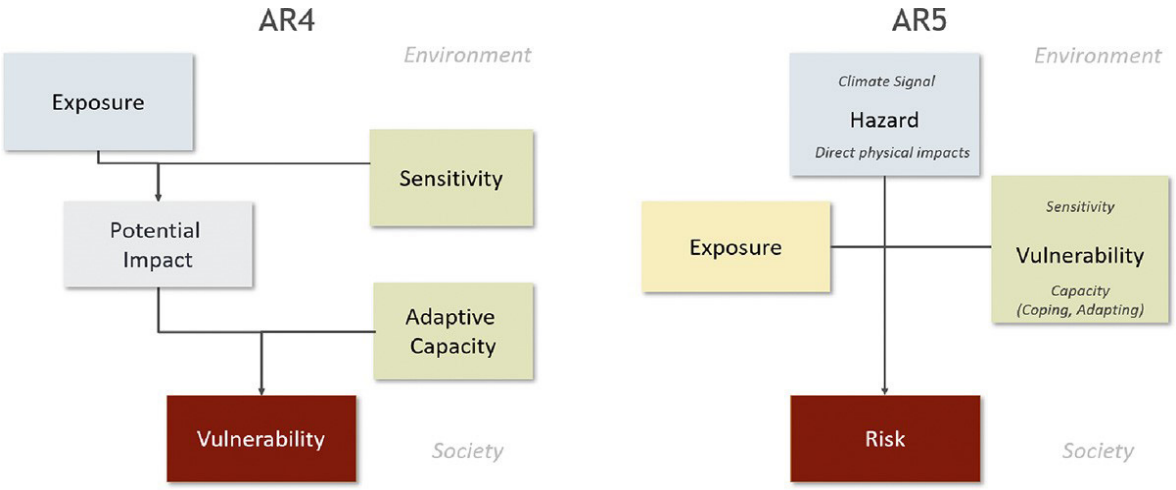


The risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation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

Source: IPCC's AR 5 framework of risk assessment (Adapted from Field et al. 2014)

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 8.

Figure 9: Change in conceptual approach to climate change risk assessment



Source: From Zebisch *et al.* (2017)

Source: Zebisch et al., 2021

The vulnerability to potential climate change impacts is determined based on sensitivity and adaptive capacity. The current vulnerability is characterized by both socioeconomic conditions including the dependency on high-risk sectors including agriculture, as well as the institutional capacity to manage and mitigate the potential for increasing climate change-related risks including floods and droughts.

4.2 Current Vulnerability – Sensitivity and Adaptive Capacity

The current climate change vulnerability for KMA is a measure of how likely the metropolis and its people are to be adversely affected by the impacts of climate change, such as rising temperatures, changing rainfall patterns, extreme weather events, and sea level rise. The vulnerability of Kumasi metropolis depends on the exposure, sensitivity, and adaptive capacity of the metropolis and its sectors or systems, such as infrastructure, health, agriculture, and environment.

4.2.1 Economic Vulnerability

The economic vulnerability of KMA is a measure of how likely the metropolis and its people are to suffer from economic losses or hardships due to the impacts of climate change and other factors. The economic vulnerability of KMA depends on the level of economic activity, the structure of the economy, the income and poverty levels, the access to basic services and infrastructure, and the availability of financial and human resources. For instance, for the level of economic activity, KMA is one of the most economically active metropolis in Ghana, with a Gross Domestic Product (GDP) of 11.5 billion Ghana cedis in 2019, accounting for 4.3% of the national GDP (The World Bank, 2022). The metropolis has a diverse economy, with sectors such as trade, manufacturing, services, agriculture, and mining. Kumasi is also a major commercial hub in the region, attracting traders and customers from neighboring districts and countries. However, the high level of economic activity also exposes the metropolis to various risks, such as market fluctuations, competition, inflation, and taxation, which can affect the income and livelihoods of the people in the metropolis. In terms of the structure of the economy, KMA has a predominantly informal economy, with about 80% of the labor force engaged in informal activities, such as petty trading, street vending, artisanal production, and transport services (GSS, 2014). The informal sector provides employment and income opportunities for many people, especially the poor and the marginalized, who lack the skills, education, and capital to enter the formal sector. However, the informal sector also faces challenges such as low productivity, poor working conditions, lack of social protection, and limited access to credit, markets, and infrastructure, which can increase the vulnerability of workers and entrepreneurs to shocks and stresses (GSS, 2014).

Concerning income and poverty levels, KMA has a relatively high-income level, with a per capita income of 7,096 Ghana cedis in 2019, which was higher than the national average of 6,571 Ghana cedis (The World Bank, 2022). The metropolis also has a low poverty incidence, with only 9.6% of the population living below the national poverty line of 792 Ghana cedis per year in 2017, which was lower than the national average of 23.4% (GSS, 2021). However, the income and poverty levels vary across the sub-metropolitan areas, with some areas having higher levels of inequality and deprivation than others. For example, the poverty incidence in Suame sub-metro was 19.8%, while the poverty incidence in Nhyiaeso sub-metro was 2.9% (GSS, 2014). Moreover, the income and poverty levels are sensitive to changes in economic conditions, such as inflation, unemployment, and recession, which can erode the purchasing power and welfare of the people in the metropolis.

In terms of access to basic services and infrastructure, KMA has a moderate level of access to basic services and infrastructure, such as water, sanitation, electricity, health, education, and transport. According to the 2010 Population and Housing Census, the metropolis had 91.4% access to improved water sources, 76.9% access to improved sanitation facilities, 93.4% access to electricity, 97.1% access to health facilities, 98.4% access to educational facilities, and a 94.9% access to road network (GSS, 2014). However, access to basic services and infrastructure is not evenly distributed across the sub-metropolitan areas, with some areas having lower levels of access than others. For example, the access to improved water sources in the Suame sub-metro was 84.2%, while the access to improved water

sources in the Nhyiaeso sub-metro was 97.8% (GSS, 2014). Moreover, access to basic services and infrastructure is often inadequate, unreliable, and costly, due to the rapid urbanization, population growth, and underinvestment in the metropolis, which can affect the quality of life and productivity of the people in the district.

Lastly, regarding financial and human resources, KMA has some availability of financial and human resources, which can enhance the economic resilience and development of the metropolis. The metropolis has a strong local government, which is responsible for planning, budgeting, and implementing development projects and programs in the metropolis. The metropolis also has a vibrant civil society, which includes various non-governmental organizations, community-based organizations, faith-based organizations, and professional associations, which provide support and advocacy for the people in the district. The district also has a diverse and skilled labor force, which can contribute to the economic growth and innovation of the district. However, the availability of financial and human resources is limited by the lack of adequate funding, technical expertise, and information, as well as the low awareness and participation of the stakeholders, which can hinder the effectiveness and efficiency of the economic activities and interventions in the metropolis. Therefore, the economic vulnerability of KMA is moderate and requires careful and coordinated action from the local, national, and international levels to reduce the risks and enhance the opportunities for the metropolis and its people.

4.2.2 Physical/Environmental Vulnerability

The physical or environmental vulnerability of KMA in Ghana is a complex and multifaceted issue that affects the quality of life and well-being of the urban population. The metropolis faces several physical and environmental challenges due to urbanization and climate change (Cobbinah, 2019). Some of the key vulnerabilities are poor integrated land use planning, water resources, and climate change. For instance, poor integrated land use planning has resulted in urban sprawl, traffic congestion on major roads, and poor road safety (MobiliseYourCity Global Monitor, 2021). Some of the factors that contribute to this vulnerability are rapid population growth and urbanization, leading to increased demand for water, sanitation, housing, energy, and other services (Suraj, 2004; GSS, 2014). Furthermore, climate change impacts, such as rising temperatures, erratic rainfall patterns, flooding, and drought, affect the availability and quality of water resources, food security, health, and livelihoods. For example, flooding in the Kumasi metropolis is a recurrent problem, often resulting in fatalities, destruction of property, and displacement of residents. For instance, in June 2021, heavy rainfall caused extensive flooding in many parts of the metropolis.

Figure 10: Some flooded places in Kumasi

Source: Kumasi floods: Death toll rises to seven I 3News

Also, inadequate infrastructure and service delivery, especially in the peri-urban areas, where access to safe water, sanitation, drainage, waste management, and electricity is limited. Lastly, low adaptive capacity and resilience of the urban poor, who are more exposed and sensitive to environmental hazards and shocks, and have fewer resources and opportunities to cope and recover. These factors interact and reinforce each other, creating a vicious cycle of vulnerability and poverty in the KMA. To address this challenge, there is a need for a holistic and integrated approach that considers the social, economic, and environmental dimensions of urban development and involves the participation and collaboration of all stakeholders, including the local government, civil society, the private sector, and the urban residents themselves.

4.2.3 Social Vulnerability and Adaptive Capacity

Social vulnerability and adaptive capacity are two interrelated concepts that measure the extent to which a system or a community can cope with and recover from the impacts of hazards, shocks, and stresses. Social vulnerability refers to the characteristics of a population that influence their susceptibility to harm from exposure to hazards, as well as their ability to access resources and opportunities that enable them to adapt and thrive (Fordham et al., 2013). Adaptive capacity refers to the potential or capability of a system or a community to adjust to hazards, shocks, and stresses, or to respond to opportunities, by modifying its characteristics or behavior to cope and survive (Intergovernmental Panel on Climate Change [IPCC], 2007).

The Kumasi Metropolitan Assembly faces various challenges that affect its social vulnerability and adaptive capacity. For example, rapid urbanization and population growth put pressure on the existing infrastructure, services, and resources, and increase the exposure and sensitivity of the urban poor to hazards and shocks (GSS, 2014). Also, climate change and environmental degradation, which increase the frequency and intensity of natural disasters, such as floods, droughts, landslides, and heat waves, pose threats to the health, livelihoods, and well-being of the urban population, especially the vulnerable groups (Cobbinah, 2019; Antwi-Agyei et al., 2023). Further, weak governance and institutional capacity limit the effectiveness and efficiency of the KMA in planning, implementing, and monitoring urban development policies and programs, and in coordinating and collaborating with other stakeholders, such as the traditional authorities, the private sector, and the civil society (Devas & Korboe, 2000). In addition to that, low levels of social capital and civic engagement reduce the trust, cooperation, and participation of the urban population in the decision-making and problem-solving processes, and in the collective action and mutual support for coping and adapting to hazards and shocks (Devas & Korboe, 2000).

However, the KMA also has some strengths and opportunities that can enhance its social vulnerability and adaptive capacity. For instance, the metropolis has a rich cultural and historical heritage, which provides a sense of identity, belonging, and pride for the urban population, and a source of attraction for tourism and investment (GSS, 2014). It has a vibrant and diversified economy, which offers a range of income and employment opportunities for the urban population, and a potential for innovation and entrepreneurship (GSS, 2014). It has a strategic location and connectivity, which facilitate the access and mobility of the urban population to other regions and markets, and the integration and cooperation with other urban centers (GSS, 2014). Also, the metropolis has a committed and visionary leadership, which demonstrates a strong political will, a clear direction for urban development, and a willingness to engage and partner with other actors and sectors (Amoako et al., 2023).

Therefore, the social vulnerability and adaptive capacity of the KMA depend on the balance and interaction between these challenges and strengths, and on the actions and interventions that are taken to address them. The KMA can improve its social vulnerability and adaptive capacity by enhancing the resilience and sustainability of the urban infrastructure, services, and resources, by adopting and implementing policies and standards that promote low-carbon, green, and inclusive urban development (Ghana News Agency, 2020). There is also a need to strengthen disaster risk management and climate change adaptation strategies, by conducting risk assessments and vulnerability analyses, developing and implementing contingency plans and early warning systems, and raising awareness and preparedness among the urban population (Antwi-Agyei et al., 2023). KMA can also improve the governance and its institutional capacity, by strengthening the legal and regulatory frameworks, enhancing the transparency and accountability mechanisms, and building the human and financial resources and capabilities (Devas & Korboe, 2000). Lastly, there is a need to increase the social capital and civic engagement of the urban population, by fostering social cohesion and inclusion, enhancing participation and empowerment, and facilitating networking and collaboration among the urban population and other stakeholders.

4.2.4 Gender Vulnerabilities

Climate change is not “gender neutral.” Women and girls experience the greatest impacts of climate change, which amplifies existing gender inequalities and poses unique threats to their livelihoods, health, and safety (UNWomen, 2022). Across the world, women depend more on, yet have less access to, natural resources. In many regions, women bear a disproportionate responsibility for securing food, water, and fuel. Agriculture is the most important employment sector for women in low- and lower-middle-income countries like Ghana. During periods of drought and erratic rainfall, women, as agricultural workers

and primary procurers, work harder to secure income and resources for their families. This puts added pressure on girls, who often have to leave school to help their mothers manage the increased burden. Additionally, climate change escalates social, political, and economic tensions in fragile and conflict-affected settings. As disasters strike, women are less likely to survive and more likely to be injured due to long-standing gender inequalities that create disparities in information, mobility, decision-making, and access to resources and training. In KMA, Climate change interacts with gender vulnerabilities in all socioeconomic sectors including health, agriculture, disaster risk reduction, water and sanitation, etc. For example:

Health sector:

- **Heat stress:** Women in the metropolis, especially pregnant women and girls, are more susceptible to heat-related illnesses due to biological differences and potential limitations on clothing choices.
- **Increased burden of waterborne diseases:** Women in Kumasi metropolis responsible for water collection face a higher risk of exposure to contaminated water sources due to changing rainfall patterns or flooding.
- **Mental health:** Women in the metropolis are disproportionately affected by climate change-induced stress due to concerns about family well-being, food security, and displacement.

Agricultural Sector:

- **Loss of crop yields:** Women farmers in the metropolis reliant on traditional crop varieties become less resilient to drought or erratic rainfall.
- **Limited access to climate-smart technologies:** Social norms limit women's access to training or resources for drought-resistant crops or water-saving irrigation techniques.
- **Food insecurity:** Women in the metropolis face a greater burden of ensuring household food security when climate change disrupts food production.

Disaster Risk Reduction:

- **Increased flooding risk:** Women and girls living in flood-prone areas in the metropolis are more vulnerable due to limited mobility or difficulty reaching evacuation points.
- **Loss of shelter:** Women are responsible for rebuilding homes after disasters and face challenges accessing materials or financial support.
- **Gender-based violence:** Disasters that occur in the metropolis heighten the risk of violence against women and girls in overcrowded shelters or temporary housing.

Water and Sanitation Sector:

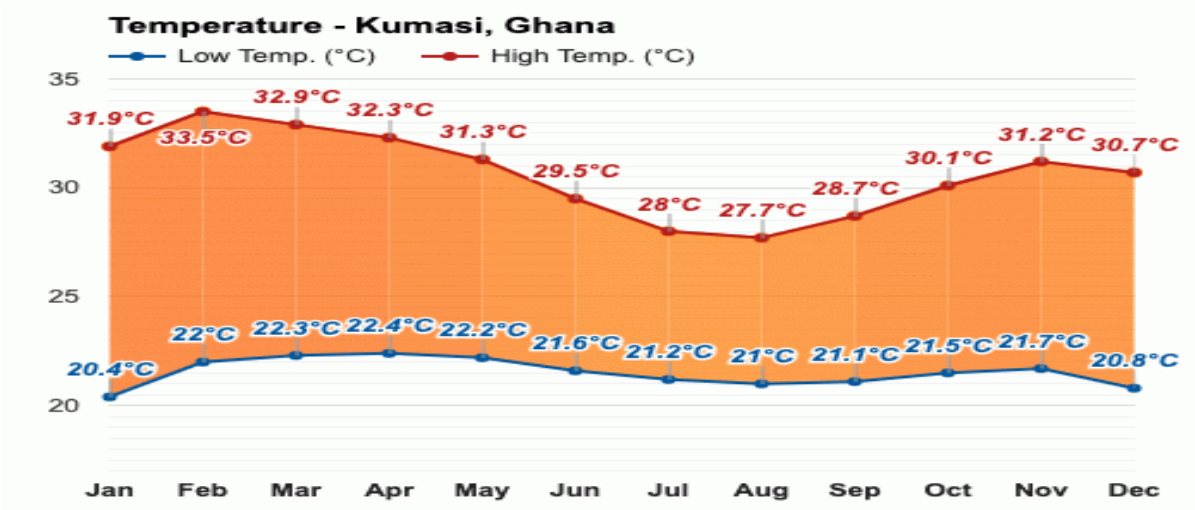
- **Water scarcity:** Women responsible for water collection in the metropolis travel further distances or spend more time searching for water during droughts.
- **Sanitation challenges:** Limited water availability exacerbates sanitation issues, particularly for women and girls in the metropolis during menstruation or needing to use toilets at night.
- **Competition for water resources:** Conflicts over scarce water resources disproportionately affect women who manage household water needs.

5 Observed Climate Trends at Kumasi Metropolitan Assembly

5.1 Local Level Climate and Trends

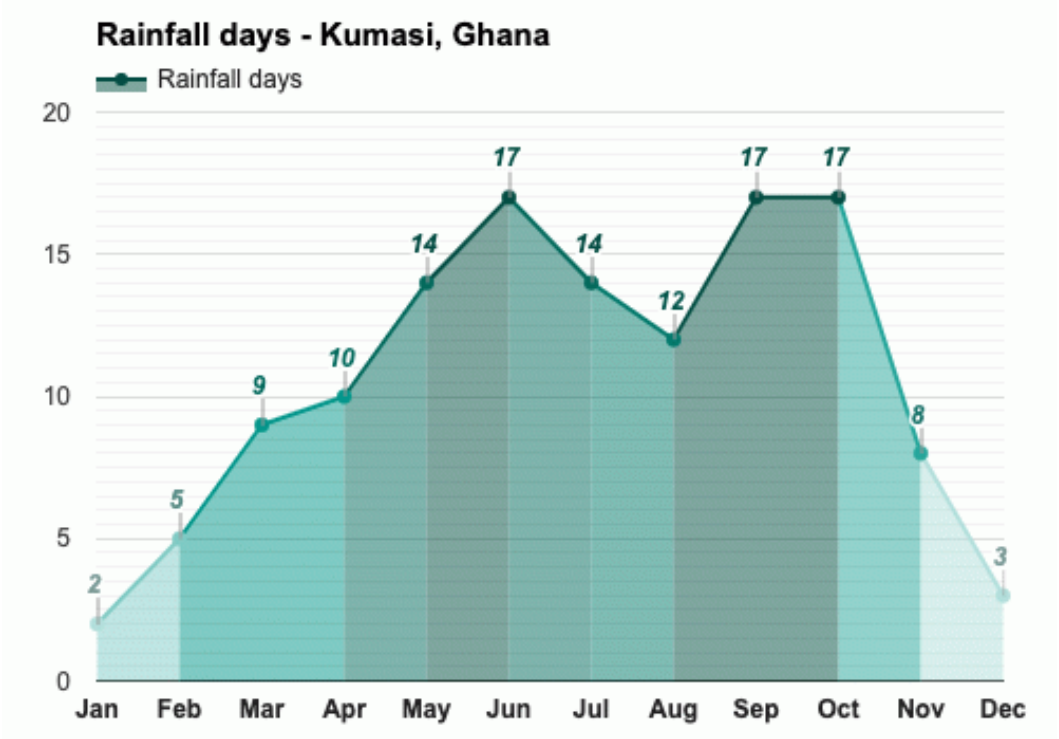
The climate of KMA is classified as tropical wet and dry according to the Köppen-Geiger climate classification system (Weather Atlas, 2023). This means that the metropolis has warm and humid conditions throughout the year, with a distinct dry season from December to February and a rainy season from March to November. Figure 13 shows the average temperature in the metropolis. The warmest month (with the highest average high temperature) is February (33.5°C) while the month with the lowest average high temperature is August (27.7°C). The month with the highest average low temperature is April (22.4°C). The coldest month (with the lowest average low temperature) is January (20.4°C). The rainfall pattern reveals a unique characteristic of Kumasi's weather. While rainfall is observed nearly year-round, it peaks from May to August with an all-time high of 214.3 mm in June (Figure 14). Thus, the wettest month (with the highest rainfall) is June (214.3 mm). January, on the other hand, marks the driest month (with the least rainfall) with a comparatively meager 15.1 mm of rain. The months with the highest number of rainy days are June, September, and October (17 days). The month with the least rainy days is January (2 days) (Figure 15).

Figure 11: Average temperature in Kumasi



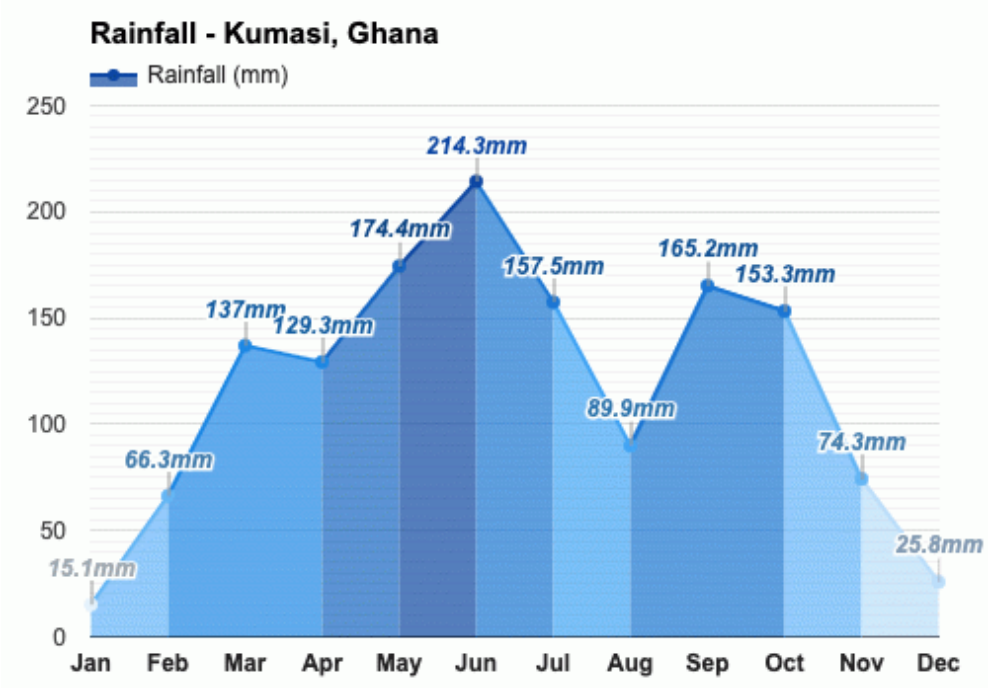
Source: Weather Atlas (2023)

Figure 12: Average rainfall in Kumasi



Source: Weather Atlas (2023)

Figure 13: Average rainfall days in Kumasi



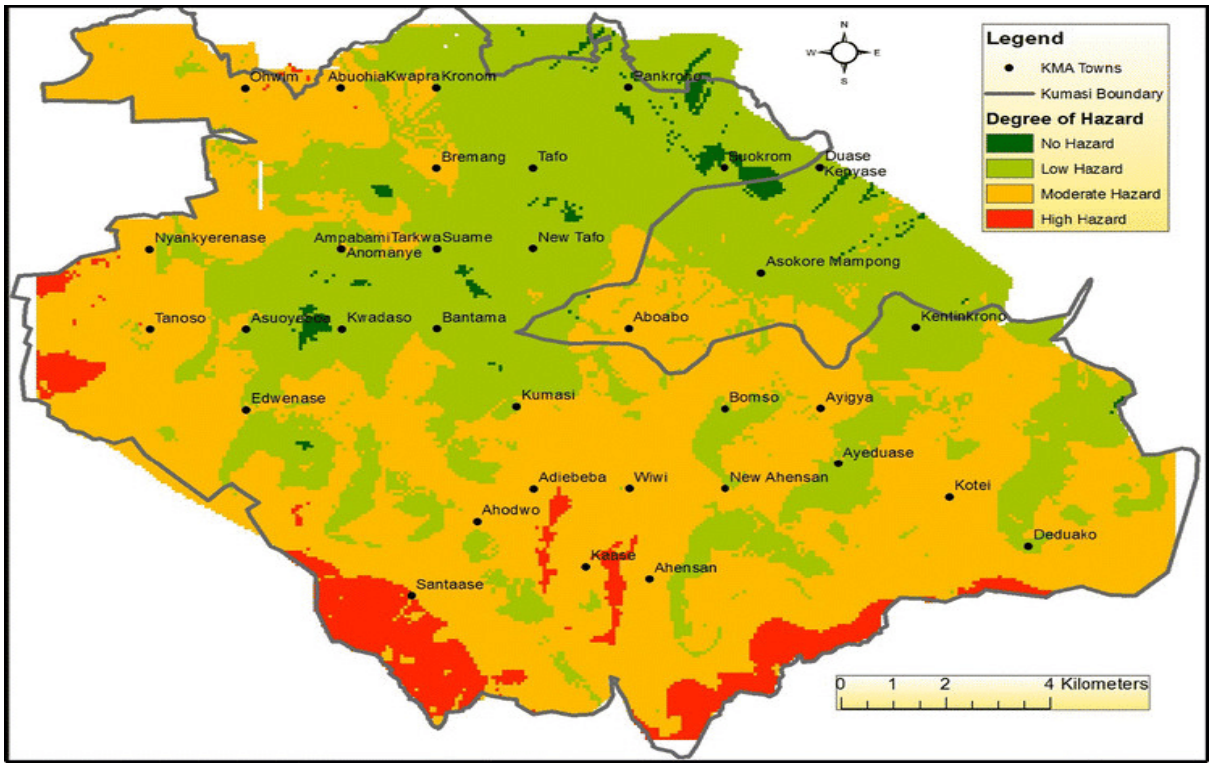
Source: Weather Atlas (2023)

5.2 Observed Hazards and Extreme Events

The Kumasi metropolis is prone to two extreme events including floods and droughts. Floods are a common natural hazard in Kumasi, especially during the rainy seasons, from April to July and from September to November. Floods occur mainly due to heavy rainfall, poor drainage, urbanization, and deforestation (Korah & Cobbinah, 2017; Antwi-Agyei et al., 2023). Floods can cause loss of lives, property, and infrastructure, and increase the risk of waterborne diseases. Some of the past major flood events in Kumasi are:

- In 2015, floods affected more than 10,000 people in Kumasi, killing four people and injuring 15 others. The floods also destroyed houses, roads, bridges, and power lines, and disrupted economic activities and public services.
- In 2018, floods affected more than 20,000 people in Kumasi, killing six people and injuring 18 others. The floods also damaged crops, livestock, infrastructure, and public services, and increased the risk of waterborne diseases.
- In 2020, floods affected more than 30,000 people in Kumasi, killing eight people and injuring 22 others. The floods also destroyed houses, roads, bridges, and power lines, and disrupted economic activities and public services.

Figure 19: Flood vulnerability map of Kumasi



***Source**: Korah & Cobbinah (2017)*

Figure 20: Anloga junction in Kumasi, Ghana flooded after a heavy downpour

***Source**: Graphic Online (2018)*

Droughts are a rare but severe natural hazard in Kumasi, especially during the dry seasons, from December to March and from August to September. Droughts occur mainly due to low rainfall, high temperatures, evaporation, and climate change. Droughts can cause crop failures, food shortages, water scarcity, and power outages. Some of the major drought events in Kumasi are:

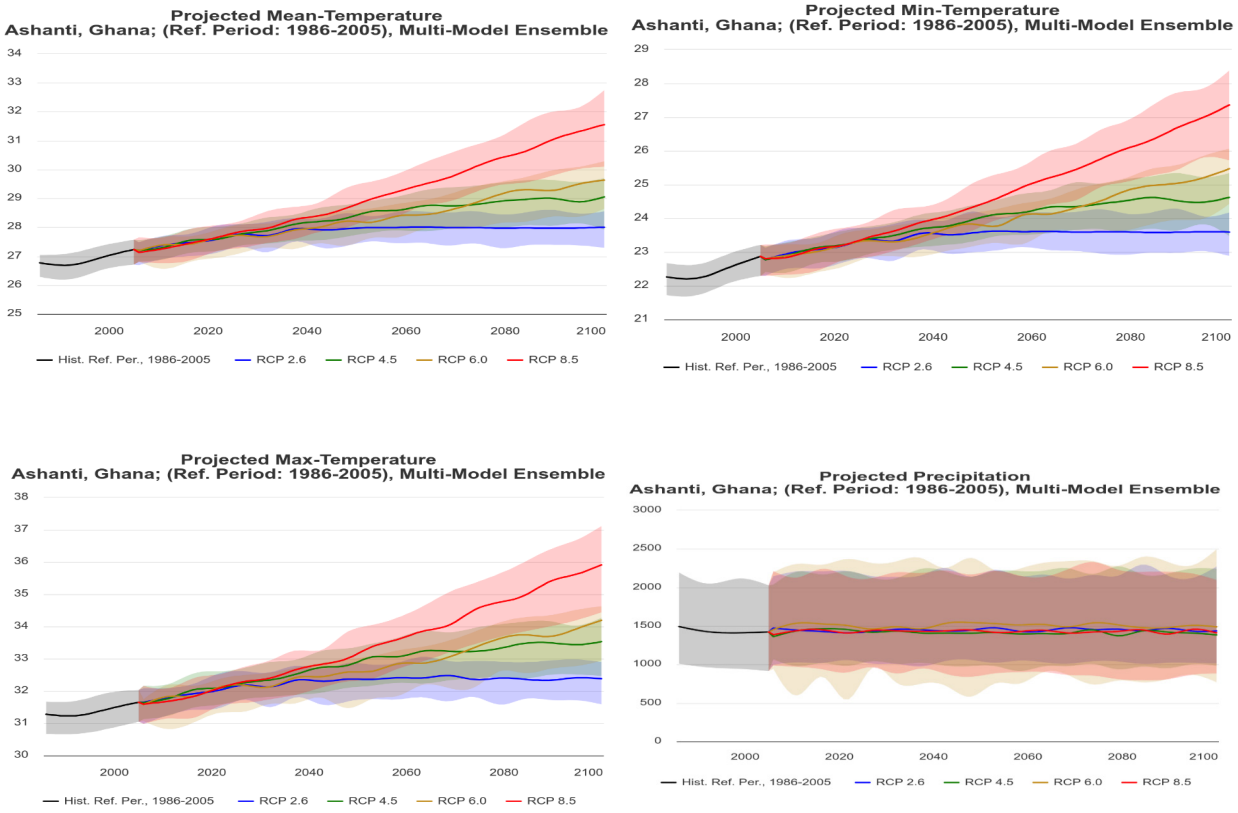
- In 1983, a severe drought affected the entire country, including Kumasi, causing crop failures, food shortages, famine, malnutrition, and migration. The drought also reduced hydroelectric power generation, affecting industrial production and service delivery.
- In 2012 and 2016, a moderate drought affected the southern regions, including Kumasi, causing crop losses, food insecurity, water shortages, and power outages. The drought also affected the Volta Lake, reducing its water level and hydroelectric power generation.

5.3 Plume Plots Analysis for Kumasi Metropolitan Assembly

Individual plume plots indicating the range of anticipated impacts on key climate variables (i.e., temperature and rainfall) were also produced for KMA. This also shows how future climate scenarios evolve. Climate projection data is modeled data from the global climate model compilations of the Coupled Model Inter-comparison Projects (CMIPs), overseen by the World Climate Research Program. The plume plots showing the range of possible climate scenarios derived from the CMIP5 ensemble of climate models for KMA are shown in Figure 27. For CMIP5, the variables or indicators were investigated either as a multi-model ensemble or by model. The individual plume plots show the 50th Percentile or Median and the 10-90th Percentile range. CMIP5 supported the IPCC's Fifth Assessment Report. For CMIP6 data, indicators are presented as a multi-model ensemble, which represents the range and distribution of the most plausible projected outcomes of change in the climate system for a selected Shared Socioeconomic Pathway (SSP). SSPs are meant to provide insight into future climates based on defined emissions, mitigation efforts, and development paths. These represent the combined global emission scenarios of SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5. The plume plots

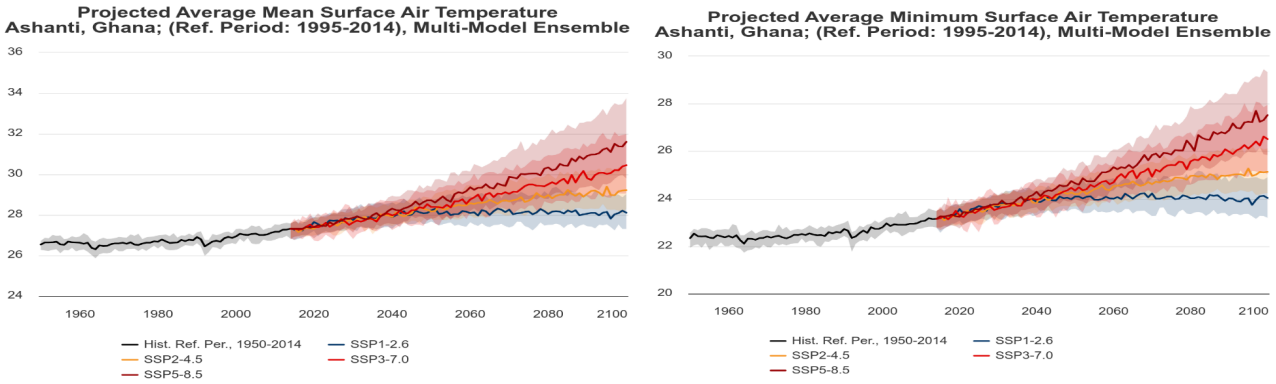
showing the range of possible climate scenarios derived from the CMIP6 ensemble of climate models for KMA are shown in Figure 6.12. CMIP6 supports the IPCC's Sixth Assessment Report.

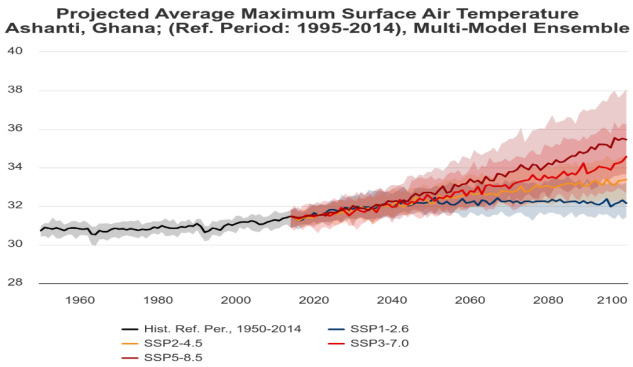
Figure 22: Plume plots showing the projection of mean annual temperature, minimum temperature, maximum temperature, and annual rainfall in Kumasi Metropolitan Assembly in simulations of historical and future climate in Multi-model Ensemble (CMIP5)

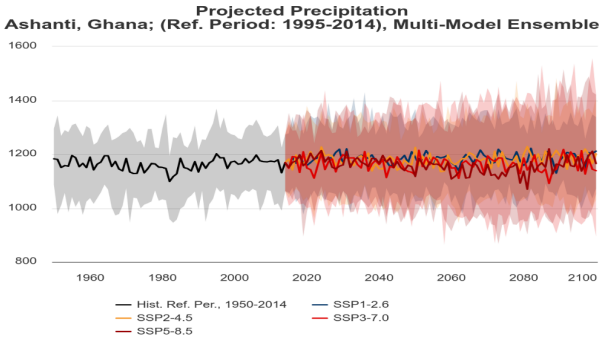


Source: The World Bank (2021)

Figure 23: Plume plots showing the projection of average mean surface air temperature, average minimum surface air temperature, average maximum surface air temperature, and precipitation in Kumasi Metropolitan Assembly in simulations







Source: The World Bank (2021)

5.4 Downscaled Climate Change Scenarios

For Ghana, downscaled climate change scenarios indicate that the country will experience increased temperatures, reduced rainfall, and more frequent and intense droughts in the coming decades. These changes will have significant implications for the country's agriculture, water resources, health, and biodiversity.

5.4.1 Temperature

There is a higher probability for more significant increases in temperature in the Kumasi Metropolis. The projected mean annual temperature for the period **2021-2050** under the RCP **4.5** is **28.2°C**, which is **1.6°C** higher than the baseline period **1971-2000**. The projected mean annual temperature for the same period under the RCP **8.5** is 28.7°C, which is **2.1°C** higher than the baseline period. The projected mean annual temperature for the period **2071-2100** under the RCP **4.5** is **29.1°C**, which is **2.5°C** higher than the baseline period. The projected mean annual temperature for the same period under the RCP **8.5** is **30.4°C**, which is **3.8°C** higher than the baseline period. The projected mean annual temperature change for the period **2021-2050** relative to the baseline period is **+1.6°C** for the RCP **4.5** and **+2.1°C** for the RCP **8.5**. The projected mean annual temperature change for the period **2071-2100** relative to the baseline period is **+2.5°C** for the RCP **4.5** and **+3.8°C** for the RCP **8.5**. Table 2 provides the projected changes in seasonal temperature for the four seasons in the metropolis: December-January-February (DJF), March-April-May (MAM), June-July-August (JJA), and September-October-November (SON).

Table 1: Projected changes in seasonal temperature for Kumasi Metropolis

Season	RCP 4.5 (2021-2050)	RCP 8.5 (2021-2050)	RCP 4.5 (2071-2100)	RCP 8.5 (2071-2100)
DJF	+ 1.5	+2.0	+2.4	+3.7
MAM	+1.6	+2.1	+2.5	+3.8
JJA	+1.7	+2.2	+2.6	+3.9
SON	+1.6	+2.1	+2.5	+3.8

Source: The World Bank (2021)

5.4.2 Extreme Heat

Extreme heat is defined as hot days with a maximum above 30 (Horton et al., 2016). Extreme heat events are becoming more intense and frequent in Ghana as a result of climate change and the Kumasi Metropolis is no exception. The projected number of days with maximum temperature above **35°C** for the period **2021-2050** under the RCP **4.5** is **14 days**, which is **11 days** more than the baseline period **1971-2000**. The projected number of days with a maximum temperature above 35°C for the same period under the RCP **8.5** is **18 days**, which is **15 days** more than the baseline period. The projected number of days with maximum temperature above 35°C for the period **2071-2100** under the RCP **4.5** is **23 days**, which is **20 days** more than the baseline period. The projected number of days with a maximum temperature above 35°C for the same period under the RCP **8.5** is **40 days,** which is **37 days** more than the baseline period.

The projected number of days with a maximum temperature above **40°C** for the period **2021-2050** under the RCP **4.5** is **0 days**, which is the same as the baseline period. The projected number of days with a maximum temperature above 40°C for the same period under the RCP **8.5** is **1 day**, which is **1 day** more than the baseline period. The projected number of days with maximum temperature above 40°C for the period **2071-2100** under the RCP **4.5** is **1 day**, which is **1 day** more than the baseline period. The projected number of days with a maximum temperature above 40°C for the same period under the RCP **8.5** is **9 days**, which is **9 days** more than the baseline period. Table 3 provides the projected changes in extreme heat indices for the four seasons in the metropolis: December-January-February (DJF), March-April-May (MAM), June-July-August (JJA), and September-October-November (SON).

Table 2*:* Projected changes in extreme heat indices for Kumasi Metropolis

Season	RCP 4.5 (2021-2050)	RCP 8.5 (2021-2050)	RCP 4.5 (2071-2100)	RCP 8.5 (2071-2100)
DJF	+11 days	+15 days	+20 days	+37 days
MAM	+11 days	+15 days	+20 days	+37 days
JJA	+11 days	+15 days	+20 days	+37 days
SON	+11 days	+15 days	+20 days	+37 days

Source: The World Bank (2021)

5.4.3 Precipitation

There is a slightly greater chance of small decreases in annual precipitation compared to the base years in the Kumasi Metropolis. For instance, the projected mean annual precipitation for the period **2021-2050** under the RCP **4.5** is **1,348 mm**, which is **2.6%** lower than the baseline period **1971-2000**. The projected mean annual precipitation for the same period under the RCP **8.5** is **1,328 mm**, which is **3.9%** lower than the baseline period. The projected mean annual precipitation for the period **2071-2100** under the RCP 4.5 is **1,331 mm**, which is **3.6%** lower than the baseline period. The projected mean annual precipitation for the same period under the RCP **8.5** is **1,271 mm**, which is **8.8%** lower than the baseline period. Thus, the projected mean annual precipitation change for the period **2021-2050** relative to the baseline period is **-2.6%** for the RCP **4.5** and **-3.9%** for the RCP **8.5**. The projected mean annual precipitation change for the period **2071-2100** relative to the baseline period is **-3.6%** for the RCP **4.5** and **-8.8%** for the RCP

8.5. Table 4 provides the projected changes in seasonal precipitation for the four seasons: December-January-February (DJF), March-April-May (MAM), June-July-August (JJA), and September-October-November (SON).

Table 3: Projected changes in annual precipitation for Kumasi Metropolis

Season	RCP 4.5 (2021-2050)	RCP 8.5 (2021-2050)	RCP 4.5 (2071-2100)	RCP 8.5 (2071-2100)
DJF	-4.1%	-5.7%	-5.1%	-10.4%
MAM	-2.9%	-4.1%	-3.7%	-8.6%
JJA	-1.6%	-2.3%	-2.1%	-4.9%
SON	-2.0%	-2.8%	-2.6%	-5.9%

Source: The World Bank (2021)

5.4.4 Extreme rainfall

Extreme rainfall is a term used to describe rainfall events that are significantly above the normal range for a given location and time of year (Koutsoyiannis & Papalexiou, 2017). For example, a rainfall event that exceeds **50 mm** in a day or **100 mm** in a month is considered extreme, regardless of how often it occurs. For Kumasi Metropolis, the projected number of days with precipitation above **50 mm** for the period **2021-2050** under the RCP **4.5 is 2 days**, which is **1 day** less than the baseline period **1971-2000**. The projected number of days with precipitation above **50 mm** for the same period under the RCP **8.5** is **2 days**, which is the same as the baseline period. The projected number of days with precipitation above 50 mm for the period **2071-2100** under the RCP **4.5** is **2 days**, which is the same as the baseline period. The projected number of days with precipitation above 50 mm for the same period under the RCP **8.5** is **3 days**, which is **1 day** more than the baseline period. The projected number of days with precipitation above **100 mm** for the period **2021-2050** under the RCP **4.5** is **0 days**, which is the same as the baseline period. The projected number of days with precipitation above 100 mm for the same period under the RCP **8.5** is **0 days**, which is the same as the baseline period. The projected number of days with precipitation above **100 mm** for the period **2071-2100** under the RCP **4.5** is **0 days**, which is the same as the baseline period. The projected number of days with precipitation above 100 mm for the same period under the RCP **8.5** is **1 day,** which is **1 day** more than the baseline period. Table 5 also provides the projected changes in extreme rainfall indices for the four seasons: December-January-February (DJF), March-April-May (MAM), June-July-August (JJA), and September-October-November (SON).

Table 4: Projected changes in extreme rainfall for Kumasi Metropolis

Season	RCP 4.5 (2021-2050)	RCP 8.5 (2021-2050)	RCP 4.5 (2071-2100)	RCP 8.5 (2071-2100)
DJF	-1 day	0 days	0 days	+1 day
MAM	-1 day	0 days	0 days	+1 day
JJA	0 days	0 days	0 days	0 days
SON	0 days	0 days	0 days	0 days

Source: The World Bank (2021)

6

Potential Impacts for Priority Risk Domains

6.1 Initial Assessment of Critical Climate-Related Hazards

The preliminary critical climate-related risks can be assessed using a tool like the Think Hazard! Tool. Kumasi metropolis assessed several climate-related threats using data from ThinkHazard! Tool. These hazard levels from the ThinkHazard! report is supported by the experiences of local stakeholders who participated in district workshops. Their observations and experiences add significant ground truth to the simulated data, showing the real-world consequences of these climate-related risks for the Kumasi metropolis. Below is a comprehensive analysis of each hazard category as presented in Table 1.

Table 5: Summary of critical climate-related hazards for Kumasi Metropolitan Assembly

District	Hazard			
	Floods	Heat waves	Drought	Water scarcity
Kumasi Metropolitan Assembly	High	Medium	Medium	Low

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

Floods: Floods are considered a high-risk hazard in Kumasi. This is because Kumasi experiences heavy rainfall, leading to urban flooding. Poor drainage systems exacerbate this risk, affecting infrastructure, livelihoods, and health.

Heat waves: Heat waves are marked as a medium-risk hazard for the Kumasi metropolis. Rising temperatures due to climate change can lead to heatwaves. While not as severe as floods, they still pose health risks, especially for vulnerable populations in the metropolis.

Drought: Drought is identified as a medium-risk hazard in the Kumasi metropolis. This is because prolonged dry spells can impact agriculture, water availability, and food security. Droughts are a concern, although not as frequent as other hazards in the Kumasi metropolis.

Water scarcity: Water scarcity is marked as a low-risk hazard in the Kumasi metropolis. This is because Kumasi benefits from abundant water sources, including the Owabi Dam and Barekese Reservoir. These reservoirs provide a stable supply of water for domestic, agricultural, and industrial purposes. While Kumasi is densely populated, it has not reached critical levels where water demand significantly outstrips supply. The existing infrastructure can meet current needs. However, climate change, population growth, and urbanization could alter this situation over time. Sustainable water management practices are crucial to maintaining this low-risk status.

6.2 Stakeholder Engagement

Stakeholder engagement in climate change vulnerability or risk assessment should be a participatory process because it ensures that the diverse perspectives and knowledge of all community members are included, leading to more comprehensive and effective solutions. A participatory approach is sensitive to issues of gender, youth, and vulnerable groups, recognizing that these groups often face unique challenges and have different needs and priorities in the context of climate change. Some of the key reasons for a participatory approach include:

- **Inclusivity:** It ensures that all voices, especially those of marginalized and vulnerable groups, are heard and considered in the assessment process.
- **Equity:** It addresses power imbalances by giving equal opportunity to all stakeholders to contribute to the discussion and decision-making process.
- **Local knowledge:** Local communities often have valuable insights and traditional knowledge that can contribute to a more accurate assessment of climate risks and vulnerabilities.
- **Ownership:** When stakeholders are involved in the assessment process, they are more likely to take ownership of the outcomes and support the implementation of adaptation strategies.
- **Resilience:** By considering the specific needs and capacities of different groups, including women, youth, and vulnerable populations, the community can develop more resilient and sustainable responses to climate change.

A participatory process also helps to identify and prioritize actions that are culturally appropriate and have the best chance of success because they are rooted in the community's context and experiences. To inform the development of the climate risk assessment for Kumasi Metropolitan Assembly, the project team engaged stakeholders on 28th of February 2024 to (i) introduce the National Adaptation Plan (NAP) project and process to them, (ii) provide them with an overview of climate change in Ghana and its impacts, (iii) identify the key climate change vulnerabilities of KMA and their possible adaptation options. In total, 40 participants attended the workshop (stakeholder list in Appendix A).

Plate 1: Stakeholder engagement session in Kumasi

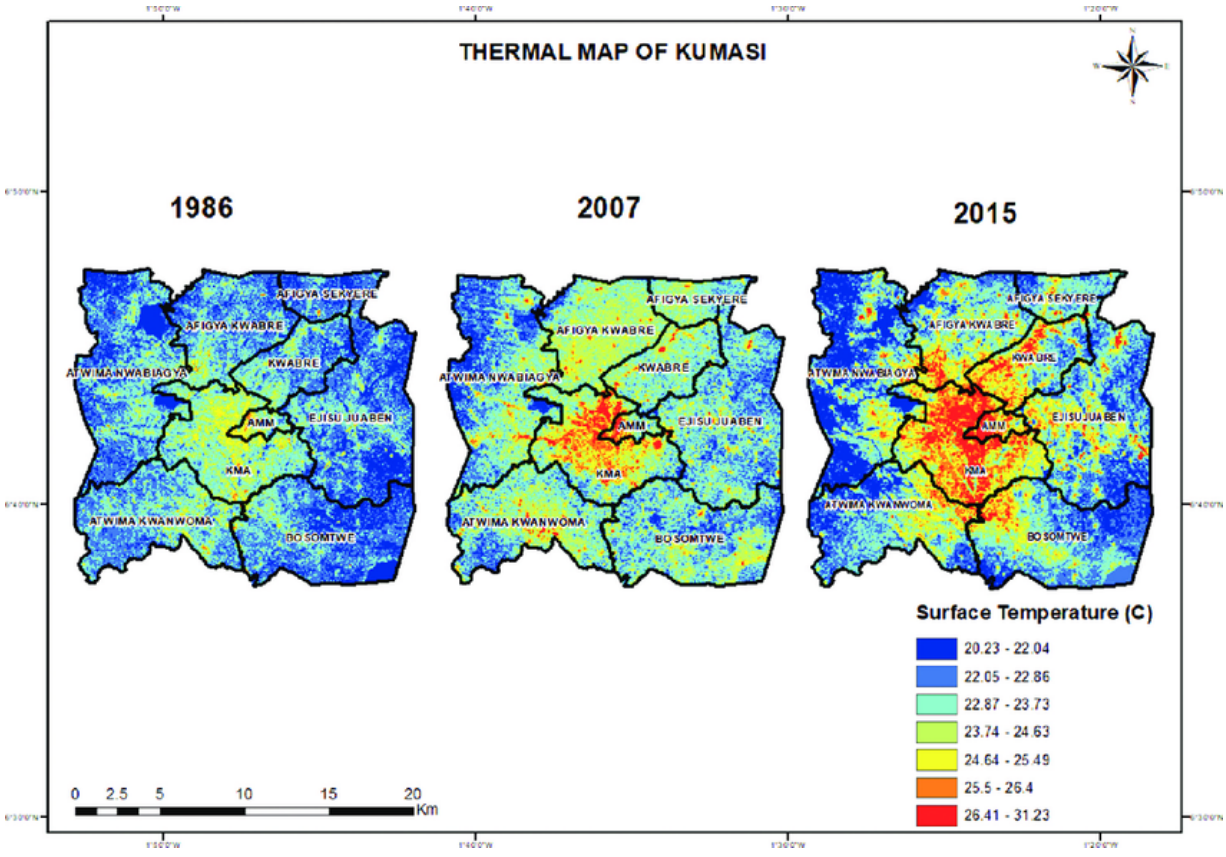
The potential impact of climate change on the priority risk domains is described here, including, urban heat island effect; water scarcity and flooding; extreme weather events; health risks; infrastructure vulnerability; ecosystem changes; energy supply and demand; food security; social vulnerability; and waste management.

6.3 Priority Risk Domains

6.3.1 Urban Heat Island Effect

The potential impact of climate change on the urban heat island effect in the KMA is likely to be negative, as the city will experience higher temperatures and more heat waves due to the combined effects of global warming and urbanization. The urban heat island effect is a phenomenon where urban areas are warmer than the surrounding rural areas, due to the absorption, production, and retention of heat by vehicles, buildings, and paved surfaces (Li et al., 2021). Koranteng et al. (2019) assessed the extent of urban heat in Kumasi Metropolis over 42 years (1976 to 2018). They found out that there has been a 2ºC rise in mean annual temperature from 1976 to 2018 in the metropolis.

Figure 24: Thermal map of Kumasi in January 1986, 2007, and 2015.



Source: Mensah et al. (2020)

The urban heat island effect can have harmful impacts on human health, the environment, and energy consumption. For instance, the urban heat island effect can pose significant health risks, such as heat stroke, heat exhaustion, and heart attacks (Buo et al., 2021). It can also increase energy consumption, air pollution, and greenhouse gas emissions (Buo et al., 2021). To mitigate the urban heat island effect, some possible solutions are to reintroduce vegetation, such as expanding parkland, planting street trees, and installing green roofs (Buo et al., 2021). Another option is to build cool roofs and pavements that reflect more sunlight and absorb less heat (Buo et al., 2021). These measures can help lower air temperatures and improve the quality of life in KMA.

6.3.2 Water Scarcity and Flooding

Climate change and other factors are expected to have significant impacts on water scarcity and flooding in KMA. For water scarcity, climate change is projected to increase the temperature and reduce the rainfall in Ghana, especially in the northern and middle belts of the country (Agodzo et al., 2023). This will affect the availability and quality of surface water and groundwater sources, such as rivers, lakes, dams, wells, and boreholes supplying water to the metropolis. Also, the metropolis is located in the middle belt of Ghana, where the annual rainfall ranges from 1,200 mm to 1,600 mm, with a bimodal pattern (GSS, 2014). However, the rainfall is becoming more erratic and unpredictable, leading to frequent droughts. This will affect the agricultural production and food security of the metropolis, as well as the water supply and sanitation systems (Agodzo et al., 2023).

Furthermore, the increasing population and urbanization in the metropolis will put more pressure on the existing water resources and infrastructure, which are already inadequate and poorly managed

(International Water Management Institute [IWMI], 2020). The water demand in the metropolis exceeds the supply, resulting in water rationing, low pressure, intermittent service, and high tariffs (IWMI, 2020). Kumasi metropolis also faces the challenge of water pollution from various sources, such as industrial effluents, agricultural runoff, domestic sewage, and solid waste (IWMI, 2020) (Figure 30). These contaminants could reduce the quality and quantity of water available for human consumption and other uses and pose health risks to the population. Kumasi Metropolis lacks a comprehensive and integrated water management plan that can address the current and future water challenges in the face of climate change (IWMI, 2020). There is a need for more investment, coordination, regulation, and participation of various stakeholders, such as the government, the private sector, civil society, and the local communities, to ensure the sustainable and equitable use of water resources in the metropolis.

Figure 25: Poor sanitation and solid waste in some parts of the metropolis

Source: GhanaWeb (2021a)

On the other hand, climate change could also increase the frequency and intensity of flooding in KMA, as the metropolis experiences heavy rainfall events that exceed the capacity of the drainage system and the natural watercourses (Antwi-Agyei et al., 2023). Floods will affect various parts of the metropolis, especially the low-lying areas and the areas near the watercourses, such as the newly-built Kejetia Market, Asuoyeboa, Aboabo, Anloga, and Sawaba (GhanaWeb, 2021b). These areas will experience inundation, erosion, and displacement of residents and properties (GhanaWeb, 2021b). Floods will have devastating effects on both lives and properties, such as deaths, injuries, diseases, destruction of buildings, roads, markets, household items, and crops, decreased economic productivity, and increased poverty (The Business & Financial Times, 2021). Floods will pose challenges for the water management and disaster response systems, which are already inadequate and poorly managed. Therefore, climate change poses a serious challenge to water management and disaster risk reduction in KMA.

6.3.3 Extreme Weather Events

The potential impacts of climate change on extreme weather events in KMA are as follows: Climate change is likely to increase the frequency and intensity of heat waves (IPCC, 2021) in the metropolis, which can have adverse effects on human health, agriculture, and energy demand. Climate change is also likely to increase the occurrence and severity of heavy rainfall and pluvial flooding in the metropolis, which can cause damage to infrastructure, property, and livelihoods, as well as increase the risk of waterborne diseases and landslides. Climate change may also affect the frequency and intensity of storms, including tropical cyclones, which can bring strong winds, and heavy rain, leading to flooding, and displacement of people in the metropolis.

Climate change may also exacerbate the urban heat island effect, which is a phenomenon whereby cities experience higher air temperatures than the surrounding countryside. This effect can increase the demand for cooling, worsen air quality, and amplify the health impacts of heat waves in the metropolis (Buo et al., 2021). Climate change may also increase the likelihood of compound events, which are combinations of multiple or concurrent extremes that can have synergistic or cascading impacts. For example, dry and hot conditions can increase the risk of fire weather, which can lead to wildfires that emit smoke and pollutants, affecting air quality and health. These impacts of climate change on extreme weather events can have significant implications for the social, economic, and environmental well-being of KMA and its residents. Therefore, it is important to take adaptive and mitigative measures to reduce the vulnerability and exposure to these events and to enhance the resilience and coping capacity of the metropolis and its people.

6.3.4 Health Risks

The potential impacts of climate change on health risks in KMA will be numerous. For instance, climate change can increase the exposure and vulnerability of the population to various infectious diseases, such as malaria, cholera, typhoid, and meningitis. These diseases are influenced by changes in temperature, rainfall, humidity, and water quality, which can affect the transmission and survival of pathogens and vectors (KMA, 2023). For example, malaria is endemic in the metropolis, and climate change can extend the transmission season and the geographic range of the mosquito vector (KMA, 2023). Climate change can also worsen the burden of non-communicable diseases, such as cardiovascular, respiratory, and mental disorders. These diseases are affected by heat stress, air pollution, allergens, and psychological stress, which can be exacerbated by climate change (United Nations Framework Convention on Climate Change [UNFCCC], 2021). For example, heat waves can increase the risk of heat stroke, dehydration, and heart attacks, especially among the elderly and those with pre-existing conditions (KMA, 2023). Air pollution can aggravate respiratory problems, such as asthma and chronic obstructive pulmonary disease, especially among children and those with low immunity (KMA, 2023). Psychological stress can result from exposure to extreme events, such as floods and droughts, and the loss of livelihoods, assets, and social networks.

The health system in the metropolis may face challenges such as damage to infrastructure, disruption of supply chains, shortage of staff and resources, and increased demand for healthcare (UNFCCC, 2021). For example, flooding can damage health facilities, contaminate water sources, and hinder access to health care. Drought can affect the availability of water and electricity, and increase the risk of food insecurity and malnutrition. These impacts of climate change on health risks can have significant implications for the well-being and development of KMA and its residents. Therefore, it is important to take adaptive and mitigative measures to reduce the exposure and sensitivity to these risks and to enhance the adaptive capacity and resilience of the health system and the population.

6.3.5 Infrastructure Vulnerability

The potential impacts of climate change on infrastructure vulnerability in Kumasi Metropolis are as follows: First of all, climate change can increase the exposure and damage of infrastructure to extreme weather events, such as floods, storms, and heat waves. These events can affect the functionality and safety of roads, bridges, buildings, water networks, transmission lines, and other critical infrastructure that provide essential services for the population in the metropolis. For example, flooding can damage roads and bridges, disrupt transportation and mobility, and increase the risk of accidents and injuries. Storms can topple power lines and cause blackouts, affecting communication, health care, and education. Heat waves can increase the demand for cooling and strain the energy system, leading to power shortages

and brownouts (The Business & Financial Times, 2021; Antwi-Agyei et al., 2023). Climate change can also affect the availability and quality of water resources, which are essential for urban infrastructure and services. Changes in rainfall patterns, temperature, and evaporation can alter the hydrological cycle and affect the quantity and timing of water supply and demand. This can lead to water scarcity, drought, and conflicts over water allocation and use.

Lastly, climate change can also exacerbate the urban heat island effect, which is a phenomenon whereby cities experience higher air temperatures than the surrounding countryside. This effect can increase the thermal stress and deterioration of urban infrastructure, such as buildings, roads, and pavements, and reduce their lifespan and performance. The urban heat island effect can also increase the energy demand for cooling, worsen air quality, and amplify the health impacts of heat waves (IPCC, 2021). These impacts of climate change on infrastructure vulnerability can have significant implications for the social, economic, and environmental sustainability of Kumasi metropolis and its residents. Therefore, it is important to take adaptive and mitigative measures to reduce the exposure and sensitivity of infrastructure to climate hazards and to enhance the resilience and adaptive capacity of the infrastructure systems and the urban population.

6.3.6 Ecosystem Changes

The potential impacts of climate change on ecosystem changes in Kumasi metropolis are as follows: Firstly, climate change can affect the composition and distribution of plant and animal species in the metropolis, which is one of the rapidly growing major Ghanaian metropolis that has experienced urban sprawl and loss of vegetation over the years (UNFCCC, 2021; Agodzo et al., 2023). Changes in temperature, rainfall, humidity, and evaporation can alter the suitability and availability of habitats for different species, leading to shifts in their ranges, phenology, and interactions. For example, climate change can affect the feasibility of cultivating rubber in Kumasi, which is currently being studied by KMA and the Forestry Commission (Ghana Business News, 2021). Climate change can also affect the functioning and services of ecosystems in Kumasi Metropolis, which provides benefits such as water regulation, soil conservation, carbon sequestration, and recreation.

Changes in climate variables can affect the hydrological cycle and the soil quality, which can affect the water supply and demand, and the erosion and fertility of the land. Climate change can also affect the carbon cycle and greenhouse gas emissions, which can affect the mitigation potential and the feedback effects of the ecosystems. Climate change can also affect the recreational and cultural values of the ecosystems, which can affect the tourism and well-being of the urban population (The National Aeronautics and Space Administration [NASA], 2021).

Climate change can also increase the exposure and vulnerability of ecosystems in Kumasi Metropolis to various threats and disturbances, such as invasive species, pests, diseases, fires, and human activities. These threats and disturbances can reduce the diversity, resilience, and adaptability of the ecosystems, and cause irreversible damage or loss of ecosystem components and functions. For example, climate change can increase the risk of malaria transmission in KMA, which is influenced by changes in temperature, rainfall, humidity, and water quality, affecting the survival and reproduction of the mosquito vector (UNFCCC, 2021).

Climate change can also increase the risk of fire weather in the metropolis, which is influenced by dry and hot conditions, affecting the ignition and spread of wildfires (NASA, 2021). These impacts of climate change on ecosystem changes can have significant implications for the environmental, social, and economic sustainability of Kumasi Metropolis and its residents. Therefore, it is important to take adaptive

and mitigative measures to reduce the exposure and sensitivity of ecosystems to climate hazards and to enhance the resilience and adaptive capacity of the ecosystems and the urban population.

6.3.7 Energy supply and Demand

The potential impacts of climate change on energy supply and demand in Kumasi Metropolitan Assembly are as follows: First of all, climate change can increase the energy demand for cooling, as the city experiences higher temperatures and heat waves due to the greenhouse effect and the urban heat island effect. This can strain the electricity grid and cause power shortages and brownouts, affecting the quality and reliability of energy services. According to the Programme Based Budget Estimates for 2020, the monthly electrical energy consumption in KMA is an average of 120MW, but the spate of growth in the metropolis has far outpaced the rate of electricity generation and supply (KMA, 2020). Therefore, climate change can exacerbate the gap between energy supply and demand, and increase the need for energy efficiency and conservation measures.

Climate change can also affect the availability and quality of water resources, which are essential for hydropower generation, which is the main source of electricity in Ghana. Changes in rainfall patterns, temperature, and evaporation can alter the hydrological cycle and affect the quantity and timing of water supply and demand in the metropolis. This can lead to water scarcity, drought, and conflicts over water allocation and use. Climate change can also affect the quality of water sources, such as rivers, lakes, and groundwater, by increasing the risk of contamination from pollutants, pathogens, and saltwater intrusion. This can pose challenges for water treatment and distribution, and affect the efficiency and performance of water treatment plants in the metropolis (KMA, 2021).

Climate change can also increase the exposure and vulnerability of energy infrastructure to extreme weather events, such as floods, storms, and fires. These events can affect the functionality and safety of power plants, transmission lines, distribution networks, and other critical infrastructures that provide energy services for the metropolis. For example, flooding can damage power plants and transmission lines, disrupt electricity supply and distribution, and increase the risk of accidents and injuries. Storms can topple power lines and cause blackouts, affecting communication, health care, and education. Fires can damage power plants and transmission lines, affecting the generation and transmission of electricity in the metropolis (Ghana Today, 2022). These impacts of climate change on energy supply and demand can have significant implications for the social, economic, and environmental sustainability of KMA and its residents.

6.3.8 Food Security

The potential impacts of climate change on food security in Kumasi Metropolis are as follows: Climate change can affect the availability and quality of water resources, which are essential for agricultural production and food processing. According to a report by the Ghana Statistical Service, the Kumasi metropolis falls within the sub-equatorial type of climate and is characterized by average temperatures ranging from 21.5°C to 30.7°C. Average annual rainfall is 625mm with peaks of 214.3mm and 16.2mm in June and September respectively (GSS, 2014). The rainfall pattern is generally good and evenly distributed. However, changes in temperature, rainfall, humidity, and evaporation due to climate change can alter the hydrological cycle and affect the quantity and timing of water supply and demand. This can lead to water scarcity, drought, and conflicts over water allocation and use. Climate change can also affect the quality of water sources, such as rivers, lakes, and groundwater, by increasing the risk of contamination from pollutants, pathogens, and saltwater intrusion (Atanga & Tankpa, 2021). This can pose challenges for water treatment and distribution, and affect the health and well-being of the urban

population in the metropolis. Climate change can also affect the suitability and productivity of crops and livestock, which are the main sources of food and income for urban populations.

Climate change can affect the composition and distribution of plant and animal species in Kumasi metropolis. Changes in temperature, rainfall, humidity, and evaporation can alter the availability and quality of habitats for different species, leading to shifts in their ranges, phenology, and interactions. Climate change can also increase the exposure and vulnerability of crops and livestock to various threats and disturbances, such as invasive species, pests, diseases, fires, and human activities (Chaplin et al., 2017). These threats and disturbances can reduce the diversity, resilience, and adaptability of the crops and livestock, and cause irreversible damage or loss of food production.

Climate change can also increase the frequency and intensity of extreme weather events, such as floods, storms, and heat waves, which can affect the food security and livelihoods of the urban population in the metropolis. Climate change is projected to increase the scarcity of water in Ghana in the future, as rainfall patterns become more erratic and temperatures rise. This could affect the availability and quality of water for domestic, agricultural, and industrial uses. On the other hand, climate change could also increase the occurrence and severity of heavy rainfall and pluvial flooding, which can cause damage to infrastructure, property, and livelihoods, as well as increase the risk of waterborne diseases. These impacts of climate change on food security can have significant implications for the social, economic, and environmental sustainability of Kumasi Metropolis and its residents. Therefore, it is important to take adaptive and mitigative measures to reduce the exposure and sensitivity of food systems to climate hazards and to enhance the resilience and adaptive capacity of the food systems and the urban population.

6.3.9 Social Vulnerability

The potential impacts of climate change on social vulnerability in Kumasi Metropolis are as follows: Climate change can also increase the exposure and vulnerability of the population to various livelihood risks, such as food insecurity, water scarcity, and income loss. These livelihood risks are influenced by changes in temperature, rainfall, humidity, evaporation, and soil quality, which can affect the availability and quality of water resources, the suitability and productivity of crops and livestock, and the feasibility and profitability of economic activities. For example, climate change can affect the availability and quality of water resources in the metropolis, which are essential for domestic, agricultural, and industrial uses, as rainfall patterns become more erratic and temperatures rise, leading to water scarcity, drought, and conflicts over water allocation and use (The Conversation Africa, 2020). Climate change can also affect the feasibility and profitability of economic activities in the metropolis, which are the main sources of income and employment for urban populations, as changes in temperature, rainfall, humidity, and evaporation affect the demand and supply of goods and services, the cost and efficiency of production and transportation, and the risk and uncertainty of investment and innovation (Aboagye et al., 2018).

Climate change can also increase the exposure and vulnerability of the population to various social risks, such as inequality, marginalization, and conflict. These social risks are influenced by changes in the distribution and access of resources, opportunities, and services, the recognition and representation of rights, interests, and identities, and the participation and collaboration of actors, institutions, and networks. For example, climate change can increase the inequality and marginalization of the population in the metropolis, which is already facing a housing crisis and rapid urbanization and sprawl, as the availability and quality of resources, opportunities, and services become more scarce and uneven, and the recognition and representation of rights, interests, and identities become more contested and polarized, affecting the well-being and development of the urban population, especially the vulnerable groups, such as women, children, and the poor (UNFCCC, 2021; Aboagye et al., 2018).

Climate change can also increase the conflict and violence of the population in the metropolis, which is already facing a complex and dynamic social and political context, as the distribution and access of resources, opportunities, and services become more competitive and contentious, and the participation and collaboration of actors, institutions, and networks become more difficult and fragile, affecting the peace and security of the urban population, especially the marginalized groups, such as ethnic minorities, migrants, and refugees (UNFCCC, 2021). These impacts of climate change on social vulnerability can have significant implications for the social, economic, and environmental sustainability of Kumasi metropolis and its residents.

6.3.10 Waste Management

The potential impacts of climate change on waste management in the Kumasi metropolis are as follows: Climate change can increase the generation and accumulation of solid waste, as the metropolis experiences higher temperatures and heat waves due to the greenhouse effect and the urban heat island effect. This can increase the consumption and disposal of goods and materials, such as plastics, paper, food, and water, and create more waste that needs to be collected and treated. According to a study by Sarfo-Mensah et al. (2019), the Kumasi metropolis generates an average of 1,500 tonnes of solid waste daily, but only 1,200 tonnes are evacuated to landfill sites. The remaining 300 tonnes is what is found in gutters, container sites, and other places. Therefore, climate change can exacerbate the gap between waste generation and management, and increase the need for waste reduction and recycling measures (Sarfo-Mensah et al., 2019).

Climate change can also affect the collection and transportation of solid waste, as the city experiences heavy rainfall and pluvial flooding due to changes in precipitation patterns and intensity. This can damage the roads and bridges, disrupt the mobility and accessibility of waste vehicles and workers, and increase the risk of accidents and injuries. According to a news article, the metropolis suffered a severe flooding on June 24, 2021, that killed more than four people and displaced hundreds of residents.

The flooding was caused by an unprecedented amount of rainfall that measured up to 108.38 millimeters in three hours and six minutes. The flooding also damaged properties, roads, bridges, and markets worth millions of Ghana cedis. One of the main factors that contribute to the flooding in the Kumasi metropolis is the rapid urbanization and sprawl that has led to the loss of vegetation and wetlands, and the encroachment of buildings on waterways. These factors reduce the infiltration and retention capacity of the soil and increase the runoff and surface flow of water.

The Kumasi metropolis has two landfill sites, namely Oti and Dompoase, which are both near their maximum capacity and have inadequate leachate and gas management systems. Therefore, climate change can increase the environmental and health impacts of waste treatment and disposal, and increase the need for waste recovery and reuse measures (Graphic Online, 2022). These impacts of climate change on waste management can have significant implications for the social, economic, and environmental sustainability of the Kumasi Metropolis and its residents. Therefore, it is important to take adaptive and mitigative measures to reduce the exposure and sensitivity of waste systems to climate hazards and to enhance the resilience and adaptive capacity of the waste systems and the urban population.

7

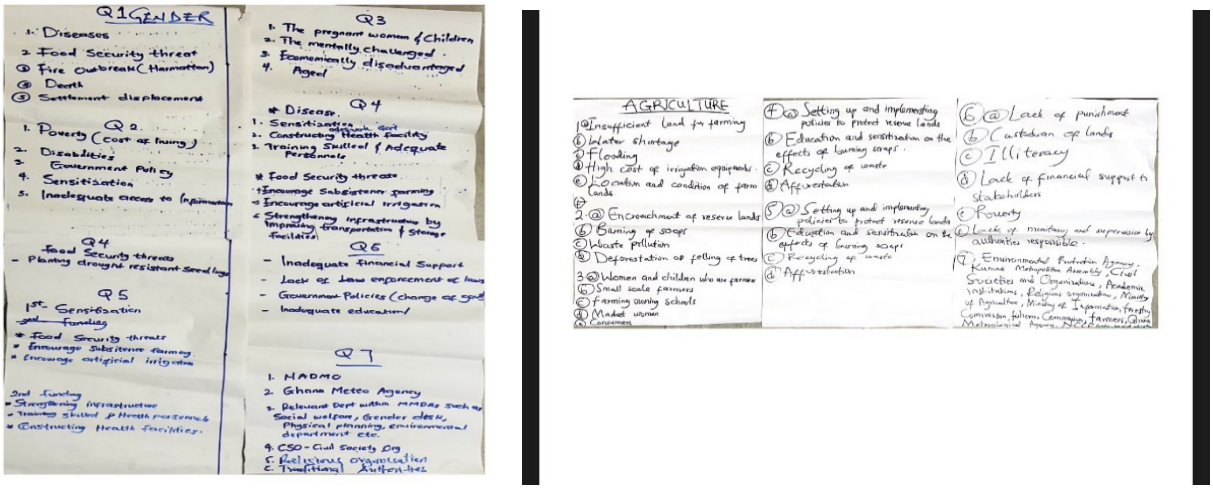
Climate Change Risk Assessment for KMA

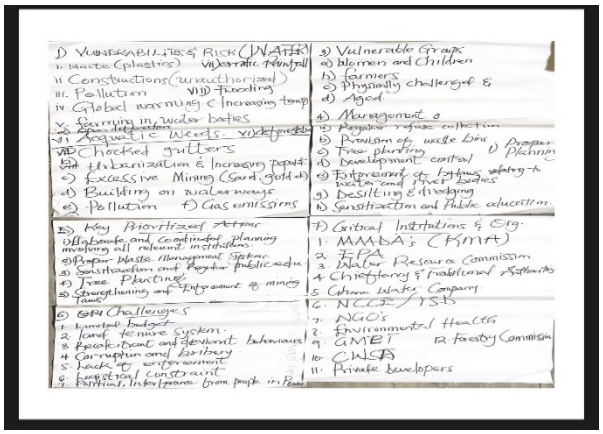
7.1 Identification of Critical Climate Change Vulnerabilities

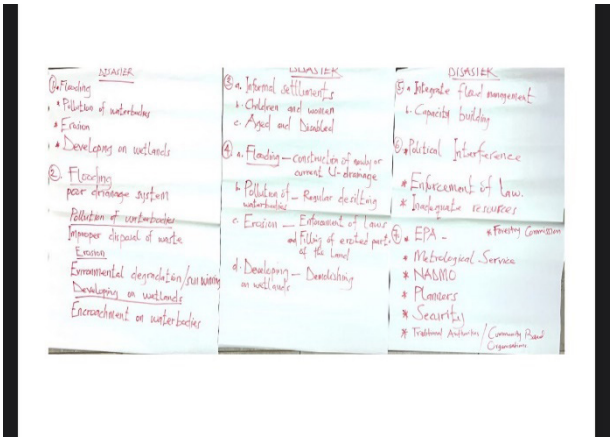
Through the stakeholder engagement workshop organized in Kumasi, the stakeholders identified the critical climate change vulnerabilities affecting the metropolis. The stakeholders were grouped into 5 sectors including gender, health, agriculture, disaster, water, and sanitation. They responded to the following questions:

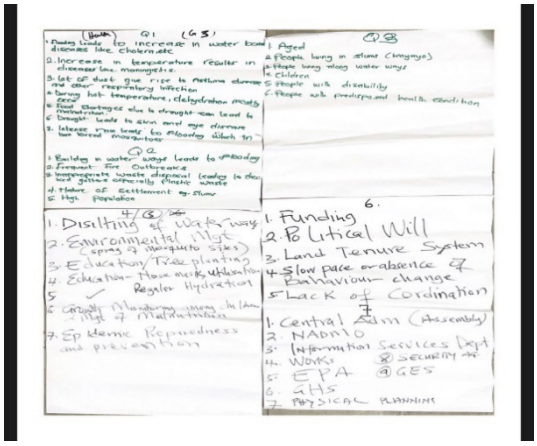
- What are the key vulnerabilities and risks in the KMA?
- Which factors contribute to the vulnerabilities to climate change in the Metropolis?
- Which groups of the population are more at risk of these vulnerabilities in KMA?
- How have you been managing each of the identified risks?
- What are key prioritized actions in addressing the identified risks in the Metropolis?
- What in your opinion are some of the challenges in implementing the adaptation action?
- Which institutions/organizations are critical in coordinating climate action in the Metropolis?

Figure 26: Flip Charts containing participants' answers according to sectors









Source: Stakeholders' engagement session

7.2 Risk Assessment Results

The key climatic risks identified in the stakeholders' engagement include the following:

Agriculture:

Heat and water stress have led to decreased productivity and reduced crop yields. Climate changes have affected the onset and length of growing seasons. Floods, droughts, and erratic rains cause direct damage to crops. Fluctuations in agricultural productivity have led to increased food prices. There is an increased risk of crop diseases and pest infestations due to changing weather patterns.

Health:

Changes in rainfall have led to water scarcity, affecting clean water supply and sanitation, which are crucial for maintaining health standards in the metropolis. Rising temperatures have exacerbated heat-related illnesses and affected the spread of temperature-sensitive diseases including headaches, dizziness, weakness, cramping, or nausea in hot environments. Floods have led to displacement, waterborne diseases (e.g., malaria, cholera, and typhoid fever), and challenges in healthcare delivery in the metropolis. Seasonal variations in the air quality of the metropolis have also impacted respiratory health.

Disaster risk reduction:

Essential infrastructure such as roads, bridges, and buildings have been at risk due to extreme weather events including floods, affecting both emergency response capabilities and the resilience of the communities in the metropolis. The loss of biodiversity and ecosystem services due to climate change has increased the

vulnerability of the people in the metropolis to natural disasters and reduced the natural buffering capacity against such events. Heavy rainfall leading to flooding, as well as prolonged dry periods resulting in droughts. have strained the capacity of the DRR sector to respond effectively.

Water and sanitation:

Increased demand for water in the metropolis due to low rainfall during dry seasons causes water sources, including boreholes and springs, to run dry. Heavy rainfall and flooding damage water sources and sanitation facilities, carry the runoff and waste into streams and rivers, and contaminate the water supply. The unplanned urban expansion in Kumasi metropolis is leading to the destruction of two rivers – Subin and Wiwi – through sewage, heavy metals, and chemical pollution. This pollution affects the quality of water resources and poses health risks. Climate change leads to more frequent and severe weather events that tend to damage water and sanitation infrastructure, leading to service disruptions in the metropolis. The contamination of water bodies due to encroachment and pollution increases the risk of waterborne diseases, which can be exacerbated by climate change effects.

Gender:

Women, who often play a significant role in agriculture, face reduced crop yields due to changing weather patterns, affecting food security and income in the metropolis. Climate change can lead to food scarcity, impacting nutrition, especially for women and children who may already be vulnerable to malnutrition. Climate changes can lead to an increase in climate-sensitive diseases, which can disproportionately affect women, particularly those who are pregnant or responsible for caring for the sick. Women are typically responsible for water collection and may have to travel longer distances as water sources become scarce. Additionally, energy needs may increase for heating or cooling, impacting household budgets. Women may be more vulnerable during disasters due to social roles and norms. They also face higher risks during migration which can be exacerbated by climate change.

7.2.1 Gender-specific vulnerability assessment

Assessing gender-specific vulnerabilities in the Kumasi Metro is essential as climate change impacts do not affect all community members equally (Thomas et al., 2019). Women, often central to resource management and caregiving, can face disproportionate challenges during climate crises. Understanding these gendered dimensions is crucial for creating equitable, targeted interventions that ensure effective adaptation and resilience-building.

The assessment of current gender-specific climate change risks in the Kumasi Municipal highlights significant vulnerabilities across different groups (**Table 10**). Women face high exposure and sensitivity to erratic rainfall, sea-level rise, and increased temperatures, which severely impact their roles in water and food provision, stressing their adaptive capacities and elevating their overall vulnerability. Youth experience medium exposure and sensitivity to extreme weather and job market instability, yet they possess a high adaptive capacity due to their innovation potential. Differently-abled individuals are extremely vulnerable, with high exposure and very high sensitivity to accessibility issues during extreme weather, compounded by low adaptive capacity due to physical barriers and inadequate inclusive planning.

Table 6: Assessment of current gender-specific climate change risks

Group	Hazard Description	Exposure	Sensitivity	Adaptive Capacity	Overall Vulnerability	Comments/Impacts
Women, children & elderly	Erratic rainfall, increased temperatures	High	Very High	Low	High	The effects of climate change in Kumasi disproportionately impact women, children, and the elderly. Women often bear the brunt of water and food provision burdens, exacerbated by erratic rainfall and heat. Children and the elderly face health risks from waterborne diseases.
Youth	Extreme weather events, job market instability	High	Medium	Low	Medium	Youth in Kumasi are significantly affected by climate change, with extreme weather events disrupting education and job market stability. Initiatives like the Youth Climate Action Fund aim to engage and empower youth to contribute to climate resilience through projects such as tree planting and waste reduction.
PLwD	Accessibility issues during extreme weather	High	Very High	Low	Very High	PLwD face considerable challenges during extreme weather events due to physical barriers and inadequate inclusive planning. This increases their vulnerability, as they often lack resources and support systems to adapt effectively. Community initiatives are needed to improve infrastructure and support for PLwD

PLwD – Persons Living with Disability

ADAPTATION ACTION PLAN FOR THE KUMASI METROPOLITAN ASSEMBLY

8 Adaptation Action Plan for the Kumasi Metropolitan Assembly

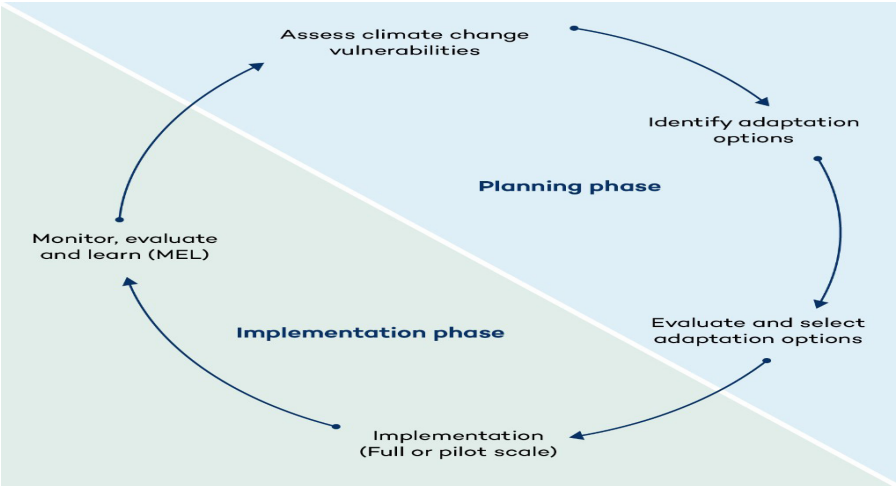
8.1 Introduction

The KMA is committed to enhancing the resilience and sustainability of the city in the face of climate change. Adaptation Action Planning is a strategic approach designed to address the specific vulnerabilities and risks posed by climate change to the Kumasi metropolis. This plan aims to integrate climate adaptation into the city's development agenda, ensuring that infrastructure, services, and communities are better prepared for the impacts of climate variability and change. The Adaptation Action Plan for Kumasi focuses on several key areas:

- **Risk Assessment and Vulnerability Analysis:** Identifying the most significant climate risks and vulnerable sectors within the metropolis.
- **Stakeholder Engagement:** Involving local communities, government agencies, and other stakeholders in the planning process to ensure inclusive and effective adaptation strategies.
- **Implementation of Adaptation Measures:** Developing and executing specific actions to mitigate identified risks, such as improving drainage systems, enhancing green spaces, and promoting sustainable land use practices.
- **Monitoring and Evaluation:** Establishing mechanisms to track the progress and effectiveness of adaptation measures, allowing for adjustments and improvements over time.

Figure 30 shows the framework for adaptation planning in the KMA adopted in the process.

Figure 27: Approach to KMA adaptation planning



8.2 Identification and Compilation of Sector-Specific Adaptation Actions

The comprehensive climate change adaptation plan for KMA outlined and gathered specific adaptation strategies tailored to the metropolis. This process enabled the examination of various potential adaptation strategies and the identification of appropriate actions. The planning team used the techniques described in Table 4 to determine these adaptation options.

Table 8. Methodology to identify adaptation options

Vulnerability assessment report recommendations	The climate change vulnerability assessment for the KMA made recommendations regarding adaptation measures that could be explored to build resilience, increase adaptive capacity, and reduce vulnerability. These recommendations were well considered in the planning process.
Literature review	An extensive review of best solutions and practices was undertaken, using desk review of government documents, scientific publications, grey literature, Metropolitan reports, etc. to identify adaptation actions that ameliorate similar impacts and vulnerabilities.
Stakeholder consultation	Identified stakeholders were engaged and consulted through participatory workshops that allowed for open and equal discussions of adaptation options based on climate scenarios, and identified prevailing and future impacts and vulnerabilities. In Kumasi, sector-specific stakeholders were consulted. The stakeholders were organized into six groups that addressed six sectors: 1. Agriculture 2. Gender (cross-cutting sector) 3. Trade 4. Water and sanitation 5. Health 6. Disaster risk reduction

Source: Author diagram based on the KMA Adaptation Plan.

In total, 70 adaptation options were identified across the six sectors. Table 9 illustrates the distribution of these actions, with agriculture having the highest number of actions (17), followed by disaster risk reduction (14).

Table 9: Distribution of adaptation actions by sector

Sector	Number of Adaptation actions	Rank
Agriculture	17	1
Disaster Risk Reduction	14	2
Health	11	3
Gender	8	4
Trade	8	4
Water and Sanitation	7	6

8.3 Methodological Approach for Ranking Adaptation Options

Based on the key vulnerabilities and climate risks identified in the KMA, a list of potential adaptation options was identified through a desk review literature search and interactions with key stakeholders. These adaptation options were then validated and screened with key stakeholders during stakeholder workshops. Following this,

workshop participants were grouped based on their expertise and interests to evaluate, prioritise and rank the key adaptation options presented. This exercise was facilitated with using clear information and criteria. This involved assessing how suitable the options were for the KMA context, their ability to enhance resilience and reduce vulnerabilities identified in the Kumasi vulnerability assessment (reported in Section A of this Report), and their overall impact on sustainable development.

This prioritization process aimed to make informed decisions that lead to effective adaptation and avoid maladaptation. To achieve this, relevant actors and stakeholders were involved in the assessment process to ensure the chosen adaptation options were appropriate and free from potential negative outcomes. Each of the six key stakeholder groups (Agriculture, biodiversity, water and sanitation, health, cities and infrastructure, and gender) evaluated the proposed adaptation options using a Multicriteria Decision Making (MCDM) Analysis (see Appendix A). This approach was necessary because each adaptation measure might perform differently across various criteria and could involve trade-offs. Therefore, they needed to be carefully and critically evaluated, and the results of the analysis integrated into decision-making about priority options.

Multicriteria Decision Making (MCDM) Analysis is a systematic approach used to evaluate and prioritize multiple options based on various criteria. It involves identifying relevant criteria, assigning weights to each criterion based on their importance, and then scoring each option against these criteria. This method helps in making informed and balanced decisions, especially when dealing with complex issues involving multiple stakeholders and conflicting objectives (Dixit & McGray, 2013). The criteria for the evaluation of the climate change adaptation strategies are defined in Table 10.

Plate 2: Consultation with the sector stakeholders for the ranking and prioritization exercise

Table 10: Criteria for the assessment of the climate change adaptation options

S/N	Dimension	Indicators	Description
1	**Technological**	**Effectiveness**	Effectiveness of importance describes how well effective an adaptation option can mitigate climate damage. In essence, an effective option yields considerable benefits in terms of avoided consequences, albeit potentially at a high cost.
2	**Economic**	**Affordability (cost efficiency)**	This refers to the cost of implementing the adaptation option
3	**Institutional**	**Institutional feasibility** **Alignment with district and/or national priorities**	Institutional feasibility refers to institutional and legal capacity. The preferred adaptation option aligns with laws, regulations, and institutional structures. The extent to which does this measure supports other development priorities of the district or the country?
4	**Technological**	**Technical feasibility**	Technical feasibility focuses on evaluating the technological expertise and the availability of necessary human, financial, and administrative resources for a specific option.
5	**Social**	**Traditional acceptance of adaptation**	Traditional acceptance refers to the degree of acceptability of an adaptation strategy aligning with the context of traditional values.
6	**Social**	**Social co-benefits**	This entails evaluating whether the proposed adaptation aligns with existing social practices and customs and whether it is likely to be embraced by the affected community or population.
7	**Environmental**	**Flexibility**	Flexibility refers to the ability to change behavior in response to changing conditions.
8	**Environmental**	**Environmental considerations**	This evaluates the potential of the intervention to improve GHG emissions, biodiversity, human health, soil quality, water quality, air quality, climate, and landscape.
9	**Social**	**Gender responsiveness**	This evaluates the extent to which the adaptation options address gender-related issues.

10	**Social**	**Equity**	The extent to which the adaptation option will benefit vulnerable groups and communities.
11	**Technological**	**Replicability or scalability**	This defines the ability or possibility of the intervention to be replicated elsewhere in the country or scaled up.
12	**Technological/Economic/ Institutional/Environmental or social**	**Barriers to implmentation**	This identifies potential institutional, economic, technological, and social barriers to the implementation of the adaptation option.

Source: Adpated from Dixit & McGray (2013)

After ranking the different indicators, it was essential to assign appropriate weights to them. An unequal weighting system, reflecting the relative importance of each indicator, was used (Zobeidi et al., 2024; Antwi-Agyei et al., 2013; UNFCCC, 2011). Therefore, a five-point Likert scale (Table 11) was utilized, where climate change experts, as well as agricultural and food experts, ranked the indicators based on their perceived importance, similar to the method used by Antwi-Agyei et al. (2013). The frequency with which each indicator was cited was used to develop the weighting system (Zobeidi et al., 2024; Antwi-Agyei et al., 2013; UNFCCC, 2011)."

Table 11: Ranking of adaptation options based

1	Low
2	Neutral
3	Medium
4	High
(….)	Enclose a number in a bracket to show high **uncertainty.**

8.3 Adaptation options

This section describes the prioritized climate change adaptation options, highlighting each option's adaptation objective, justification, and critical considerations.

8.3.1 Agriculture

From the Climate Change Rapid Risk Assessment for Kumasi Metropolitan Assembly, agriculture was recognized as highly vulnerable to the adverse impacts of climate change. Out of the 17 adaptation options that were identified and evaluated through the MCDM Analysis, six were selected and prioritized (Table 12). Agricultural stakeholders in the Kumasi Metropolitan Assembly prioritized these adaptation options for several compelling reasons. For instance, restoring degraded ecosystems can significantly improve soil health, which is crucial for maintaining and increasing agricultural productivity. Healthy soils support better crop yields and more sustainable farming practices (United Nations Environment Programme [UNEP], 2021). Green spaces help reduce the urban heat island effect, which is particularly important in densely populated areas like Kumasi. Providing technical services equips farmers with the latest knowledge and skills needed to adopt climate-smart agricultural practices (Alwarritzi et al., 2017). Also, equipping farmers with knowledge and skills helps them better understand and respond to climate change impacts. This includes adopting climate-smart agricultural practices that can improve resilience to climate variability and extreme weather events (Robinson-Pant, 2015). Furthermore, biodiverse ecosystems are more resilient to climate change impacts. By enhancing biodiversity, stakeholders aim to create agricultural systems that can better withstand extreme weather events, pests, and diseases (FAO, 2024). Drought-resistant crops are crucial for enhancing the resilience of the agricultural sector to climate change. These crops can withstand periods of low rainfall and extreme temperatures, reducing the risk of crop failure and ensuring stable food production (The Farming Insider, 2024). These adaptations aim to build a more resilient agricultural sector in Kumasi, capable of withstanding the impacts of climate change.

Table 12: Ranking of adaptation options for the agriculture sector

Adaptation option	Final score from stakeholders	Rank
Promotion of farming practices to restore degraded ecosystems	51	1
Creation of green space	51	1
Provision of technical services to farmers	51	1
Provision of knowledge and skills to farmers	50	4
Enhancement of biodiversity	50	4
Planting of drought-resistant varieties of crops	50	4

Table 13: Summary of the Adaptation Actions for the Agricultural Sector

ADAPTATION ACTIONS	OBJECTIVES	INDICATORS OF SUCCESS	TIME FRAME Short, Medium, or Long Term)	RESOURCES (Finance, Human, Technology)	IMPLEMENTING PARTNERS		Estimated costs
					Lead	Collaborating	
Promotion of farming practices to restore degraded ecosystems	Restore degraded ecosystems in the Kumasi Metropolitan Assembly focuses on several key goals including enhancing agricultural productivity, increasing resilience, restoring ecosystems, and mitigating climate change.	Increased soil organic matter, reduced soil erosion, and improved soil fertility. The percentage of farmers adopting sustainable practices. More stable and potentially increased crop yields over time. Increased participation of local communities in ecosystem restoration projects.	Medium-term	Human Finance Technology	MoFA	KMA International Organizations (e.g., FAO, UNDP, etc.) NGOs Research Institutions Private Sector	
Creation of green space	Mitigating urban heat, enhancing air quality, managing stormwater, promoting biodiversity, improving mental and physical health, carbon sequestration, and metropolis resilience.	Enhanced diversity of plant and animal species within green spaces. Reduction in air pollutants and increased oxygen levels. Increased participation of local communities in the creation and maintenance of green spaces. Higher levels of awareness and education about the benefits of green spaces. Boost in local tourism and recreational activities, contributing to the local economy.	Medium-term	Human Technical / Technology Finance	KMA	MESTI MoFA UNDP World Bank NGOs Research Institutions Private Sector	

Provision of technical services to farmers	Empower farmers with the knowledge, skills, and resources needed to adapt to climate change, ensuring sustainable agricultural development and improved livelihoods in the metropolis.	Increased productivity and resilience of crops to climate variability. Adoption of practices that reduce soil degradation and enhance soil fertility. Enhanced understanding and application of sustainable farming practices among farmers. Increased involvement of local communities in agricultural extension programs. More stable and potentially increased incomes for farmers due to improved agricultural practices.	Short term	Human Technology Finance	MoFA	KMA FAO UNDP Research Institutions (e.g., KNUST) Private Sector	
Provision of knowledge and skills to farmers	Enhance farmers' adaptive capacity and build resilience against climate change impacts. This involves equipping farmers with the necessary knowledge and skills to adopt climate-smart agricultural practices.	Increased adoption of sustainable farming techniques that improve soil health and reduce environmental degradation. Enhanced efficiency in water, fertilizers, and other inputs, leading to reduced environmental impact. Increased knowledge and skills among farmers regarding sustainable agricultural practices. Higher levels of community involvement in agricultural training programs.	Short term	Human Technology Finance	MoFA	KMA EPA FAO UNDP Research Institutions (e.g., KNUST) Private Sector	
Enhancement of Biodiversity	Promote ecosystem resilience and sustainability.	Increased variety of plant and animal species within agricultural landscapes. Higher levels of awareness and active participation by farmers in biodiversity-friendly practices. Stable or increased agricultural yields due to improved ecosystem services. Access to new markets for biodiversity-friendly products, potentially leading to higher income for farmers.	Long term	Human Technology Finance	MESTI	KMA IUCN UNDP NGOs Research Institutions (e.g., KNUST) Private Sector	

Planting of drought-resistant varieties of crops	Enhance agricultural resilience and ensure food security.	Consistent or increased crop yields despite varying rainfall patterns and drought conditions. High rates of adoption of drought-resistant crop varieties among local farmers. More stable and potentially increased incomes for farmers due to reliable crop yields. Reduced costs associated with irrigation and other water management practices. Improved access to markets for drought-resistant crops, potentially leading to better prices and higher income for farmers.	Short term	Human Technology Finance	MoFA	KMA EPA FAO UNDP Research Institutions (e.g., KNUST) Private Sector	
Use of Integrated Pest Management Strategies	Minimize the damage caused by pests, which is crucial for maintaining food security	A measurable decrease in the amount of crop damage caused by pests, leading to higher yields The percentage of farmers adopting IPM practices, reflecting the acceptance and effectiveness of the strategies	Medium-term	Human Technology Finance	KMA	MoFA EPA Research Institutions (e.g., Crops Research Institute) NGOs	
Use of improved agricultural technology and CSA practices	Increase crop yields and livestock productivity, ensuring food security even under changing climate conditions	Measurable improvements in crop yields and livestock productivity indicate the effectiveness of the new technologies and practices. The percentage of farmers adopting improved agricultural technologies and CSA practices, reflecting their acceptance and integration into local farming systems	Medium-term	Human Technology Finance	KMA	MoFA EPA Research Institutions (e.g., Crops Research Institute) NGOs Farmer Associations	

Access to agricultural credits	Giving farmers access to credit helps them invest in climate-resilient technologies and practices, thereby increasing their ability to withstand climate-related shocks.	The number of farmers who successfully obtain agricultural loans, reflecting improved access to financial resources The extent to which farmers use credit to invest in climate-smart technologies and practices, such as improved irrigation systems or drought-resistant crops.	Short term	Human Technology Finance	KMA	MoFA Financial Institutions NGOs Farmer Associations Development Partners	
Supporting agro-based development	Increase the productivity of agricultural activities, ensuring food security and economic stability	Measurable improvements in crop yields and livestock productivity, indicating the effectiveness of agro-based development initiatives. Growth in the number and profitability of agro-based businesses, showing the economic impact of development efforts	Medium-term	Human Technology Finance	KMA	MoFA Financial Institutions NGOs Farmer Associations Development Partners	
Use of drip or sprinkler irrigation	Drip and sprinkler irrigation systems are designed to use water more efficiently, reducing wastage and ensuring that crops receive the optimal amount of water.	Measurement of water use per unit of crop yield, indicating how effectively water resources are being utilized. Higher and more consistent crop yields as a result of improved irrigation practices	Medium-term	Human Technology Finance	KMA	MoFA Financial Institutions NGOs Farmer Associations Development Partners	

Access to weather and climate information	To allow farmers to anticipate and prepare for extreme weather events, reducing the risk of crop failure and other climate-related impacts.	The percentage of farmers regularly using weather and climate information for planning agricultural activities, such as planting, irrigation, and harvesting. Higher crop yields and livestock productivity as a result of better-informed farming practices	Short term	Human Technology Finance	KMA	GMet MoFA NGOs Research Institutions Farmer Associations Development Partners	
Adherence to land use planning	Ensure that agricultural activities are conducted on suitable land to maximize productivity and sustainability.	Measurable decreases in deforestation rates, soil erosion, and other forms of environmental degradation. Improvements in crop yields and livestock productivity as a result of optimized land use. The ability of agricultural systems to withstand and recover from climate-related events, such as floods and droughts.	Long term	Human Technology Finance	KMA	MoFA EPA Town and Country Planning Department NGOs Research Institutions Farmer Associations	
		The number of farmers and agricultural enterprises adhering to land use plans and regulations.	Medium-term	Human Technology Finance	KMA	MoFA NGOs Financial Institutions Research Institutions Farmer Associations Development Partners	
Livelihood diversification	Helps farmers reduce their dependence on a single source of income, making them less vulnerable to climate-related shocks such as droughts or floods	The number of farmers receiving training and resources to support livelihood diversification, indicating enhanced capacity building. The ability of households to withstand and recover from climate-related events, such as droughts or floods The percentage of farmers adopting sustainable and climate-resilient agricultural practices as part of their diversified livelihoods					

Investment in climate-resilient infrastructure	Contributes to higher and more stable agricultural productivity by protecting crops and livestock from climate impacts	A decrease in economic losses due to climate-related events, indicating improved resilience of infrastructure. Higher and more stable crop yields and livestock productivity as a result of resilient infrastructure. Increased income and profitability for farmers due to reduced losses and improved productivity.	Long term	Human Technology Finance	KMA	MoFA EPA Town and Country Planning Department NGOs Research Institutions Development Partners	
Adjustment of farming schedules to align with changing climate patterns	Ensures that crops are planted and harvested at the most optimal times, maximizing yields and reducing the risk of crop failure	The percentage of farmers adjusting their planting and harvesting schedules in response to climate forecasts, ensuring optimal crop growth periods Improvements in crop yields as a result of better alignment with favorable climate conditions	Short term	Human Technology Finance	KMA	MoFA GMet NGOs Research Institutions Farmer Associations Development Partners	
Promotion of vertical gardening techniques	By utilizing vertical spaces, urban farmers can grow more crops in smaller areas, which is crucial in densely populated regions.	Measuring the amount of produce harvested per square meter to ensure that vertical gardening is enhancing productivity. Assessing the effective use of urban spaces for agriculture, particularly in areas where traditional farming is not feasible.	Short term	Human Technology Finance	KMA	Local Government Agencies NGOs Educational Institutions Private Sector Community Groups	

8.3.2 Gender

From the Climate Change Rapid Risk Assessment for Kumasi Metropolitan Assembly, gender was recognized as vulnerable to the adverse impacts of climate change. Out of the 9 adaptation options that were identified and evaluated through the MCDM Analysis, three were selected and prioritized (Table 14). Gender stakeholders prioritized these adaptation practices in the Kumasi Metropolis for several compelling reasons. For instance, agroforestry practices provide economic opportunities, particularly for women, by diversifying income sources through the sale of tree products like fruits, nuts, and timber. This economic empowerment is crucial for gender equality and improving livelihoods (van Noordwijk et al., 2021). Furthermore, locally based projects are tailored to the unique needs and vulnerabilities of specific groups within the metropolis. This ensures that the most at-risk populations, such as women, children, and the elderly, receive targeted support to enhance their resilience to climate change impacts (Westoby et al., 2021). Women-led small businesses provide significant economic opportunities for women, helping to diversify income sources and improve financial stability. This economic empowerment is crucial for enhancing resilience to climate change impacts (Peprah et al., 2023). Women entrepreneurs often adopt innovative and sustainable business practices that can contribute to broader climate resilience.

Table 14: Ranking of adaptation options for the gender sector

Adaptation option	Final score from stakeholders	Rank
Investing in gendered tree planting/agroforestry practices in the metropolis	49	1
Implementing locally based projects to benefit vulnerable groups	46	2
Promotion of women-led small businesses	43	3

Table 15: Summary of the adaptation actions for the gender sector

ADAPTATION ACTIONS	OBJECTIVES	INDICATORS OF SUCCESS	TIME FRAME (Short, Medium and Long Term)	RESOURCES (Finance, Human, Technology)	IMPLEMENTING PARTNERS		Estimated costs
					Lead	Collaborating	
Investing in gendered tree planting and agroforestry practices in the metropolis	Enhance resilience to climate change while promoting gender equality. The gendered approach ensures that women are actively involved in the planning and implementation processes, providing them with opportunities for leadership and economic empowerment.	Measurement of the area covered by newly planted trees and agroforestry systems. Number and percentage of women involved in the planning, decision-making, and implementation processes. Revenue generated from the sale of agroforestry products such as fruits, nuts, and timber. Enhanced food security and economic stability for participating households.	Medium-term	Human Technology Finance	KMA	Forestry Commission of Ghana Ministry of Gender, Children and Social Protection NGOs Community-based organizations (CBOs) Academic and Research Institutions	
Implementing locally based projects to benefit vulnerable groups	Enhance the resilience and adaptive capacity of vulnerable populations, particularly women, children, the elderly, and marginalized communities.	Number and percentage of vulnerable groups (women, children, elderly, marginalized communities) actively involved in project activities. Increase in income levels for vulnerable groups through project-related activities. Enhanced resilience of vulnerable communities to climate impacts, measured through reduced vulnerability to extreme weather events. Overall improvement in the quality of life for vulnerable groups, including better housing and access to clean water. Strengthened social networks and community support systems.	Short term	Human Technology Finance	KMA	Ministry of Gender, Children and Social Protection CBOs NGOs International Development Agencies (e.g., UNDP) Academic and Research Institutions	

Promotion of women-led small businesses	Enhance the resilience and adaptive capacity of women entrepreneurs to climate change impacts.	Increase in the number of women-led businesses and their revenue growth. Number of women entrepreneurs accessing financial services and products, such as loans and grants. Number of jobs created by women-led businesses. Increase in the number of women in leadership roles within their businesses and communities.	Short term	Human Technology Finance	KMA	Ministry of Gender, Children and Social Protection CBOs NGOs International Development Agencies (e.g., UNDP) Academic and Research Institutions	
Promoting gendered climate change policy framework in the metropolis	Ensure that climate policies and actions are inclusive, equitable, and effectively address the different needs and vulnerabilities of all genders.	The number of climate policies and adaptation plans that explicitly include gender considerations. Strengthening of institutions to address gender issues in climate adaptation, measured by the establishment of gender units or focal points within relevant agencies. Increase in the number of women and other gender groups in decision-making roles related to climate policy and adaptation. Number and percentage of women and marginalized gender groups actively participating in climate adaptation planning and implementation processes.	Medium-term	Human Technology Finance	KMA	Ministry of Gender, Children and Social Protection CBOs NGOs International Development Agencies (e.g., UNDP) Academic and Research Institutions	

Incorporating gender-specific indicators to monitor and evaluate climate adaptation strategies	Ensure that climate adaptation efforts are inclusive, equitable, and effective in addressing the needs of all genders.	The number of climate adaptation strategies that include gender-specific indicators. Establishment and strengthening of institutional frameworks to support gender-responsive monitoring and evaluation. Improvement in the quality and comprehensiveness of gender-disaggregated data collected. Number and percentage of women and marginalized gender groups involved in the monitoring and evaluation processes.	Medium-term	Human Technology Finance	KMA	Ministry of Gender, Children and Social Protection CBOs NGOs International Development Agencies (e.g., UNDP) Academic and Research Institutions	
Access to capital resources	Enhance the financial resilience and adaptive capacity of women and other vulnerable groups.	Number and percentage of women and other vulnerable groups accessing credit and financial services. Increase in the number of women-led businesses and their revenue growth as a result of access to credit. Number of jobs created through the establishment and expansion of women-led businesses.	Short term	Human Technology Finance	KMA	Ministry of Gender, Children and Social Protection NGOs Financial Institutions CBOs Academic and Research Institutions International Development Agencies (e.g., UNDP)	
Promoting gender-based research in climate change study	Ensure that climate adaptation strategies are informed by comprehensive, gender-sensitive data and analysis.	Increase in the collection and analysis of gender-disaggregated data on climate change impacts and adaptation. The number of research studies published that focus on gender and climate change. The extent to which research findings are used to inform climate adaptation policies and practices.	Medium-term	Human Technology Finance	KMA	Ministry of Gender, Children and Social Protection CBOs NGOs International Development Agencies (e.g., UNDP) Academic and Research Institutions	

Access to credits	Enhance the financial resilience and adaptive capacity of women and other vulnerable groups.	Number and percentage of women and other vulnerable groups accessing credit and financial services. Increase in the number of women-led businesses and their revenue growth as a result of access to credit. Number of jobs created through the establishment and expansion of women-led businesses.	Short term	Human Technology Finance	KMA	Ministry of Gender, Children and Social Protection CBOs NGOs International Development Agencies (e.g., UNDP) Institutions	
Investing in solar energy to promote entrepreneurs in the metropolis	Enhance the resilience and economic empowerment of women and other vulnerable groups through sustainable energy solutions.	The number of new women-led solar energy businesses established. The number of jobs created through solar energy initiatives, particularly for women and marginalized groups. Increase in revenue for women-led businesses involved in solar energy.	Medium-term	Human Technology Finance	KMA	Ministry of Gender, Children and Social Protection NGOs CBOs International Development Agencies (e.g., UNDP)	

8.3.3 Trade

Out of the 3 adaptation options that were identified and evaluated through the MCDM Analysis, three were selected and prioritized (Table 16). Trade stakeholders in the Kumasi Metropolitan Assembly prioritized these adaptation measures for several key reasons. For example, by providing green financing, businesses can invest in climate-resilient infrastructure and practices, reducing the risk of disruptions due to climate events. This helps maintain economic stability and continuity in the trading sector (Fu et al., 2024). Green financing encourages sustainable business practices, which can lead to long-term growth and competitiveness. Businesses that adopt environmentally friendly practices are better positioned to thrive in a future where sustainability is increasingly valued. Also, Public-Private Partnerships (PPPs) can attract significant private investment, which is crucial for funding large-scale climate adaptation projects. This helps bridge the funding gap that public resources alone might not cover (World Economic Forum, 2020). By distributing risks between public and private entities, PPPs make climate adaptation projects more feasible and sustainable. This shared responsibility ensures that both sectors are committed to the success of these initiatives (World Bank Group, 2023). Furthermore, implementing strategies to enhance the city's resilience to climate change helps ensure that businesses can continue operating during and after climate events, which is crucial for maintaining economic stability and protecting livelihoods (Pamukcu-Albers et al., 2021). By implementing resilience strategies, businesses can reduce their vulnerability to climate-related risks such as extreme weather, flooding, and heat waves. This proactive approach minimizes potential losses and disruptions (World Bank Group, 2020).

Table 16: Ranking of adaptation options for the trade sector

Adaptation option	Final score from stakeholders	Rank
Green financing options to support businesses in adopting climate-resilient strategies	48	1
Public-Private Partnerships	47	2
Implementing strategies to enhance the city's resilience to climate change	45	3

Table 17: Summary of the Adaptation Actions for the Trade Sector

ADAPTATION ACTIONS	OBJECTIVES	INDICATORS OF SUCCESS	TIME FRAME (Short, Medium or Long Term)	RESOURCES (Finance, Human, Technology)	IMPLEMENTING PARTNERS		Estimated costs
					Lead	Collaborating	
Green financing options to support businesses in adopting climate-resilient strategies	Providing financial support to businesses to implement climate-resilient strategies helps them withstand climate impacts, ensuring continuity and reducing economic losses	A measurable increase in the number of businesses, especially SMEs, accessing green financing options.	Short term	Human Technology Finance	KMA	Private sector NGOs Academic and Research Institutions Philanthropic organizations	
		The number of businesses that have successfully implemented climate-resilient strategies and practices.					
		Increased awareness and capacity among business owners and managers regarding climate risks and adaptation strategies					
Public-Private Partnerships (PPPs)	Mobilizing private sector resources and expertise to finance and implement climate-resilient infrastructure and practices.	The amount of private sector investment leveraged for climate-resilient projects	Medium-term	Human Technology Finance	KMA	Private sector companies Financial institutions Development partners (e.g., UNDP, World Bank, etc) NGOs	
		The number and quality of climate-resilient infrastructure projects completed					
		Effective distribution and management of financial and operational risks between public and private partners					

Implementing strategies to enhance the city's resilience to climate change	Ensuring that trade-related infrastructure, such as markets, transportation networks, and storage facilities, can withstand climate impacts like extreme weather events and flooding	The number and quality of trade-related infrastructure projects that are designed to withstand climate impacts, such as extreme weather events and flooding. The percentage of businesses in the trade sector that have adopted sustainable practices and technologies to reduce their environmental footprint. Metrics indicating improved economic performance and stability of businesses, such as revenue growth and reduced climate-related disruptions	Medium-term	Human Technology Finance	KMA MESTI	Private sector companies Financial institutions Development partners (e.g., UNDP, AfDB, etc) NGOs Academic and Research Institutions Philanthropic organizations	
Promoting energy-efficient appliances and climate-smart agricultural products	Encouraging the use of energy-efficient appliances and climate-smart agricultural products helps lower greenhouse gas emissions, contributing to climate mitigation efforts	Quantifiable reductions in greenhouse gas emissions resulting from the use of energy-efficient appliances and climate-smart agricultural practices. The number of businesses and households adopting energy-efficient appliances and climate-smart agricultural products. Cost savings for businesses and households due to reduced energy bills and increased efficiency Enhanced resilience and productivity of agricultural practices due to the use of climate-smart products	Short-term	Human Technology Finance	KMA MoFA	Private sector companies Financial institutions Development partners NGOs Academic and Research Institutions Philanthropic organizations	

Policies that support businesses in adapting to climate change	Policies that support businesses in adapting to climate change.	The number of climate adaptation policies adopted and effectively implemented by businesses.		Human Technology Finance	KMA Ministry of Trade and Industry	Private sector companies Financial institutions Development partners NGOs Academic and Research Institutions	
		Improved resilience of businesses to climate impacts, measured through metrics such as reduced downtime and quicker recovery from climate-related disruptions.	Medium-term				
		The percentage of businesses adopting sustainable and environmentally friendly practices as a result of supportive policies.					
Enforcing regulations that promote trade development	Implementing regulations that encourage businesses to adopt sustainable practices, reducing their environmental impact and enhancing resilience to climate change.	The percentage of businesses adhering to new climate-resilient trade regulations.	Medium-term	Human Technology Finance	KMA Ministry of Trade and Industry	Private sector companies Financial institutions Development partners NGOs	
		The number and quality of trade-related infrastructure projects that meet climate resilience standards.					
		An increase in the trade of environmentally friendly and climate-resilient products.					
Trading climate-resilient products	Promoting the trade of climate-resilient products helps ensure that markets remain stable and functional despite climate impacts	The extent to which policies and regulations support and promote the trade of climate-resilient products.	Short term	Human Technology Finance	KMA Ministry of Trade and Industry	Private sector companies Financial institutions Development partners NGOs Academic and Research Institutions	
		The number of businesses and farmers adopting and trading climate-resilient products.					
		The increase in the market share of climate-resilient products within the trade sector.					

Diversifying supply chains to reduce dependency on climate-sensitive sectors	By diversifying supply chains, businesses can reduce their dependency on sectors that are highly sensitive to climate impacts, thereby minimizing the risk of disruptions.	The increase in the number of suppliers and regions involved in the supply chain reduces dependency on any single climate-sensitive sector	Medium-term	Human Technology Finance	KMA Ministry of Trade and Industry	Private sector companies Financial institutions Development partners NGOs Academic and Research Institutions Philanthropic organizations	
		Improved ability of businesses to maintain operations during climate-related disruptions, measured by reduced downtime and quicker recovery times.					
		Enhanced economic performance and stability of businesses, indicated by metrics such as revenue growth and reduced climate-related losses					

8.3.4 Water and Sanitation

From the Climate Change Rapid Risk Assessment for Kumasi Metropolitan Assembly, the water and sanitation sector was recognized as highly vulnerable to the adverse impacts of climate change. Out of the 10 adaptation options that were identified and evaluated through the MCDM Analysis, three were selected and prioritized (Table 18). The prioritization of these adaptations by water and sanitation stakeholders in the Kumasi Metropolitan Assembly can be justified by several key factors. For instance, planting trees along waterways helps filter pollutants from runoff before they enter waterways, leading to cleaner water sources (Saravanan et al., 2021). Enforcing by-laws directly reduces pollutants entering water bodies, leading to immediate improvements in water quality. This is crucial for ensuring safe drinking water and maintaining public health (Franz, 2011). Preventing of water pollution at the source is often more cost-effective than treating contaminated water. By enforcing regulations, the Assembly can avoid the high costs associated with water treatment and remediation. Also, clean water is essential for preventing waterborne diseases. By prioritizing pollution prevention, the Assembly can protect the health of its residents, reducing healthcare costs and improving overall community well-being (World Bank Group, 2022). The prioritization of investing in water and sanitation infrastructure in the face of climate and weather changes by stakeholders in the Kumasi Metropolitan Assembly can be justified by several key factors. For example, ensuring access to clean water and effective sanitation is crucial for preventing waterborne diseases, which can become more prevalent with climate change (Nichols et al., 2018). This is essential for maintaining public health, especially during extreme weather events that can compromise water quality. Reliable water and sanitation services are foundational for economic activities. Interruptions due to climate impacts can lead to significant economic losses. Investing in resilient infrastructure helps safeguard economic stability and supports livelihoods (Howard et al., 2010).

Table 18: Ranking of adaptation options for the water and sanitation sector

Adaptation option	Final score from stakeholders	Rank
Planting trees along waterways	47	1
Enforcing by-laws to prevent water pollution	46	2
Investing in the establishment of water and sanitation infrastructure in the face of climate and weather changes	46	2

Table 19: Summary of the Adaptation Actions for the Water and Sanitation Sector

ADAPTATION ACTIONS	OBJECTIVES	INDICATORS OF SUCCESS	TIME FRAME (Short, Medium or Long Term)	RESOURCES (Finance, Human, Technology)	IMPLEMENTING PARTNERS		Estimated costs
					Lead	Collaborating	
Planting trees along waterways	Lower the temperature of the water. This is crucial for maintaining aquatic ecosystems and ensuring the survival of various aquatic species	Monitoring the levels of pollutants, such as nitrates, phosphates, and sediments, in the water can indicate the effectiveness of trees in filtering runoff and improving water quality.	Medium-term	Human Technology Finance	KMA	Forestry Commission of Ghana EPA NGOs Local communities Educational Institutions Private sector	
		Measuring the rate of soil erosion along the waterways can show how well the tree roots are stabilizing the soil.					
		Tracking the diversity and abundance of plant and animal species in the riparian zones can reflect the improvement in habitat quality.					
Enforcing by-laws to prevent water pollution	Maintain clean water, which is essential for both human consumption and ecosystem health	Regular monitoring of water quality parameters, such as levels of pollutants (e.g., nitrates, phosphates, heavy metals), can indicate the effectiveness of pollution control measures.	Short term	Human Technology Finance	KMA	EPA Water Resources Commission Ghana Police Service NGOs Private Sector	
		Tracking the number of reported cases of waterborne diseases can help assess the health impact of improved water quality.					
		Measuring the compliance rates of industries, businesses, and households with the by-laws can show how well the regulations are being followed.					

Investing in the establishment of water and sanitation infrastructure in the face of climate and weather changes	By developing robust infrastructure, the KMA can ensure a reliable supply of clean water, even during periods of drought or extreme weather events.	The efficiency and reliability of water supply and sanitation services, including reduced downtime and maintenance issues. The percentage of the population with access to safe and reliable drinking water sources. The percentage of the population with access to improved sanitation facilities, such as toilets and sewage systems. The incidence rates of waterborne diseases, such as cholera and diarrhea, can indicate improvements in water quality and sanitation. The ability of water and sanitation infrastructure to withstand extreme weather events, such as floods and droughts.	Long term	Human Technology Finance	KMA	Ghana Water Company Limited (GWCL) Community Water and Sanitation Agency (CWSA) EPA Ministry of Sanitation and Water Resources NGOs Local communities Private sector	
Proper waste management	Effective waste management prevents pollutants from entering water bodies, thereby protecting water quality and reducing the risk of waterborne diseases	Monitoring the levels of pollutants in water bodies and soil can indicate the effectiveness of waste management practices in reducing contamination. Tracking the incidence of diseases related to poor waste management, such as cholera and malaria, can reflect improvements in public health. Measuring the percentage of waste that is collected and properly disposed of or recycled can show the efficiency of waste management systems.	Short term	Human Technology Finance	KMA	Ministry of Sanitation and Water Resources (MSWR) EPA Zoomlion Ghana Limited NGOs Local communities Private sector	

Desilting	Desilting removes accumulated sediments from waterways, ensuring better water flow and reducing the risk of flooding during heavy rains.	Monitoring the flow rates of de-silted waterways to ensure they are free from blockages and can handle increased water volumes during heavy rains.	Short term	Human Technology Finance	KMA	MSWR EPA GWCL NGOs Local communities Private Sector	
		Regular testing of water quality parameters, such as turbidity and pollutant levels, to assess improvements following desilting.					
		Measuring the capacity of reservoirs and dams before and after desilting to ensure they can store more water, especially during dry periods.					
Investing in wetlands infrastructure for the metropolis wastewater management	Wetlands act as natural sponges, absorbing excess rainwater and reducing the risk of flooding during heavy rainfall events.	Monitoring the frequency and severity of flooding events in areas with wetlands infrastructure can indicate the effectiveness of flood mitigation efforts.	Medium-term	Human Technology Finance	KMA	MSWR EPA WRC NGOs Local communities Private Sector	
		Regular testing of water quality parameters, such as levels of pollutants and sediments, can show improvements due to the natural filtration provided by wetlands.					
		Tracking the diversity and abundance of plant and animal species in and around wetlands can reflect the health and resilience of these ecosystems.					
Investing in rainwater harvesting in the metropolis	Rainwater harvesting provides an additional source of water, reducing dependence on traditional water supplies and ensuring availability during periods of drought or water scarcity.	Monitoring the volume of rainwater collected and used can indicate the effectiveness of rainwater harvesting systems in supplementing the water supply.	Medium-term	Human Technology Finance	KMA	MSWR EPA WRC NGOs Local communities Private Sector	
		Tracking the frequency and severity of flooding events can help assess the impact of rainwater harvesting on reducing runoff and mitigating flood risks.					

8.4.5 Health

Out of the 11 adaptation options that were identified and evaluated through the MCDM Analysis, four were selected and prioritized (Table 20). Health stakeholders in the Kumasi Metropolitan Assembly prioritized these adaptation options for several critical reasons. For example, for mainstreaming climate change risks into metropolis health sector policies, Kumasi metropolis, like many urban areas, faces significant climate-related health risks, including increased heatwaves, flooding, and vector-borne diseases. These impacts can strain the health system and disproportionately affect vulnerable populations such as women, children and the elderly. By integrating climate change considerations into health policies, the health sector can better prepare for and respond to climate-related health emergencies. This proactive approach helps in building a more resilient health infrastructure capable of withstanding extreme weather events. Also, many health facilities in Kumasi and other parts of Ghana experience frequent power outages, which can severely disrupt healthcare services. Solar energy provides a reliable and consistent power source, ensuring that critical health services are not interrupted (Apenteng et al., 2018). Furthermore, educating healthcare professionals and the public about the health impacts of climate change is crucial for building awareness and understanding. This knowledge empowers individuals and communities to take proactive measures to protect their health (Ramadani et al., 2023). By incorporating climate change into health education, healthcare workers can better recognize and respond to climate-related health issues. This preparedness is essential for managing the increasing frequency and severity of climate-related health emergencies (Diko, 2023). Lastly, raising awareness about climate risks helps communities understand their vulnerabilities and the potential health impacts of climate change. This knowledge is crucial for motivating individuals and communities to take proactive measures to protect their health (Khatibi et al., 2021).

Table 20: Ranking of adaptation options for the health sector

Adaptation option	Final score from stakeholders	Rank
Mainstreaming climate change risks into metropolis health sector policies framing	47	1
Installing solar energy in health facilities	45	2
Incorporating climate change in health education	45	2
Creating community awareness of climate risks impacts on their health	45	2

Table 21: Summary of the Adaptation Actions for the Health Sector

ADAPTATION ACTIONS	OBJECTIVES	INDICATORS OF SUCCESS	TIME FRAME (Short, Medium, and Long Term)	RESOURCES (Finance, Human, Technology)	IMPLEMENTING PARTNERS		Estimated costs
					Lead	Collaborating	
Mainstreaming climate change risks into metropolis health sector policies framing	To integrate climate change considerations into health policies and planning. This involves identifying and addressing the health risks posed by climate change, such as increased incidence of heat-related illnesses, vector-borne diseases, and other climate-sensitive health outcomes..	Evidence that climate change considerations have been incorporated into health sector policies and strategic plans.	Medium-term	Human Technology Finance	KMA	Ghana Health Service (GHS) Ministry of Health (MoH) EPA WHO NGOs Academic and Research Institutions International Development Partners (e.g., UNDP)	
		Training programs conducted for health professionals on climate change impacts and adaptation strategies.					
		Enhanced systems for monitoring climate-sensitive health outcomes, such as heat-related illnesses and vector-borne diseases.					
		Increased public awareness and education campaigns on the health risks associated with climate change.					
Installing solar energy in health facilities	To enhance the resilience and sustainability of health services. This involves ensuring a reliable and uninterrupted power supply for health facilities, especially during extreme weather events that may disrupt conventional power sources.	Reduction in power outages and improved continuity of health services.	Medium-term	Human Technology Finance	KMA	GHS Ministry of Energy EPA Solar Energy Companies NGOs International Development Partners Academic and Research Institutions Local communities	
		Decrease energy expenses for health facilities, allowing more funds to be allocated to other health services.					
		Lower greenhouse gas emissions from health facilities due to using renewable energy.					
		The number of health facilities that have successfully installed and used solar energy systems.					
		Enhanced patient care and health outcomes due to reliable power supply, especially during emergencies.					
		Increased satisfaction among health facility staff and patients due to improved service reliability.					

Incorporating climate change in health education	To raise awareness and build capacity among health professionals and the general public about the health impacts of climate change.	Higher levels of awareness among health professionals and the public about the health impacts of climate change.	Short term	Human Technology Finance	KMA	GHS MoH Ministry of Education (MoE) EPA NGOs International Development Partners Academic and Research Institutions Local communities and Traditional leaders	
		The number of training sessions conducted for health workers on climate change and health.					
		Inclusion of climate change topics in health education curricula at various levels of education.					
		Observable changes in public behavior that reduce health risks associated with climate change, such as increased use of mosquito nets and hydration practices during heatwaves.					
		Active participation of communities in climate change and health-related activities and discussions.					
Creating community awareness of climate risks impacts on their health	To empower communities with the knowledge and tools they need to protect their health from the adverse effects of climate change.	Higher levels of knowledge among community members about the health risks associated with climate change.	Short term	Human Technology Finance	KMA	GHS MoH EPA NGOs CBOs Traditional leaders and local authorities International Development Partners Academic and Research Institutions	
		Observable changes in community practices that reduce vulnerability to climate-related health risks, such as increased use of mosquito nets and better hydration practices during heatwaves.					
		Active involvement of community members in climate change and health-related activities, workshops, and discussions.					
		Improvement in health outcomes related to climate-sensitive conditions, such as reduced incidence of vector-borne and waterborne diseases.					

Proper waste management practices	To reduce the health risks associated with improper waste disposal, which can be exacerbated by climate change. This involves minimizing the spread of diseases that can result from poor waste management, such as vector-borne diseases (e.g., malaria, dengue) and waterborne diseases (e.g., cholera).	Decrease in the number of cases of diseases related to poor waste management, such as malaria, dengue, and cholera. Establishment and effective operation of waste disposal systems, including regular collection and proper disposal of medical and general waste. Active involvement of community members in waste management initiatives, such as recycling programs and clean-up campaigns. Improvement in environmental indicators, such as reduced pollution levels and cleaner public spaces.	Short term	Human Technology Finance	KMA	GHS MoH EPA Waste management companies NGOs CBOs International Development Partners Academic and Research Institutions Local communities	
Desilting	To reduce the risk of flooding and waterborne diseases, which can be exacerbated by climate change. This involves removing silt and debris from drainage systems and waterways to ensure they function properly and reduce the risk of flooding during heavy rains.	Decrease in the frequency and severity of flooding events in areas where desilting has been carried out. Enhanced flow capacity of drainage systems and waterways, preventing waterlogging and stagnation. Reduction in the incidence of waterborne and vector-borne diseases, such as cholera and malaria, due to improved water management.	Short term	Human Technology Finance	KMA	GHS MoH EPA National Disaster Management Organization (NADMO) Waste Management Companies NGOs CBOs Local communities	

Encourage behavioral change	To promote actions and habits that reduce vulnerability to climate-related health risks. This involves encouraging behaviors that minimize exposure to climate-sensitive health risks, such as using mosquito nets to prevent malaria and staying hydrated during heatwaves.	Higher rates of behaviors that reduce climate-related health risks, such as the use of mosquito nets, regular hydration during heatwaves, and proper waste disposal. Increased awareness among community members about the health impacts of climate change and the importance of adopting protective behaviors. Active involvement of community members in health and climate adaptation initiatives, such as clean-up campaigns and educational workshops.	Medium-term	Human Technology Finance	KMA	GHS MoH EPA NGOs CBOs Traditional leaders and authorities Academic and Research Institutions	
Promote climate-smart health practices	To integrate sustainable and resilient practices into healthcare delivery. This involves encouraging the efficient use of resources such as water and energy in health facilities to reduce environmental impact and enhance resilience.	Reduction in energy consumption and increased use of renewable energy sources in health facilities. Implementation of water-saving measures and technologies, such as rainwater harvesting and low-flow fixtures. Decrease in the amount of waste generated and improved waste segregation and recycling practices.	Medium-term	Human Technology Finance	KMA	GHS MoH EPA Ministry of Energy NGOs Academic and Research Institutions	

Promote flood control mechanisms	To protect public health and health infrastructure from the adverse effects of flooding. This involves implementing measures to reduce the risk and impact of flooding on health facilities and communities, ensuring continuous access to healthcare services.	Decrease in the frequency and severity of flooding events affecting health facilities and communities.	Medium-term	Human Technology Finance	KMA	GHS MoH NADMO EPA Ministry of Works and Housing NGOs CBOs International Development Partners Local communities	
		The number of health facilities with improved flood defenses, such as elevated structures, flood barriers, and drainage systems.					
		Reduction in the incidence of waterborne and vector-borne diseases following flood events, such as cholera and malaria.					
		Development and implementation of effective emergency response plans for health facilities and communities during flood events.					
Boost health systems to counteract climate-related diseases	To strengthen the capacity of the health system to effectively prevent, detect, and respond to diseases that are influenced by climate change.	Enhanced systems for monitoring and tracking climate-sensitive diseases, with timely reporting and data analysis.	Long term	Human Technology Finance	KMA	GHS MoH EPA WHO NGOs Academic and Research Institutions Local Communities and Traditional Leaders	
		Number of training sessions conducted for health professionals on climate-related diseases and their management.					
		Adequate supply of medical resources, such as vaccines, medications, and diagnostic tools, to address climate-related health issues.					

Cultivating medicinal plants in the communities	To enhance the resilience of local healthcare systems. By cultivating medicinal plants locally, communities can reduce their dependence on external sources for medicinal supplies, which may be disrupted by climate change.	A measurable increase in the quantity and variety of medicinal plants grown locally.	Medium-term	Human Technology Finance	KMA	Health Sector Agencies Agricultural Extension Services CBOs NGOs Academic and Research Institutions Traditional Healers and Herbalists Internation Development Partners	
		Reduction in health issues that can be treated with cultivated medicinal plants.					
		Increased income for local farmers and communities from the sale of medicinal plants.					
		Decreased reliance on imported medicinal products, ensuring more stable access during climate disruptions.					
		Higher levels of community participation in cultivation activities and increased knowledge about the benefits and uses of medicinal plants.					

8.3.6 Disaster Risk Reduction (DRR)

Out of the 15 adaptation options that were identified and evaluated through the MCDM Analysis, three were selected and prioritized (Table 22). DRR stakeholders in the Kumasi Metropolitan Assembly prioritized these adaptation options for several key reasons. For example, integrating DRR and climate change adaptation ensures a comprehensive approach to managing risks. This integration helps address both immediate disaster risks and long-term climate impacts, leading to more resilient development outcomes (UNDP, 2020). Combining DRR and climate adaptation strategies allows for more efficient use of resources. By addressing multiple risks through a unified approach, the metropolis can optimize investments and avoid duplicative efforts (Mysiak, 2021). Engaging citizens in the planning process fosters a sense of ownership and responsibility towards climate adaptation measures. This involvement can lead to more resilient communities that are better prepared to respond to and recover from climate-related disasters. Furthermore, by building the capacity of personnel, the assembly ensures that staff are well-equipped to assess, manage, and mitigate climate risks effectively. This leads to more informed decision-making and better implementation of adaptation strategies. Trained personnel can respond more efficiently to climate-related emergencies, reducing the impact of disasters on the community. This includes faster and more effective deployment of resources during events such as floods or heat waves.

Table 22: Ranking of adaptation options for the disaster risk reduction sector

Adaptation option	Final score from stakeholders	Rank
Integrating Disaster risk reduction and climate change adaptation strategies into development planning with the metropolis	50	1
Involving citizens within the metropolis in climate risk assessment and planning process	47	2
Building the capacity of personnel to address climate risks	47	2

Table 23: Summary of the Adaptation Actions for the Disaster Risk Reduction Sector

ADAPTATION ACTIONS	OBJECTIVES	INDICATORS OF SUCCESS	TIME FRAME (Short, Medium and Long Term)	RESOURCES (Finance, Human, Technology)	IMPLEMENTING PARTNERS		Estimated costs
					Lead	Collaborating	
Integrating Disaster risk reduction and climate change adaptation strategies into development planning with the metropolis	To enhance the resilience and sustainability of the metropolis against climate-related hazards. This integration aims to minimize the exposure and susceptibility of communities, infrastructure, and ecosystems to climate-related disasters.	A measurable decrease in the economic, social, and environmental losses due to climate-related disasters.	Medium-term	Human Technology Finance	KMA	NADMO EPA Urban Planning and Development Partners Local Health Departments CBOs NGOs Academic and Research Institutions Private Sector	
		Improved response times and effectiveness of emergency services during climate-related events.					
		Higher levels of community awareness, preparedness, and participation in DRR and climate adaptation activities.					
		Incorporation of climate risk assessments and adaptation measures in urban planning and development projects.					

Involving citizens within the metropolis in climate risk assessment and planning process	To enhance community resilience and ensure that adaptation strategies are inclusive, effective, and sustainable. This objective aims to engage citizens in identifying and understanding climate risks, which empowers them to take proactive measures to protect themselves and their properties.	A higher number of citizens actively participating in climate risk assessment and planning meetings, workshops, and activities.	Short term	Human Technology Finance	KMA	NADMO EPA CBOs NGOs Local Health Departments Academic and Research Institutions Traditional Leaders and Community Elders Media Organizations International Development Partners	
		Greater awareness and understanding of climate risks and adaptation strategies among the general public, measured through surveys or feedback.					
		Evidence of local knowledge and community input being integrated into climate risk assessments and adaptation plans.					
		Increased trust and confidence in local government and DRR initiatives, as indicated by community feedback and engagement levels.					
		Inclusion of diverse community groups, including vulnerable populations, in the planning process, ensuring their needs and perspectives are addressed.					
		Establishment and use of effective communication channels between local authorities and citizens for sharing information and updates on climate risks and adaptation measures.					

Building the capacity of personnel to address climate risks	To enhance the effectiveness and efficiency of disaster risk management and climate adaptation efforts. This objective aims to equip personnel with the latest knowledge, skills, and tools needed to understand, assess, and manage climate risks effectively.	A high percentage of personnel completing climate risk management and adaptation training programs.	Medium-term	Human Technology Finance	KMA	NADMO EPA CBOs NGOs Local Health Departments Academic and Research Institutions Private Sector Professional Training Organizations International Development Partners	
		Measurable improvements in the knowledge and skills of personnel, assessed through pre- and post-training evaluations.					
		Increased readiness and ability of personnel to respond to climate-related disasters, demonstrated through drills, simulations, and real-world responses.					
		Improved communication and coordination among departments and agencies involved in DRR, leading to more cohesive and efficient operations.					
		Development and implementation of robust institutional frameworks and processes for managing climate risks.					

Implementing measures to protect and restore ecosystems or vegetation	To enhance the resilience of natural and human systems to climate impacts. This objective aims to strengthen the ability of ecosystems to withstand and recover from climate-related stresses and disturbances.	A measurable increase in the area covered by vegetation, including reforested areas and restored habitats. Higher diversity of plant and animal species in restored ecosystems indicates a healthy and resilient environment. Improved provision of ecosystem services such as water regulation, soil stabilization, and carbon sequestration. Decrease in soil erosion rates, leading to better soil health and reduced sedimentation in water bodies.	Medium-term	Human Technology Finance	KMA	EPA Forestry Commission NADMO CBOs NGOs Academic and Research Institutions Private Sector International Development Partners	
Planting of trees along the banks of waterbodies in flood-prone areas	To reduce the risk and impact of flooding while enhancing the resilience of the local environment. This objective aims to:	A measurable decrease in the frequency and severity of flooding events in areas where trees have been planted. Reduced erosion and improved stability of riverbanks, as observed through regular monitoring and assessments. Enhanced water quality in nearby waterbodies, indicated by lower levels of pollutants and sediments. A significant increase in the area covered by trees and other vegetation along waterbodies.	Medium-term	Human Technology Finance	KMA	Forestry Commission EPA NADMO Local communities CBOs NGOs Academic and Research Institutions Private Sector International Development Partners	

Creation of green spaces	To enhance urban resilience and improve the quality of life for residents.	A measurable increase in the area covered by parks, gardens, and other green spaces within the metropolis. Lower temperatures in areas with newly created green spaces, as measured by temperature monitoring. Reduced instances of urban flooding and better stormwater absorption rates in areas with green spaces. Greater diversity of plant and animal species in urban green spaces, indicating healthier ecosystems.	Medium-term	Human Technology Finance	KMA	Parks and Gardens Department EPA NADMO CBOs NGOs Academic and Research Institutions Private Sector International Development Partners	
Developing and implementing early warning systems for extreme climate events	To enhance the preparedness and response capabilities of the community, thereby reducing the adverse impacts of extreme climate events.	The ability to issue warnings well in advance of extreme climate events, allowing sufficient time for preparation and response. High accuracy in predicting the occurrence, intensity, and impact of extreme climate events. Increased public awareness and understanding of early warning messages and the actions to take in response, measured through surveys and feedback.	Medium-term	Human Technology Finance	KMA	NADMO GMet EPA CBOs NGOs Academic and Research Institutions Media Organizations International Development partners	

Establishing community emergency response teams to counter basic disasters in the metropolis	To enhance local resilience and preparedness by empowering communities to effectively respond to and manage disasters	A significant increase in the number of community members trained in disaster response and emergency management. Reduced time taken for community emergency response teams to mobilize and respond to disasters. Regularly conducted and well-attended community preparedness drills and simulations.	Short term	Human Technology Finance	KMA	NADMO Local Health Departments CBOs NGOs Academic and Research Institutions Local Emergency Services (E.g., fire Departments) Private Sector International Development Partners	
Proper waste management	To reduce the vulnerability of communities to climate-related hazards. This involves improving waste management systems to prevent flooding, contamination, and other environmental issues that can be exacerbated by climate change.	A measurable decrease in the frequency and severity of flooding events, particularly in areas previously prone to such disasters due to poor waste management. Lower incidence of diseases related to poor waste management, such as cholera and malaria, indicates better sanitation and hygiene practices. Increased efficiency and coverage of waste collection services, with more waste being properly disposed of or recycled.	Short term	Human Technology Finance	KMA	EPA NGOs Waste management companies Private sector CBOs Academic and Research Institutions International Development Partners Public Health Agencies	

Constructing of rain gardens in flood-prone areas	To mitigate flooding and enhance water management. Rain gardens help absorb and filter stormwater runoff, reducing the volume and speed of water flow during heavy rains. This not only decreases the risk of flooding but also improves water quality by filtering pollutants.	A noticeable decrease in the frequency and severity of flooding events in areas where rain gardens have been implemented. Enhanced capacity to manage and absorb stormwater runoff, leading to reduced surface water accumulation during heavy rains. Better water quality in local water bodies due to the filtration of pollutants by rain gardens, resulting in lower levels of contaminants. Higher rates of groundwater recharge as rain gardens facilitate the infiltration of rainwater into the soil.	Medium term	Human Technology Finance	KMA	EPA NGOs Private Sector CBOs Academic and Research Institutions Public Health Agencies International Development Partners	
Enhancing the resilience of critical infrastructure to withstand extreme climate/ weather events	To ensure the continued functionality and safety of essential services and systems during and after such events. This involves strengthening the design, construction, and maintenance of infrastructure such as roads, bridges, hospitals, water supply systems, and power grids to make them more resistant to the impacts of extreme weather conditions like floods, storms, and heat waves.	A measurable decrease in the extent and frequency of damage to critical infrastructure during extreme weather events. The ability to maintain uninterrupted services such as electricity, water supply, healthcare, and transportation during and after extreme weather events. Faster restoration of services and infrastructure functionality following extreme weather events, minimizing downtime and disruption.	Long term	Human Technology Finance	KMA	Engineering and construction firms Utility Companies Academic and Research Institutions NGOs International Development Partners CBOs Public Health Agencies	

Adherence to building codes	To ensure that all new and existing buildings are designed, constructed, and maintained to withstand the impacts of extreme climate and weather events.	High levels of compliance with updated building codes and regulations among new and existing buildings.	Medium-term	Human Technology Finance	KMA	Building and Construction Regulatory Bodies Ministry of Works and Housing Engineering and Architectural Firms	
		A measurable decrease in the extent and frequency of damage to buildings during extreme weather events indicates that structures are more resilient.					
		Lower incidence of injuries and fatalities related to building failures during climate-related disasters.				Real Estate Developers Academic and Research Institutions NGOs	
		Increased frequency and thoroughness of building inspections, along with effective enforcement of building codes.					
Desilting	To reduce the risk of flooding and improve water flow in rivers, streams, and drainage systems. Desilting involves removing accumulated silt, debris, and other materials from water bodies and drainage channels to restore their capacity and functionality.	A measurable decrease in the frequency and severity of flooding events in areas where desilting has been carried out.	Short term	Human Technology Finance	KMA	National Government Agencies EPA Engineering and construction firms CBOs NGOs Academic and Research Institutions Public Health Agencies	
		Enhanced flow capacity of rivers, streams, and drainage systems, leading to better management of stormwater and reduced risk of overflow.					
		Higher efficiency of drainage systems in quickly and effectively channeling water away from urban areas during heavy rainfall.					

Establishing bioswales to capture stormwater runoff	To manage and mitigate the impacts of heavy rainfall and reduce the risk of flooding. Bioswales are designed to capture, filter, and slowly release stormwater, thereby reducing the volume and speed of runoff entering drainage systems and water bodies.	A noticeable decrease in the frequency and severity of flooding events in areas where bioswales have been implemented.	Medium-term	Human Technology Finance	KMA	EPA Engineering and Landscaping Firms CBOs NGOs Ministry of Sanitation and Water Resources MESTI Ministry of Works and Housing Ministry of Local Government, Decentralization and Rural Development	
		Enhanced capacity to manage and absorb stormwater runoff, leading to reduced surface water accumulation during heavy rains.					
		Better water quality in local water bodies due to the filtration of pollutants by bioswales, resulting in lower levels of contaminants.					
		Higher rates of groundwater recharge as bioswales facilitate the infiltration of rainwater into the soil.					
		Increased presence of native plant species and wildlife in urban areas, contributing to greater urban biodiversity.					

9 Framework for Adaptation Monitoring, Evaluation, and Learning

Monitoring, evaluation, and learning (MEL) are crucial for effective adaptation actions in the Kumasi Metropolis for several reasons:

- **Tracking Progress:** MEL systems help in continuously tracking the progress of adaptation actions, ensuring that they are on course to meet their objectives (European Environment Agency, 2024).
- **Assessing Effectiveness:** By evaluating the outcomes of adaptation measures, MEL allows for an assessment of what works, what doesn't, and why. This helps in refining strategies to enhance their effectiveness.
- **Informed Decision-Making:** The insights gained from MEL activities provide valuable information that can guide future planning and decision-making processes. This ensures that adaptation actions are based on evidence and are more likely to succeed (NAP Global Network, 2024).
- **Learning and Improvement:** MEL fosters a culture of learning within the adaptation planning process. By understanding the successes and challenges of past actions, the Kumasi Metropolitan Assembly can continuously improve its strategies and interventions.
- **Resource Optimization**: Effective MEL helps in identifying the most efficient use of resources, ensuring that investments in adaptation actions yield the best possible outcomes.
- **Stakeholder Engagement:** MEL processes often involve various stakeholders, including local communities, which helps in building trust and ensuring that adaptation actions are inclusive and address the needs of all affected groups.
- **Accountability and Transparency:** Regular monitoring and evaluation promote accountability and transparency in the implementation of adaptation actions, which is essential for maintaining public trust and securing ongoing support.

9.1 Building on Existing Structures to Facilitate Mainstreaming

MEL can build on existing structures to facilitate mainstreaming in the KMA in several ways. For instance, the KMA can integrate MEL processes into its current data collection and management systems. This ensures that adaptation actions are informed by accurate and up-to-date information, enhancing decision-making and resource allocation. By building on existing institutional frameworks, MEL can enhance the capacity of KMA staff through training and capacity-building initiatives. This helps in developing a skilled workforce capable of effectively implementing and monitoring adaptation actions. MEL can facilitate better coordination among various departments and stakeholders within KMA. By using existing communication channels and collaborative platforms, MEL can ensure that all relevant parties are engaged and informed about adaptation efforts. KMA can incorporate MEL into its established reporting mechanisms, such as annual progress reports

and development plans. This integration ensures that adaptation actions are regularly reviewed and adjusted based on performance and feedback. MEL can build on existing community engagement structures to involve local communities in the adaptation planning process. This ensures that adaptation actions are inclusive and address the needs and priorities of the residents. By using existing knowledge-sharing platforms, MEL can promote the dissemination of best practices and lessons learned from adaptation actions. This helps in creating a culture of continuous learning and improvement within KMA. By integrating MEL into existing structures, KMA can ensure that adaptation actions are effectively mainstreamed, leading to more resilient and sustainable urban development.

9.2 MEL Design

MEL in the KMA is designed to achieve several key climate change adaptation objectives:

- **Enhancing Resilience:** MEL helps to ensure that adaptation actions effectively enhance the resilience of infrastructure, communities, and ecosystems to climate impacts.
- **Informed Decision-Making:** By providing continuous feedback on the effectiveness of adaptation measures, MEL supports informed decision-making and the adjustment of strategies based on real-time data and outcomes.
- **Resource Optimization:** MEL ensures that resources are used efficiently by identifying the most effective adaptation actions and reallocating resources to areas where they are most needed.
- **Stakeholder Engagement:** MEL facilitates the involvement of various stakeholders, including local communities, in the adaptation planning process, ensuring that actions are inclusive and address the needs of all affected groups.
- **Accountability and Transparency:** Regular monitoring and evaluation promote accountability and transparency in the implementation of adaptation actions, which is essential for maintaining public trust and securing ongoing support.
- **Continuous Improvement:** MEL fosters a culture of learning and continuous improvement, allowing KMA to refine and enhance its adaptation strategies over time based on lessons learned.

By achieving these objectives, MEL helps KMA to effectively mainstream climate change adaptation into its development agenda, ensuring sustainable and resilient urban growth. Implementing the adaptation MEL system necessitates deliberately incorporating climate adaptation considerations into municipal development plans and policies, such as the MTDP, and aligning them with the current monitoring and evaluation framework.

Table 24: Outline of approach to MEL of KMA's adaptation actions

Steps	Indicative activities—to be led by the KMA Planning Coordination Unit
1. Monitoring the adaptation actions	• Identify adaptation activities that will be monitored through qualitative and quantitative performance measures to determine progress made toward the adaptation objective(s). • Define metrics and indicators for documenting progress for the adaptation activities identified for monitoring. • Collect information on the metrics and indicators throughout the adaptation process.

2. Reviewing the adaptation process to assess progress, effectiveness, and gaps – Evaluation	• Determine the means for measuring and communicating levels of effectiveness and assessing gaps. • Gather and combine insights from recent studies and new scientific developments, along with feedback and results from current adaptation efforts. This process is essential for evaluating and modernizing the approach or strategy in question. • Revise the adaptation activities using evaluation information and metrics.
3. Iteratively updating the NAP – Learning	• Update the adaptation activities based on the information collected. • Document key lessons of what worked and what did not. • Establish a basis of success and/or failure. • Implement remedial measures. • Align learning and correctional measures with broader targets within the KMA MTDP.
Steps	**Indicative activities—to be led by the KMA Municipal Planning Coordination Unit**
4. Communication Report progress, process effectiveness, outreach, and knowledge and information dissemination	• Disseminate adaptation documents and learning products. • Provide information in the KMA annual progress report on the progress and effectiveness of the adaptation process.

Source: Adapted (and modified) from the Government of Liberia's four-step approach to the MEL of its NAP. See Environmental Protection Agency, Republic of Liberia, 2022.

10 Conclusion and Recommendations

10.1 Future Climate Change Scenarios for Kumasi Metropolitan Assembly

According to climate projections, KMA is expected to experience a significant increase in mean annual temperatures. By 2065, the projected average temperature is estimated to peak at approximately 1.80°C higher than the reference period (1995-2014)(The World Bank, 2021). This warming trend could lead to more frequent and severe heatwaves, creating health risks for vulnerable populations and placing additional stress on energy grids struggling to meet increased cooling demands. Rainfall patterns in Kumasi are expected to become more erratic under climate change. While the total annual rainfall might not change significantly, the distribution is likely to shift. Droughts could become more frequent and intense, with longer dry spells punctuated by sudden, heavy downpours. This variability would strain water supplies, impacting everything from household use to agriculture.

10.2 Priority Climate-Related Hazards and Risks

The top climate-related hazards and risks facing Kumasi Metropolis identified are:

- **Flooding:** Studies have shown a worrying rise in the frequency and intensity of floods in Kumasi, likely linked to climate change and exacerbated by local factors like poor waste management and blocked drainage (Antwi-Agyei et al., 2023). These floods cause damage to property and infrastructure, and can even displace residents and lead to health problems.
- **Droughts and Water Scarcity:** While total rainfall might not change drastically, predictions suggest a shift towards erratic patterns with longer dry periods interspersed with heavy downpours. This disrupts water availability, impacting everything from household use to agriculture. As temperatures rise, evaporation rates will also increase, further straining water resources.
- **Heatwaves:** Rising temperatures are a major concern. Increased frequency and severity of heat waves pose health risks, especially for vulnerable populations like children and the elderly. The urban heat island effect, intensified by reduced green spaces, can further worsen these conditions.

10.3 Climate Change Risk Assessment Results

Based on the stakeholders' engagement and review of the future climate scenarios, the following impacts on socioeconomic sectors were developed for the priority hazards and risks identified above:

Gender

Women often bear primary responsibility for water collection and securing food for their families. Erratic rainfall patterns and water scarcity could significantly increase this burden. Heatwaves and malnutrition due to decreased agricultural productivity could disproportionately impact pregnant women and girls. Disruptions caused by climate events like floods can increase competition for resources and heighten tensions, potentially leading to an increase in gender-based violence.

Health

Floods and inadequate sanitation can contaminate water sources, increasing the risk of diarrhoeal diseases and other waterborne illnesses. Rising temperatures and heatwaves can lead to heatstroke, and dehydration, and exacerbate pre-existing health conditions, particularly among vulnerable populations like children and the elderly. Dust storms associated with droughts can worsen air quality, triggering respiratory problems like asthma.

Agriculture

Changes in rainfall patterns and increased temperatures can negatively impact crop yields, leading to food insecurity. Droughts and heat stress can harm livestock populations, affecting livelihoods and food security. Farmers may struggle to adapt to changing weather patterns and extreme events, requiring new skills and technologies.

Disaster

Heavy downpours, coupled with poor drainage, can lead to more frequent and destructive floods. These events can cause loss of life, damage to infrastructure, and displacement of residents. Informal settlements and inadequate infrastructure can make communities more vulnerable to the impacts of disasters. More frequent and severe climate events could overwhelm emergency response capacities.

Water

Erratic rainfall and increased evaporation rates will likely lead to water scarcity, impacting households, agriculture, and industry. Floods can contaminate water sources with sewage and other pollutants. Droughts can also lead to increased salinity in groundwater sources. Competition for limited water resources could increase between different sectors, potentially leading to conflict.

Sanitation

Increased flooding can overwhelm sanitation systems, leading to overflowing sewage and increased health risks. Water scarcity can make it difficult for people to maintain proper hygiene practices, increasing the risk of disease outbreaks. Floods and extreme weather events can damage sanitation infrastructure, further compromising sanitation services.

10.4 Adaptation Action Plan for the KMA

The Adaptation Action Plan for the KMA represents a comprehensive and collaborative effort to address the multifaceted challenges posed by climate change. By engaging sector stakeholders across agriculture, gender, trade, water and sanitation, health, and disaster risk reduction, the plan ensures that adaptation actions are both inclusive and targeted. Prioritizing sustainable farming practices, enhancing biodiversity, and promoting drought-resistant crops will help restore degraded ecosystems and improve food security. Investing in gender-sensitive agroforestry, supporting vulnerable groups, and promoting women-led businesses will foster gender equity and economic resilience. Implementing green financing, fostering public-private partnerships, and enhancing climate resilience strategies will support sustainable economic growth. Planting trees along waterways, enforcing anti-pollution by-laws, and investing in infrastructure will safeguard water resources and improve sanitation. Integrating climate risks into health policies, installing solar energy in health facilities, and raising community awareness will enhance public health resilience. Incorporating climate adaptation into development planning, involving citizens in risk assessment, and building capacity will strengthen the metropolis's ability to manage climate risks. The framework for adaptation monitoring, evaluation, and learning

will ensure that the plan remains dynamic and responsive to emerging challenges, fostering a resilient and sustainable future for Kumasi. This holistic approach not only addresses immediate climate impacts but also builds long-term resilience across all sectors.

10.5 Recommendations

The Ghanaian government has recognized the threat of climate change and taken steps towards adaptation in various socioeconomic sectors. For instance, in terms of national initiatives, Ghana has established a National Climate Change Policy (NCCP) and National Climate Change Adaptation Strategy (NCCAS) that emphasize adaptation across sectors. The NCCP encourages gender-responsive adaptation strategies to ensure women's needs are addressed. The National Disaster Management Organization (NADMO) coordinates disaster preparedness and response efforts.

Recommendations for KMA

- **Localized Action Plans:** KMA can develop a city-specific climate change adaptation plan based on the national framework, focusing on the city's unique vulnerabilities.
- **Gender-Specific Programmes:** Design programs that empower women in agriculture through access to drought-resistant crops, training, and financial resources. Partner with women's groups for community outreach and education.
- **Strengthen Early Warning Systems:** Implement robust weather forecasting and early warning systems to alert communities about floods and droughts, allowing them to prepare and mitigate impacts.

General Recommendations for Kumasi Metropolis:

- **Local Adaptation Planning:** Involve stakeholders in climate planning processes. Design context-relevant, inclusive, and sustainable adaptation strategies.
- **Capacity Building:** Strengthen local institutions and communities to implement climate adaptation measures effectively.
- **Research and Data:** Invest in climate research, monitoring, and data collection specific to Kumasi's needs.
- **Community Awareness:** Educate residents about climate risks and adaptation options.
- **Ecosystem-Based Approaches:** Promote green infrastructure, urban forests, and sustainable land use practices.
- **Funding:** Explore innovative financing mechanisms like public-private partnerships and climate finance initiatives to support adaptation efforts.

By building on Ghana's national framework and implementing targeted adaptation strategies, KMA can become more resilient to the impacts of climate change and ensure a sustainable future for its citizens.

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Appendix C: Kumasi Metropolitan Assembly: Risk Description and Proposed Adaptation Measures

Sectors	Risks	Adaptation measures	Assessment of the impact of proposed actions	Supporting policies/laws or measure
Agriculture	Heat and water stress have led to decreased productivity and reduced crop yields. Climate changes have affected the onset and length of growing seasons. Floods, droughts, and erratic rains cause direct damage to crops. Fluctuations in agricultural productivity have led to increased food prices. There is an increased risk of crop diseases and pest infestations due to changing weather patterns.	**Policy/Institutional/Social Measures** -Encourage farmers to explore alternative income-generating activities. -Provide farmers with knowledge and skills to adapt to climate change. Farmers are advised to adjust farming schedules to better align with changing climate patterns. -Support agribusiness development and diversify farmer income sources. **Nature Based Solution (NBS)** -Adopt farming practices that restore ecosystems and enhance biodiversity. -Promoting small-scale farms within the Kumasi city limits, utilizing vertical gardening techniques and incorporating native, drought-resistant plants. Integrated Pest Management practices like using beneficial insects and natural pesticides can reduce reliance on chemical controls and protect pollinators. **Technological measure** -Invest in climate-resilient infrastructure. -Introduce seed varieties that can tolerate drier conditions and fight off disease to farmers. -Disseminate appropriate improved technology and provide technical services to farmers. -Encouraging the adoption of drip irrigation or sprinkler systems can significantly improve water efficiency in Kumasi's farms. These deliver water directly to the plant roots, minimizing waste and maximizing crop yields even during dry periods. This can help farmers adapt to changing weather patterns and reduce reliance on unpredictable rainfall.	The adaptation measures aim to enhance the resilience of the agricultural sector to climate variability and extreme weather events. By adopting drought-resistant crops and modernizing agricultural production, farmers can maintain or even improve crop yields despite changing climatic conditions. Diversification into other businesses and investing in climate-resilient infrastructure can provide socio-economic benefits and reduce vulnerability to climate-induced shocks. Practices such as regenerative agriculture and small-scale aquaculture promote environmental sustainability and biodiversity, which are crucial for long-term agricultural success. Education and training initiatives are critical for equipping farmers with the necessary skills to implement and benefit from these adaptation strategies.	-Planting for Food and Jobs (PFJ) -Ghana Commercial Agriculture Project (GCAP) Cocoa Sector - Development Strategy -Food and Agriculture Sector Development Policy (FASDEP II): -National Climate-Smart Agriculture and Food Security Action Plan

Sectors	Risks	Adaptation measures	Assessment of the impact of proposed actions	Supporting policies/laws or measure
Health	Changes in rainfall have led to water scarcity, affecting clean water supply and sanitation, which are crucial for maintaining health standards in the metropolis. Rising temperatures have exacerbated heat-related illnesses and affected the spread of temperature-sensitive diseases including headaches, dizziness, weakness, cramping, or nausea in hot environments. Floods have led to displacement, waterborne diseases (e.g., malaria, cholera, and typhoid fever), and challenges in healthcare delivery in the metropolis. Seasonal variations in the air quality of the metropolis have also impacted respiratory health.	**Nature-Based Solutions (NBS)** -Establishing medicinal gardens near healthcare facilities or within communities can provide a readily available source of locally adapted medicinal plants. **Technological/Engineering Measures** -Investing in solar power systems for health clinics and hospitals in Kumasi can ensure a reliable source of electricity for critical medical equipment during power outages. -Enhance public health systems to cope with climate-related diseases and conditions, including improving surveillance and response to disease outbreaks. -Promote climate-smart healthcare practices, such as using renewable energy sources for health facilities and reducing carbon footprints. **Policy/Institutional/Social Measures** -Train health workers to deal with climate risks and integrate climate change into health professionals' education. -Community engagement and awareness programs to educate the public on climate change impacts on health and preventive measures. -Develop and implement a national strategy for mainstreaming climate change risks into health sector policies and measures.	These measures are crucial for building climate-resilient health systems that can withstand the impacts of climate change and protect public health. The interventions will also help to promote resilience against both climatic and infectious threats, which can also strengthen primary healthcare more broadly in the metropolis. Implementing integrated risk monitoring and early warning systems will capacitate the health workforce to respond effectively to climate-related health risks.	-Ghana National Climate Change Policy -National Climate Change Adaptation Strategy - Ghana's Adaptation Communication to the United Nations Framework Convention on Climate Change.

Sectors	Risks	Adaptation measures	Assessment of the impact of proposed actions	Supporting policies/laws or measure
Disaster risk reduction (DRR)	Essential infrastructure such as roads, bridges, and buildings have been at risk due to extreme weather events including floods, affecting both emergency response capabilities and the resilience of the communities in the metropolis. The loss of biodiversity and ecosystem services due to climate change has increased the vulnerability of the people in the metropolis to natural disasters and reduced the natural buffering capacity against such events. Heavy rainfall leading to flooding, as well as prolonged dry periods resulting in droughts. have strained the capacity of the DRR sector to respond effectively.	**Nature-Based Solutions (NBS)** -Implement measures to protect and restore ecosystems that provide natural buffers against climate impacts, such as re-vegetation of degraded lands and enforcement of buffer strips. -The KMA can leverage the natural benefits of vegetation by creating green spaces strategically placed throughout the city. This could involve planting trees along waterways, constructing rain gardens in flood-prone areas, and establishing bioswales (ditches with vegetation) to capture and filter stormwater runoff. **Technological/Engineering Measures** -Develop and implement early warning systems to alert communities of impending extreme weather events. -Investing in an early warning system tailored for Kumasi's specific climate risks. This system would utilize weather monitoring stations, rain gauges, and river level sensors to detect potential floods, heat waves, or landslides. Disseminating real-time alerts via SMS, radio, and community loudspeakers allows residents to take preventative measures and reduces the impact of disasters. -Enhance the resilience of critical infrastructure to withstand extreme weather events through both soft interventions, like changing maintenance schedules based on vulnerability and risk assessments, and structural measures. **Policy/Institutional/Social Measures** Involve local communities in risk assessment and planning processes, and build their capacity to respond to and recover from climate-related disasters. Integrate DRR and climate change adaptation into development planning and governance to ensure cohesive action towards risk-informed development. The KMA in collaboration with local NGOs and community leaders, can organize training programs on disaster preparedness. These programs can educate residents on identifying early warning signs, creating emergency plans, and preparing emergency kits. Additionally, establishing Community Emergency Response Teams (CERTs) can equip residents with basic disaster response skills and promote a culture of preparedness within communities.	Involving stakeholders, including local communities, in the assessment process will ensure that the measures meet the needs of those most affected by climate change in the metropolis. The adaptation measures will also reduce the vulnerabilities of the populace in the metropolis and enhance their resilience against climate-related disasters. Overall, the assessment would aim to ensure that the proposed actions are not only theoretically sound but also practically viable and beneficial for the Kumasi Metropolis in the face of climate change challenges.	-National Climate Change Adaptation Strategy -Ghana National Climate Change Policy

Sectors	Risks	Adaptation measures	Assessment of the impact of proposed actions	Supporting policies/laws or measure
		Policy/Institutional/Social Measures -Involve local communities in risk assessment and planning processes, and build their capacity to respond to and recover from climate-related disasters. -Integrate DRR and climate change adaptation into development planning and governance to ensure cohesive action towards risk-informed development. -Additionally, establishing Community Emergency Response Teams (CERTs) can equip residents with basic disaster response skills and promote a culture of preparedness within communities.		

Sectors	Risks	Adaptation measures	Assessment of the impact of proposed actions	Supporting policies/laws or measure
Water and Sanitation	Increased demand for water in the metropolis due to low rainfall during dry seasons causes water sources, including boreholes and springs, to run dry. Heavy rainfall and flooding damage water sources and sanitation facilities, carry the runoff and waste into streams and rivers and contaminate the water supply. The unplanned urban expansion in Kumasi metropolis is leading to the destruction of two rivers – Subin and Wiwi – through sewage, heavy metals, and chemical pollution. This pollution affects the quality of water resources and poses health risks. Climate change leads to more frequent and severe weather events that tend to damage water and sanitation infrastructure, leading to service disruptions in the metropolis. The contamination of water bodies due to encroachment and pollution increases the risk of waterborne diseases, which can be exacerbated by climate change effects.	**Nature-Based Solutions (NBS)** -Encouraging citizens to plant more trees and possibly unseal their residential landscapes can minimize the risk of floods and extreme heat while providing ecosystem services. -Tree Planting: The Kumasi Metropolitan Assembly has been involved in planting various species of trees to help clean the environment by absorbing harmful gases and mitigating global warming effects. -The KMA can explore utilizing constructed wetlands for wastewater treatment, particularly in peri-urban areas. These engineered systems mimic natural wetlands by using plants and microbial communities to filter and purify wastewater. **Technological/Engineering Measures** -Implementing rainwater harvesting systems and promoting water conservation practices can help mitigate water scarcity during dry periods. -Upgrading and maintaining drainage infrastructure can reduce the impact of flooding on water and sanitation systems. -Building resilient water and sanitation infrastructure that can withstand extreme weather events is essential for ensuring continuous service delivery. **Policy/Institutional/Social Measures** Enforcing regulations to prevent industrial and residential waste from contaminating water bodies is crucial. Initiatives like recycling human waste and containing urban sprawl can help maintain water quality.	Enhancing water storage and conservation measures, such as rainwater harvesting, can help ensure a more reliable water supply during periods of low rainfall, thus improving water security. Upgrading drainage systems can mitigate the impact of flooding on water and sanitation infrastructure, reducing the risk of waterborne diseases and property damage. Pollution control measures can lead to improved water quality by preventing industrial and residential waste from contaminating water bodies. Building resilient water and sanitation infrastructure can withstand extreme weather events, ensuring continuous service delivery and reducing the need for costly repairs and replacements. By securing water quality and availability, the adaptation measures can contribute to better public health outcomes, reducing the incidence of water-related diseases. Community engagement in tree planting and other eco-friendly practices can foster a sense of ownership and responsibility towards local environmental resources. These measures can contribute to the achievement of Sustainable Development Goals by providing clean water and sanitation, promoting sustainable cities, and combating climate change impacts	- Ghana's Adaptation Communication to the United Nations Framework Convention on Climate Change. - Climate Governance in Ghana - National Climate Change Adaptation Strategy. - Ghana National Climate Change Policy. - Climate Governance in Ghana - National Community Water and Sanitation Programme (NCWSP) -National Water Policy

Sectors	Risks	Adaptation measures	Assessment of the impact of proposed actions	Supporting policies/laws or measure
Gender	Women, who often play a significant role in agriculture, face reduced crop yields due to changing weather patterns, affecting food security and income in the metropolis. Climate change can lead to food scarcity, impacting nutrition, especially for women and children who may already be vulnerable to malnutrition. Climate changes can lead to an increase in climate-sensitive diseases, which can disproportionately affect women, particularly those who are pregnant or responsible for caring for the sick. Women are typically responsible for water collection and may have to travel longer distances as water sources become scarce. Additionally, energy needs may increase for heating or cooling, impacting household budgets. Women may be more vulnerable during disasters due to social roles and norms. They also face higher risks during migration which can be exacerbated by climate change.	**Nature-Based Solutions (NBS)** -Empowering women through participation in tree planting programs and sustainable agroforestry projects can address climate challenges and promote gender equality. Women can be trained in selecting and planting drought-resistant trees or establishing community fruit tree orchards into existing farming practices. This improves food security, provides income-generating opportunities for women, and creates a more sustainable urban environment. **Technological/Engineering Measures** -Installing solar-powered mobile phone charging stations within markets can ensure uninterrupted access to communication and financial services during power outages. This not only empowers women entrepreneurs but also promotes economic activity and financial inclusion. **Policy/Institutional/Social Measures** Many small business owners in Kumasi, particularly women, rely on mobile phones for communication and mobile money transactions -Developing and implementing frameworks for analysis, policy, and action that specifically address gender disparities and strengthen the resilience of women to climate change impacts in the metropolis. -Enhancing the capacity for gender-disaggregated data collection and conducting gender analysis during the planning stages of adaptation plans. -Ensuring equitable representation of women in decision-making spaces related to climate change adaptation. -Empowering women's groups and recognizing women as agents of change and innovation, rather than merely victims of climate change. -Implementing local and community-based projects that take into account the specific needs and roles of women and the vulnerable. -Incorporating gender-specific indicators in monitoring and evaluation processes to assess the effectiveness of adaptation measures.	By addressing gender disparities and strengthening the resilience of women in the metropolis to climate change impacts, these measures can help reduce vulnerability and enhance the capacity of women to cope with adverse conditions. Initiatives that focus on agricultural production, food and nutrition security, and access to water and energy can improve the livelihoods of women, who often bear the brunt of climate change impacts. Measures that mitigate climate-sensitive diseases can lead to better health outcomes for women, who are typically responsible for caring for the sick and are more vulnerable to health-related impacts. By promoting gender equality in access to resources, technology, and information, adaptation measures can empower women economically and increase their participation in climate-resilient practices. Inclusive decision-making and community-based projects that consider the specific needs and roles of women can promote social equity and ensure that the benefits of adaptation measures are distributed fairly. Gender-responsive adaptation measures contribute to sustainable development by ensuring that climate actions are equitable and inclusive, leading to long-lasting and efficient policies.	- Ghana National Climate Change Policy - Ghana's Nationally Determined Contributions (NDCs) -National Gender Policy