Adapting Together, Thriving Tomorrow

Climate Change Rapid Risk Assessment in Keta Municipal Assembly (KeMA) in Ghana

Enhancing multi-sector planning and capacity for effective adaptation in Ghana

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Document Information

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List of Abbreviations

Acronym	Expanded Form
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
MCDM	Multi Criteria 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

1 Introduction

1.1 Background

Climate change currently dominates international discussions as increasingly many countries around the world continue to experience its brutish impacts on development processes. This is particularly critical for sub-Saharan Africa countries whose economies depend heavily on climate sensitive sectors including agriculture (Intergovernmental Panel on Climate Change (IPCC), 2022). Ghana continues to experience is disruptive climate change impacts in key climate-sensitive sectors and sustainable development processes. The country has experienced increases in temperature, erratic rainfall, floods, and more extreme weather events, which all manifest in different ways in diverse places with worsening impacts (Asante and Amankwa-Mensah, 2015). This could compromise the attainment of sustainable development goals in the country. This calls for an urgent need for carefully considered and place-responsive adaptation measures.

As climate change impacts become even more pervasive in key economic sectors such as agriculture, fisheries, forestry, water resources, mining, health, and many others, the extent and spread of risks and vulnerabilities are also increasing requiring that intentional and purposeful steps are taken to explore such risks and to put in place adaptation measures that respond proactively to both current and projected future impacts.

As awareness of impacts continues to grow across Ghana, and as efforts intensify to ensure adaptation to the complexities of climate change phenomenon, it has also become urgently important that conscious efforts are made to understand the nature of impacts and how such impacts translate into risks and vulnerabilities. Effective climate adaptation in Ghana will therefore mean an intentional assessment of risks and vulnerabilities across sectors and places and the deliberate use of such insights and understandings to drive adaptation planning at both national and sub-national levels and in key climate-sensitive sectors.

Effective adaptation also calls for a gender responsive approach to ensure that the needs of different socioeconomic groups including the most vulnerable in society such as women, children, differently abled persons and the elderly are taken into consideration. This is especially so because different socioeconomic groups are impacted differently by climate change risks. It is widely acknowledged that women are more vulnerable to the threats of climate change due largely to their limited control over the productive assets that could help them to address the threats posed by climate change (Antwi-Agyei et al., 2015). Cultural norms defined along biological lines have limited the roles played by women in co-management of resources, leadership and in decision making, thus increasing their vulnerabilities (Okyere-Nyako & Nsiah, 2016). Ghana's National Adaptation Plan (NAP) Framework stipulates that, the NAP process should adopt a gender-responsive approach in addressing the threats of climate change.

Effective and proactive climate change adaptation planning is therefore a learning issue and one that requires a conscious process to uncover impacts and to assess associated risks and vulnerabilities (Manteaw, 2020). Central to identifying, assessing, and appreciating the nature and distribution of climate risks is the ability to understand the science and signs behind changing climatic conditions and the varying impacts of such changes on people, communities, and sectors. Such knowledge and understanding, once obtained, become

the basis to address uncertainties as well as to make bold and evidence-based predictions about the future. It also becomes the premise for adaptation planning and actionable adaptation decision-making (Manteaw et al, 2022).

Ultimately, therefore, adaptation planning and resilience building against climate change impacts should be premised on knowledge development and deeper understanding of climate impact manifestations and associated risks and vulnerabilities in diverse places and sectors. Such knowledge should also form the basis of capacity building processes that ensure effective climate adaptation governance are aimed at building the requisite adaptive capacities in diverse sectors, communities and at multi levels. Ghana's National Adaptation Planning (NAP) process has been initiated to respond to these needs and to also ensure that climate adaptation imperatives are mainstreamed in governance processes at different levels.

1.2 Project Background

The National Adaptation Plan (NAP) process emerged from the 16th Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in Cancun in 2010, where Parties affirmed that "adaptation must be addressed with the same priority as mitigation" (UNFCCC, 2010, p.3). The Cancun Adaptation Framework established a national adaptation planning process to identify medium- and long-term adaptation needs and to develop and implement strategies and programs to address those needs. Guided by this frame, countries around the world are putting in place programs to advance their NAP processes, taking steps to assess development needs and climate vulnerabilities, analyze current climate and future scenarios and review and appraise adaptation options while making conscious effort to communicate or sharing learnings with stakeholders.

The goal is to integrate adaptation into policies and plans for climate-sensitive sectors, such as agriculture, water, health, energy, ecosystems, etc. Most developing countries have also included adaptation within their Nationally Determined Contributions (NDCs) under the Paris Agreement. The Paris Agreement (2015) in its global goal on adaptation (Article 7) brought new elements and dimensions to the climate change adaptation discussions. Namely, enhancing adaptive capacity, strengthening resilience, and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the global temperature limit of less than 2°C. The UNFCCC's Least Developed Expert Group (LEG) on adaptation released Guidelines for National Adaptation Plans (December 2012).

The Government of Ghana, through the Environmental Protection Agency (EPA), under the auspices of the Ministry of Environment, Science, Technology, and Innovation (MESTI), is currently implementing a 3-year Green Climate Fund's (GCF) Readiness Project on National Adaptation Plans (NAPs) to build capacity to advance adaptation planning in Ghana. The UN Environment is the Delivery Partner for the project, with the role of supporting and overseeing the project implementation. As part of this process, the government of Ghana, working with development partners, have initiated various efforts to identify, quantify and understand the mediating effects of both current and future climate change impacts and to respond with the appropriate adaptation measures. Ghana's NAP, which is the vehicle for adaptation planning and mainstreaming at both national and sub-national levels, has adopted a district-focused adaptation planning process which uses district level risk and vulnerability assessments to ground adaptation planning for districts and key climate sensitive sectors, with appropriate gender responsive adaptation measures.

A central objective, as specified in Ghana's NAP Framework (Antwi-Agyei, 2018), is to reduce vulnerability to adverse impacts of climate change by building adaptive capacity and resilience in local communities. And to achieve this, the Ghana NAP process and indeed this project are both premised on the fact that adaptation impacts are not homogeneous; they are place and context-specific with different impact on different gender

groups and that there is the need for planning processes to be place-based,context-responsive and gender responsive.

The intention therefore is to develop standalone costed district or municipal adaptation plans for all 261 Assemblies constituting Ghana's local governance system. Eight districts have already completed climate risks and vulnerability assessments (six financed by the IISD and two by UNEP) and are currently in the process of completing adaptation plans.

This project financed by the UNEP is an advancement of the NAP process and a part of a broader vertical integration process that uses place, or district-based climate risk and vulnerability assessment as starting point to co-create knowledge to address uncertainties, build capacity, as well as mainstream climate change considerations in policy and development decision-making processes at the sub-national level. Complementing the district-specific risk and vulnerability assessments, and as part of this project is a prioritized sector-specific risks and vulnerabilities assessment to inform the development of adaptation plans for four critical and prioritized sectors in Ghana's sustainable development processes. While the intention is to develop standalone costed adaptation plans for both districts and the four prioritized sectors key climate-sensitive sectors, the different adaptation plans will be consolidated into a composite costed national adaptation plan.

1.3 Study Aims and Objectives

This study is part of the project "Enhancing multi-sector planning and capacity for effective adaptation in Ghana" which seeks to

- To conduct rapid climate risk assessments in 8 districts in Ghana.
- To develop costed adaptation plans for ten (10) districts in Ghana.
- To Develop four (4) prioritized sectoral Adaptation Plans.
- Complete a composite national cost adaptation plan that incorporates the four sectoral adaptation plans.
- Provide Training for staff from twenty (20) Districts and municipal Assemblies in Adaptation Mainstreaming

1.4 Document Purpose

This Climate Change Risk Assessment (CCRA) for KeMA is designed to identify, analyze, and prioritize climate-related risks within the Keta Municipal. The primary purpose of this document is to guide local experts and stakeholders through a systematic evaluation of the district's climate risks to climate change impacts, emphasizing the integration of hazard, exposure, and vulnerability components as per the AR5 framework adopted from the IPCC. Specifically, the document through this assessment aims to:

1. **Provide a Comprehensive Overview of Climate Risks:** To capture a detailed picture of the climate hazards specific to KeMA, including their current and potential future impacts on people, livelihoods, and ecosystems. This entails a rapid but thorough collection of information that informs adaptation planning and decision-making processes.
2. **Enhance Understanding of Vulnerabilities:** To deepen the understanding of the district's vulnerabilities, considering varied gender situations and the multifaceted nature of climate risks that affect social, economic, and environmental dimensions.

3. **Support Adaptation Planning:** To offer a foundational basis for developing targeted and effective adaptation strategies and measures that address the prioritized risks, thereby strengthening the resilience of the KeMA to climate change.

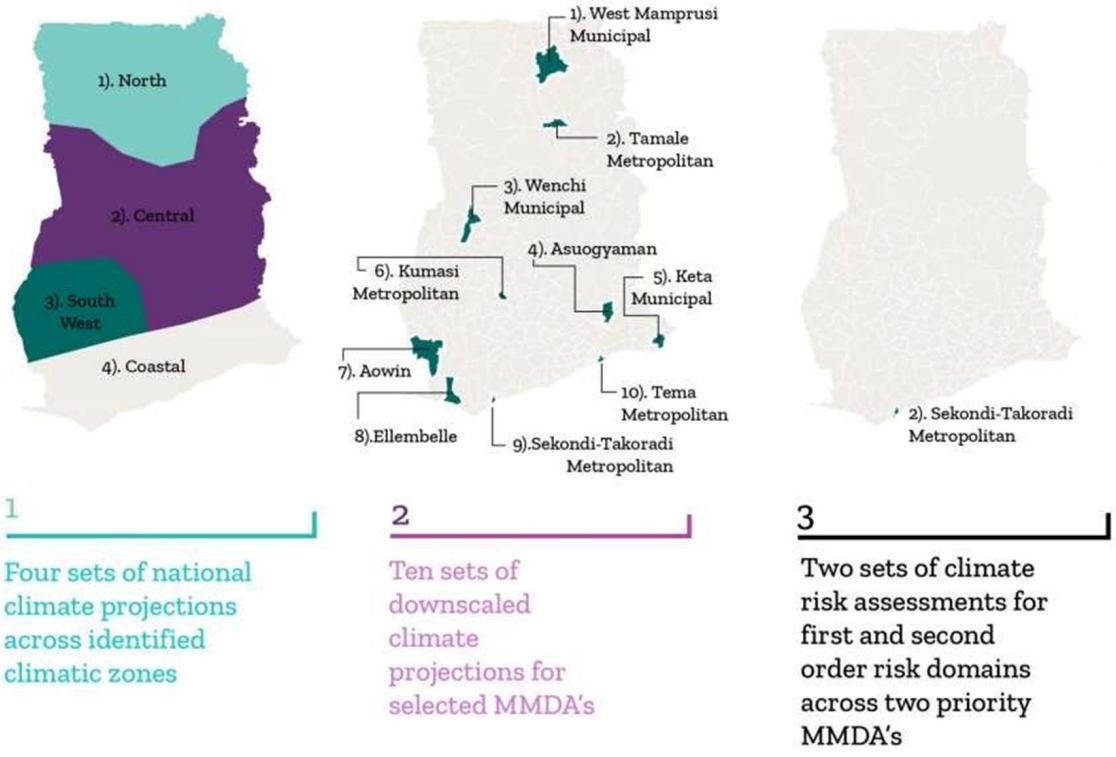
4. **Promote Stakeholder Engagement and Collaboration:** To facilitate an inclusive process that engages a wide range of stakeholders, including government agencies, local communities, NGOs, and private sector actors, ensuring that the CCRA process is grounded in local realities and benefits from diverse perspectives and expertise.

Accept or
Reject Risks

5. **Align with National and Regional Climate Change Frameworks:** To ensure that the findings and recommendations of the CCRA for KeMA are consistent with national climate change strategies and action plans, contributing to the broader efforts to mitigate and adapt to climate change in Ghana.

The identification of priority MMDAs followed a selection process developed in consultation with representatives of the Government of Ghana and with technical support from the UNEP (Figure 1).

Figure 1 I Spatial scale of key deliverables

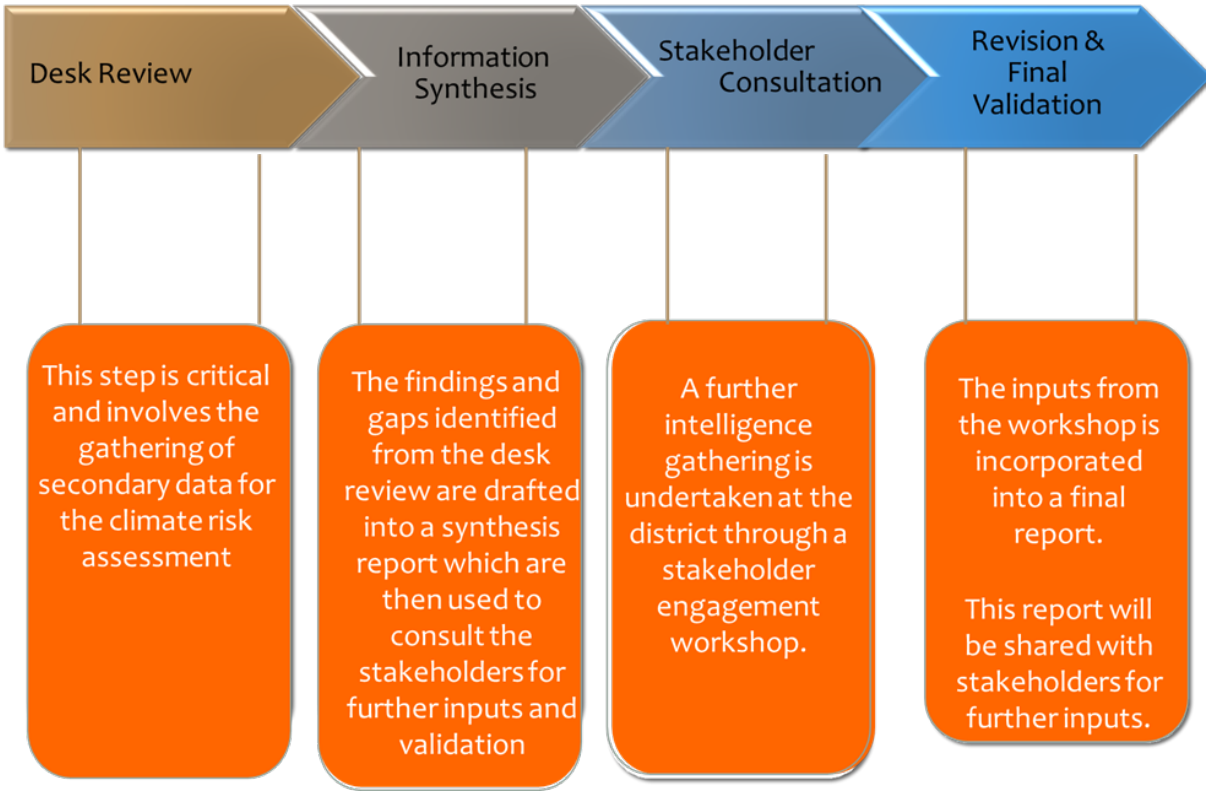


2 Approach and Methodology

2.1 Approach

The work approach for this Climate Change Risk Assessment for the Keta Municipal Assembly involves a structured, iterative process that encompasses the following steps:

Figure 2 I Overall work approach for the Climate Change Risk Assessment for the Keta Municipal Assembly



- **Desk Review:** This foundational step is vital as it involves the collection of secondary data pertinent to the climate risk assessment. This data gathering phase focused on accumulating existing information from various sources to construct a preliminary understanding of the climate risks relevant to the KMA. This process also took extensive review of international and national gender policies and sources.
- **Information Synthesis:** Building upon the desk review, the findings and identified gaps were then compiled into a synthesis report. This document serves to integrate the data collected and provides a coherent overview of the initial assessment. This synthesis report was essential as it formed the basis for subsequent consultations, encapsulating the current state of knowledge and highlighting areas requiring further exploration. Again, gender information gathered led to the development of a gender guideline to guide stakeholder engagements and other aspects of this report.

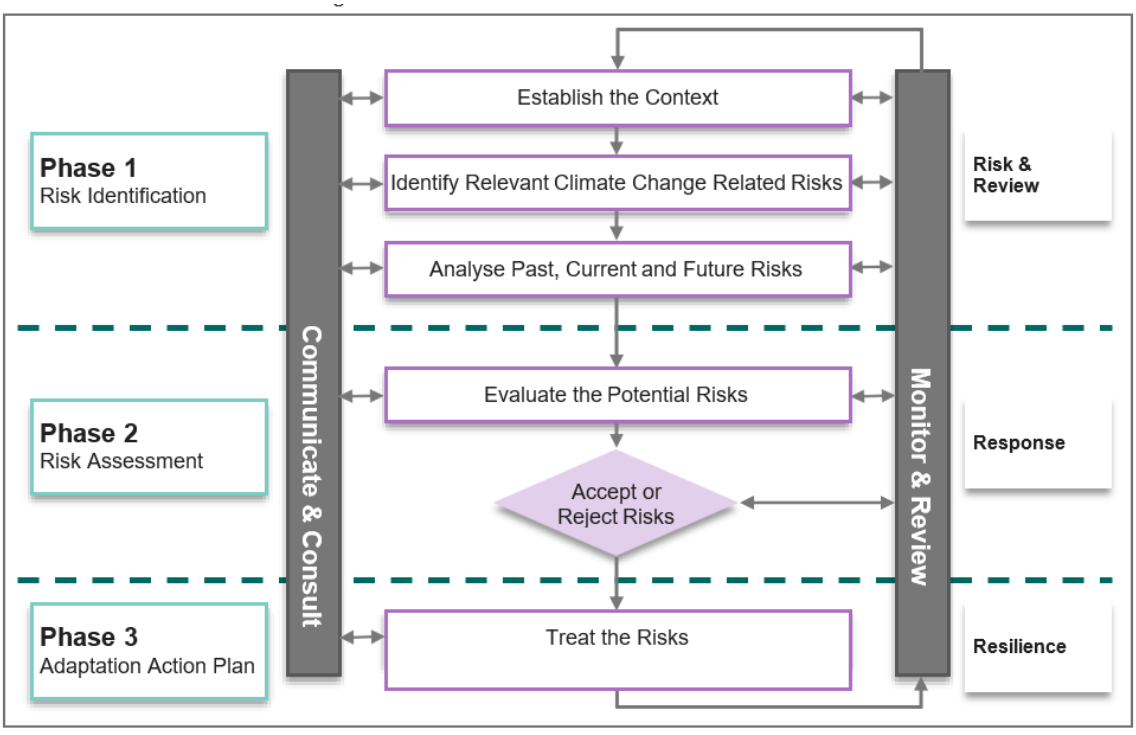
- **Stakeholder Consultation:** The process continues with an in-depth stakeholder engagement workshop conducted within the district. This workshop was a critical intelligence-gathering exercise that involves various stakeholders, tapping into their insights and experiences. It serves as an interactive platform for stakeholders to validate the findings of the desk review and information synthesis, and to contribute additional knowledge and perspectives that might not have been captured through secondary research. Gender inclusiveness was considered in the selection of participants in the stakeholders and gender discussions were extensively discussed.

- **Revision & Final Validation:** The culmination of this process was the integration of the insights gathered during the stakeholder workshop into a final report. This report is a comprehensive document that not only reflects the outcomes of the previous stages but also incorporates the practical contributions and validations from the district's stakeholders. Also, the report was extensively reviewed by gender experts.

2.2 Methodology

The approach undertaking in determine the Climate Change Risk Assessment for KeMA follows the general risk assessment process designed and used for the Tamale and Sekondi Takoradi CCRA as shown in Figure 2.

Figure 3 I General overview of the risk assessment process.



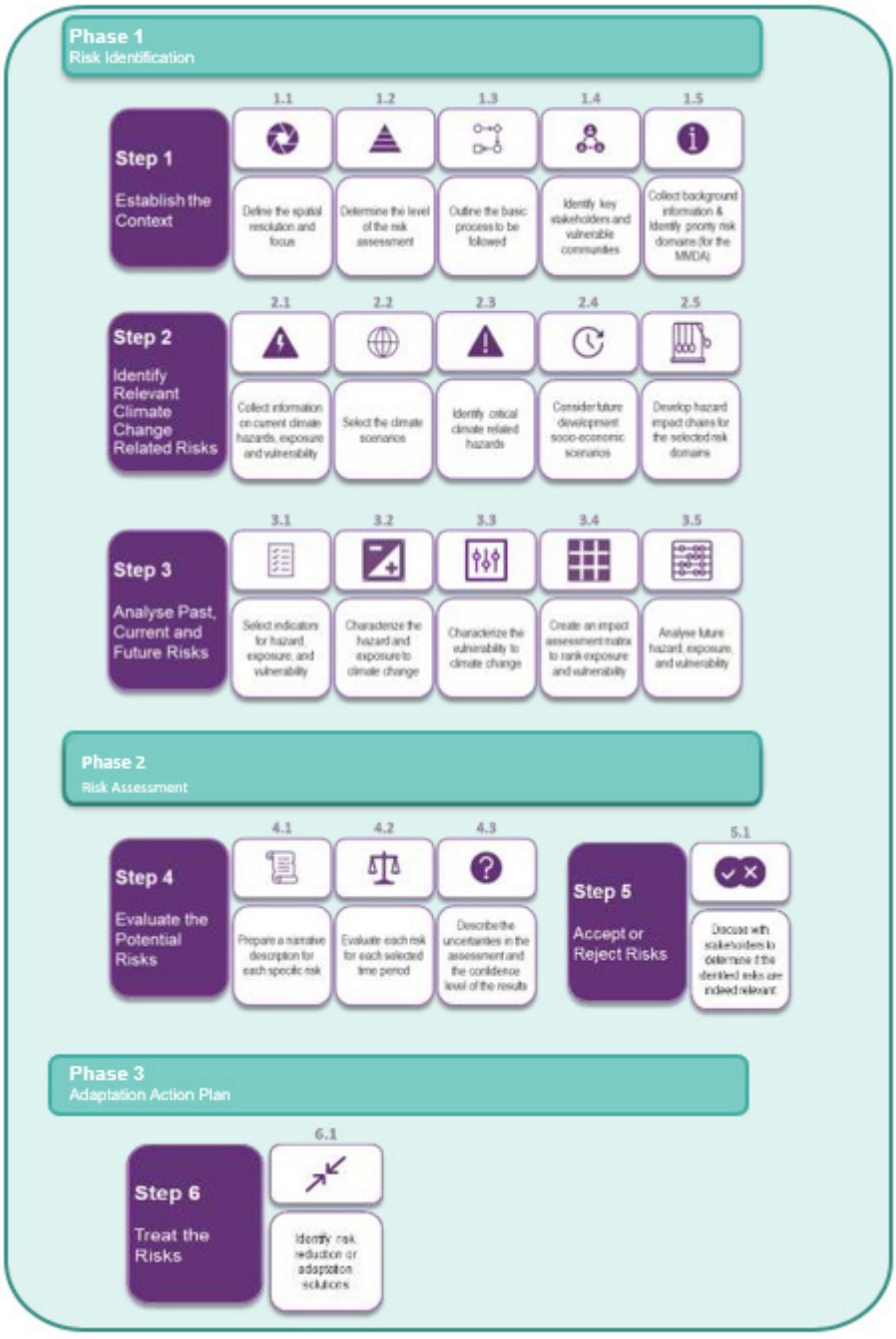
Source: Adapted from (Norman, et al., 2014)

Unlike the comprehensive assessment for the earlier two district (Tamale and Sekondi Takoradi Municipal assemblies), the process taken to conduct this assessment is mainly desk review of relevant academic literature, national and international reports, media articles, etc. To ensure that the risks identified are grounded in the local context and considers the specific needs and concerns of the communities within the two MMDAs, a validation workshop is organized at the district level to authenticate the information. The workshop also took advantage to further collect data and anecdotal evidence to understand better the current and potential future climate change related risks, their impacts and the adaptive capacity of local communities and institutions.

The basic approach to identifying the climate risk involved selecting the relevant key risk domains and then determining the relevant climate hazards and level of exposure and sensitivity and the potential for adaptive capacity pertinent to that specific risk domain or sub-sector.

Figure 3 summarises the specific steps, and timeline, followed for undertaking the CCRA

Figure 4 I Process followed during the CCRA



3 Background and Context

3.1 Defining Climate Change Risk and Vulnerability

According to the Intergovernmental Panel on Climate Change (IPCC), climate risk results from the interaction of hazard, exposure, and vulnerability. In the IPCC online glossary[1] the revised definition of **Risk** [used in the Special Report on Climate Change and Land and Special Report on the Ocean and Cryosphere in a Changing Climate – SRCCL (09/2019)] is the following, and is shown graphically in Figure 4 (from IPCC, 2014):

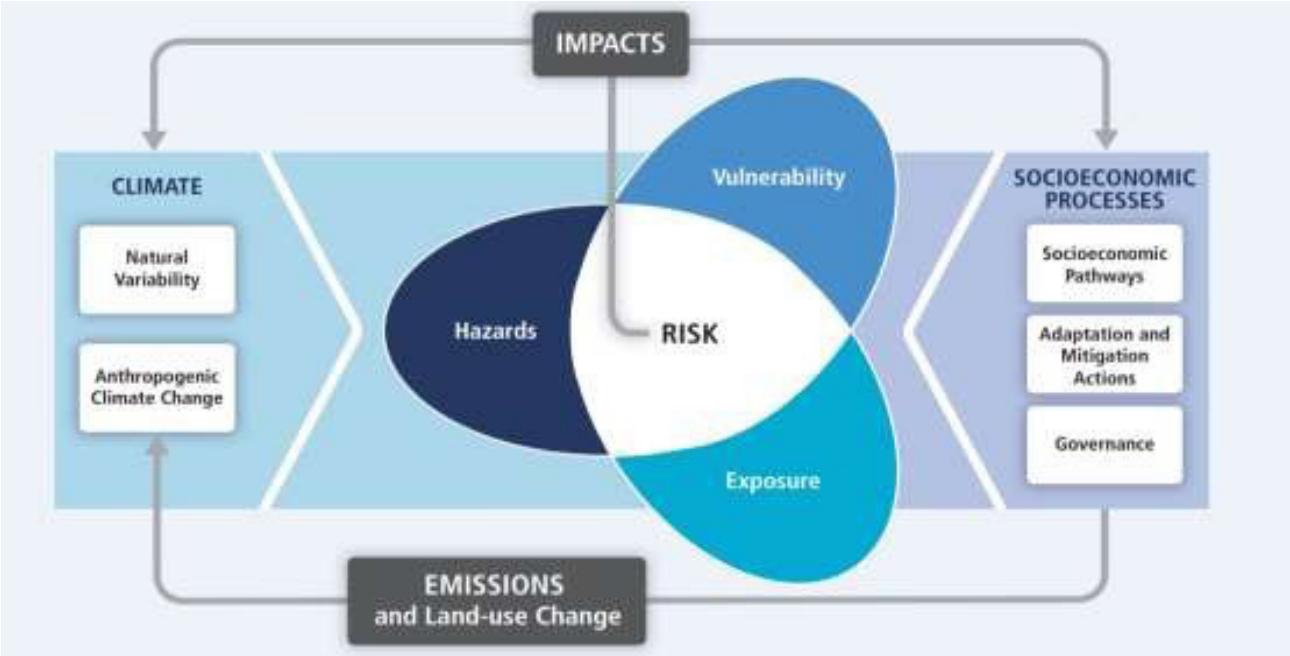
Climate Change Risk is defined as the potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses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

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

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

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

Figure 5 I Risk assessment framework for evaluating climate change risks (IPCC, 2015)



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

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

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

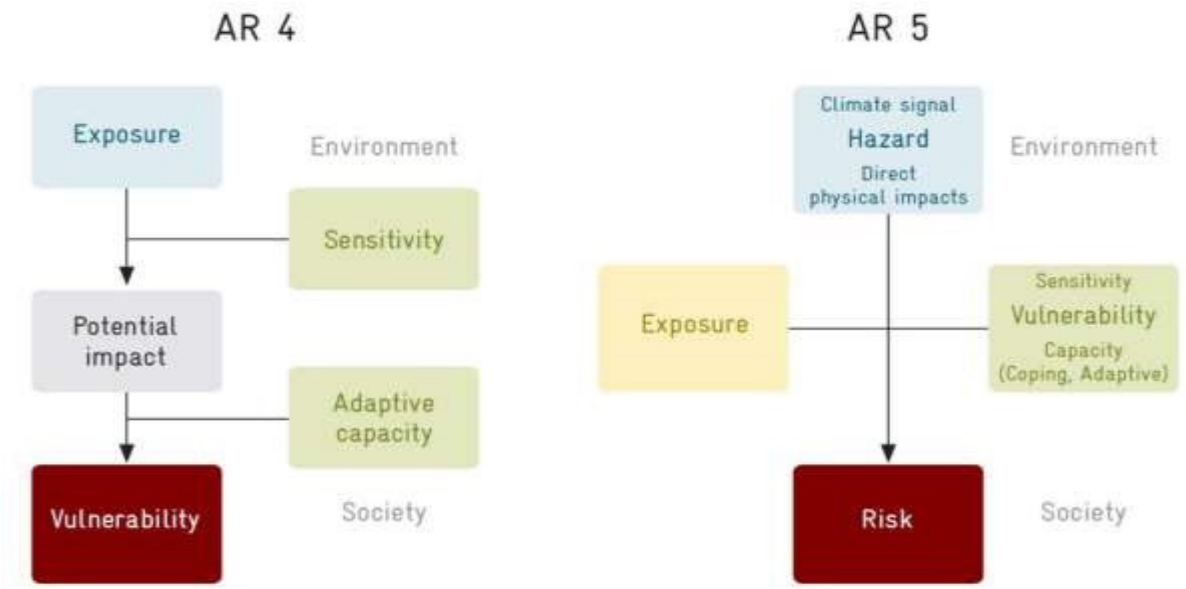
- **Hazard** *is the potential occurrence of a natural or human-induced physical event or trend that maycause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.*
- **Exposure**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

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

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

It is important to note the change in the definitions used for determining vulnerability and risk, as discussed above, between the fourth (AR4) and fifth (AR5) assessment reports as shown in Figure 5.

Figure 6 I Change in the conceptual approach to climate change risk and vulnerability assessment



Source: (Zebisch, et al., 2021)

3.2 Initial Assessment of Critical Climate Related Hazards

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

Table 1 I Summary of critical climate related hazards for Keta municipal from ThinkHazard! Tool

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

Source: ThinkHazard! (Global Facility for Disaster Reduction and Recovery (GFDRR), 2024)

Table 1 shows that KeMA has the following critical climate risks:

1.1.1 **Coastal flood hazard** is classified as medium. This means that there is more than a 20% chance of potentially damaging coastal flood waves occurring in the next 10 years.

1.1.2 **River flood** is classified as medium. This means that there is a chance of more than 20% that potentially damaging and life-threatening river floods occurring in the coming 10 years.

1.1.3 **Extreme heat hazard** is classified as medium. This means there is more than a 25% chance that at least one prolonged exposure to extreme heat, resulting in heat stress, will occur in the next five years. According to the IPCC, continued emissions of greenhouse gases will cause further warming, and it is virtually certain that there will be more frequent hot temperature extremes over most land areas during the next fifty years. Warming will not be uniform. In this area, the temperature increase will be slightly lower than the worldwide average, but still significant.

1.1.4 **Wildfire hazard** is classified as high. This means there is a greater than 50% chance of encountering weather that could support a significant wildfire that is likely to result in life and property loss in any given year. In areas already affected by wildfire hazard, the fire season is likely to increase in duration, and include a greater number of days with weather that could support fire spread because of longer periods without rain during fire seasons. Climate projections indicate

that there could also be an increase in the severity of fire. Areas of very low or low wildfire hazard could see an increase in hazard, as climate projections indicate an expansion of the wildfire hazard zone.

Although urban, river and coastal flooding were not considered high risk in this tool, there is anecdotal evidence that an increase in urban flooding is a major area of concern for Keta Municipaland most cities in Ghana as a result of climate change. This has almost become an annual event as a result of excessive rainfalls causing the rivers to overflow their banks (Danso & Addo, 2017; Ansah et al., 2020[2]). Coastal floods are major issue for the assembly with evidence pointing to an increase in the frequency of coastal floods[3] (Brempong et al., 2023). The potential for increase in coastal storms/storm surges and sea level rise, combined with urbanisation could potentially increase the risk and worsen the potential impacts of urban and coastal flooding (TripleLine Consulting Limited, 2022). The assessment that flooding risk is low, is likely because *Thinkhazard!* is based mainly on the result of the climate models, i.e. based on the relative change in critical climate variables and does not necessarily take into considerations the underlying vulnerability of each location. For this reason, it is important to take into consideration local level climate risk.

3.3 Stakeholder Engagement

A crucial aspect of this climate risk assessment is engaging interested and affected parties (I&APs) in the process to enhance their awareness and understanding of the issues of climate change and impacts in the district and transfer capacity to relevant stakeholders for implementation. In essence, two workshops were held with the first focusing on introduction to the assessment process and data collection while the second focused on validating the final findings draft. The first workshop was organized on the ….and held at the Aborigines Resort, Keta. Among the 30 workshop participants are representatives from National Disaster Management Organization (NADMO) and Keta Municipal Assembly, professionals from environmental and water agencies like the Community water and sanitation agency, as well as local media and education sectors. Community voices are also well-represented, with women-led groups, local farmers and community media personnel. The stakeholder engagement workshop provided the Consultant team the opportunity to:

(a). Introduce the NAP project framework to stakeholders and outline the collaborative process.

(b). Educate stakeholders about climate change, its potential impacts, and the various factors to be considered in the risk assessment.

(c). Share the initial down-scaled climate projections for temperature and precipitation.

(d). Validate these climate change projections with empirical evidence and local expertise.

(e). Undertake gender discussions on gender implications of climate change.

(f). Identify critical climate-related risks and gather both quantitative data and qualitative accounts to deepen the understanding of these risks, their consequences, and the community's adaptive capacity.

The workshop activities entailed a first presentation by the consultant team to set and frame the context of the workshop.

2 Ansah, S. O., Ahiataku, M. A., Yorke, C. K., Otu-Larbi, F., Yahaya, B., Lamptey, P. N. L., & Tanu, M. (2020). Meteorological analysis of floods in Ghana. Advances in Meteorology, 2020, 1-14.

3 Brempong, E. K., Almar, R., Angnuureng, D. B., Mattah, P. A. D., Jayson-Quashigah, P. N., Antwi-Agyakwa, K. T., & Charuka, B. (2023). Coastal Flooding Caused by Extreme Coastal Water Level at the World Heritage Historic Keta City (Ghana, West Africa). Journal of Marine Science and Engineering, 11(6), 1144.

This was followed by more participatory activities aiming to engage the participants to identify key hazards, exposures, vulnerabilities, frame and rank various risk. For example, sector groups were engaged in participatory activities that included physical/resource and hazard mapping. They identified the most vulnerable and at-risk locations within the municipal, an exercise that not only pinpointed the geographical areas prone to climate impacts but also highlighted the critical resources that could be affected by these hazards. Simultaneously, another set of sector group activities revolved around climate hazards identification.

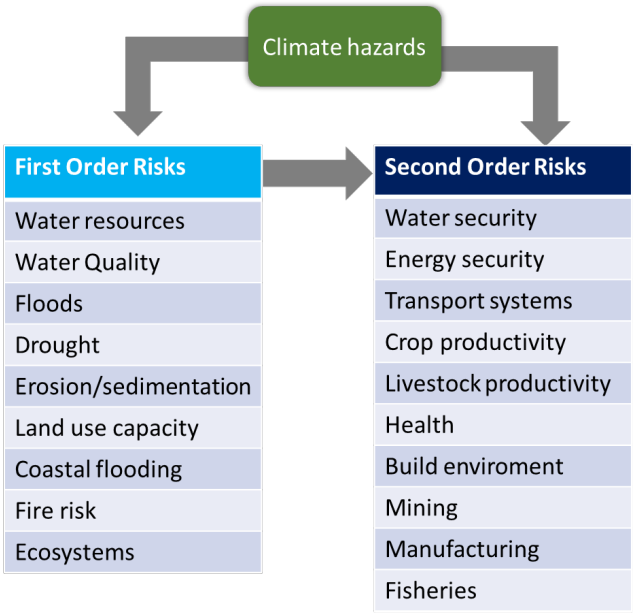
Building on this, the sector groups diligently worked on creating a sector-specific climate risk and adaptation matrix. They scored and prioritized each identified risk, considering both the severity of impact and the probability of occurrence. This methodical approach helped in quantifying the relative risks and framing targeted adaptation responses. Additionally, gendered discussions on climate impacts and adaptation were conducted, ensuring that the workshop addressed the differentiated impacts of climate change on men, women and other vulnerable groups. These conversations brought to light unique challenges faced by various gender groups and fostered inclusive strategies that recognize and integrate gender-specific needs and perspectives.

3.4 Identification of Priority Risk Domains and Critical Assets

The Keta Municipality is unique in terms its specific priority risk domains because of its location and economic activities. The desk review process has identified the following risk domains which a few has been prioritized to be addressed as part of the CCRA. The criteria used in selecting first and second order risk domains is shown in Figure 6.

Figure 7 I Criteria in selecting first and second order risk domains

- For first order risk domains:
  - Magnitude/severity of project change in risk
  - Vulnerability of second order (economic) categories to the first order (biophysical) risk category.
- For second order risk domains:
  - Importance to local economy
  - Level of vulnerability/exposure
- For both first and second order domains
  - A non-overlapping list of categories across the two case studies to be representative of approaches.



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

Table 2 I Considerations for identifying critical first and second order risk domains for KeMA.

Second order risk domains	First order risk domains
An important economic sector is the **crop production** and **fisheries industry** which are area of concern due to possible climate changerisks. A component of this is also the potential impact on **transport systems** (i.e., roads and ports), mainly due to sea-level rise, as well as the overall impact onthe **settlement and tourist infrastructure.** E**nergy security** could be considered as a secondorder risk domain, given the dependency on hydropower as well as reliable **water supply.**	Critical first order risk domains that affect fisheries, crop production, transport and the built environment include **coastal flooding** and **inland flooding**, and in particularly areaswhere they overlap. **Upland and coastal ecosystems** are important in terms of ecosystem-based adaptation**.** It has been noted that there are several important **tourist** and **cultural sites** located on the coast near to Keta municipal that could be impacted by **sea level rise** and increased **coastal flooding**. **Water resources (availability)** is an important first orderrisk domain that should be considered.

Table 3 I Identified priority first and second order risk domains selected for Keta.

First Order Risk Domain	Second Order Risk Domain
Water Resources	Crop production.
Coastal Flooding	Energy Security (e.g., hydro)
Ecosystems	Transport Systems
	Settlements
	Fisheries

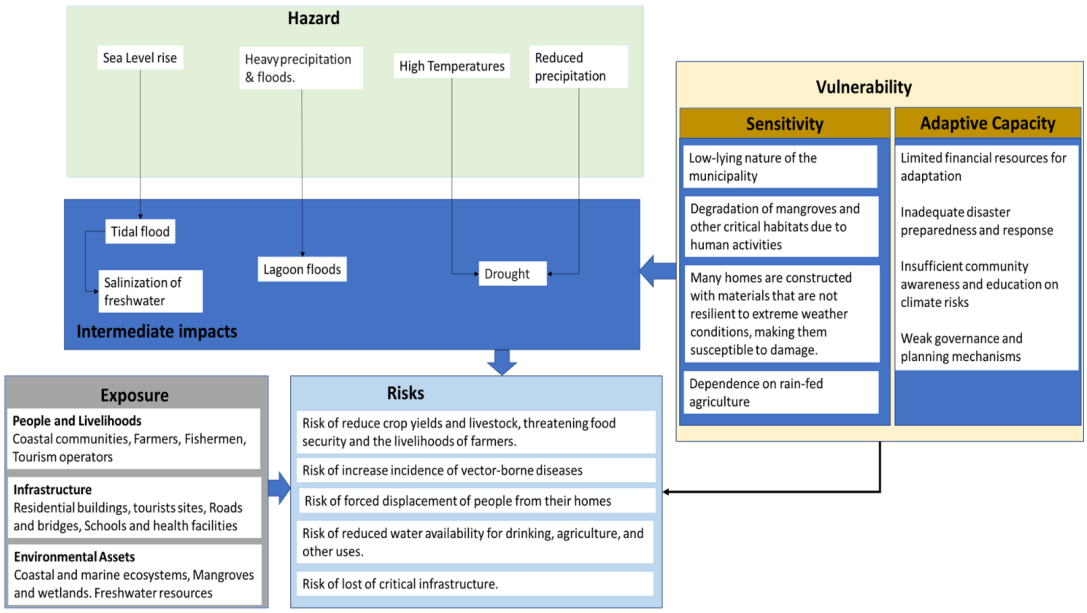
Through the engagement in the stakeholder workshop, the following critical systems and assets were identified and become the primary focus of the local level climate change risk assessment for Keta.

- Fisheries
- Water Supply
- Industries
- Settlement
- Critical infrastructure
- Agriculture
- Health systems
- Coastal Ecosystem

3.5 Overview of Impact Chain Analysis

An Impact Chain Analysis is useful for understanding and visualising the cause-and-effect relationships between climate hazards, vulnerabilities, and their impacts on specific sectors or communities. Below is an overview of the Impact Chain Analysis for the Keta Municipality focusing on results from the stakeholder engagement:

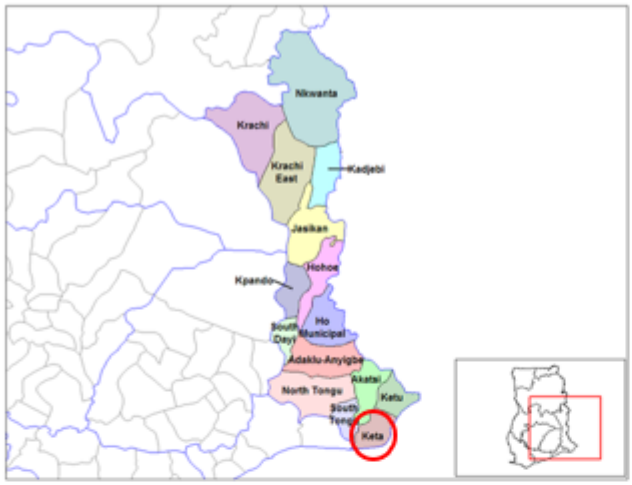
Figure 8 I Overview of impact analysis



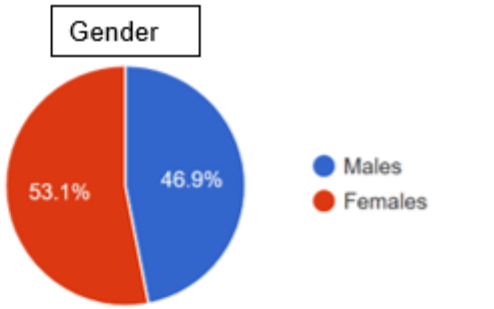
4

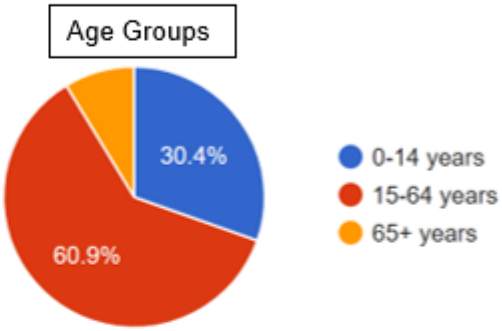
Overview of Keta Municipal Assembly

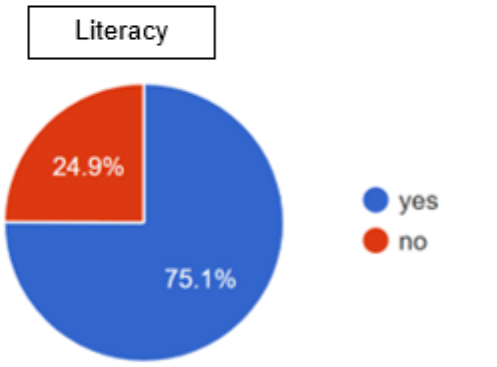
Figure 9 I Keta Municipal Assembly overview.

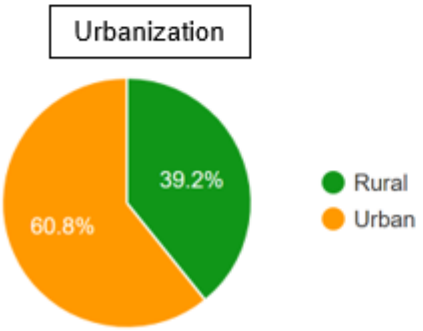


Age Distribution (C 2021)	
80+ years	1,986
70-79 years	2,756
60-69 years	4,798
50-59 years	6,381
40-49 years	7,146
30-39 years	9,365
20-29 years	11,733
10-19 years	18,660
0-9 years	16,037









Source: https://www.citypopulation.de/en/ghana/admin/volta/0402__keta_municipal/

Geographical Location and Size

The Keta Municipality is situated between Longitudes 0.30E and 1.05W and Latitudes 5.45N and 6.005S. Positioned to the east of the Volta estuary, it is approximately 160km east of Accra, accessed via the Accra-Aflao main thoroughfare. The municipality shares borders with the Akatsi South District (north), Ketu North and Ketu South Districts (east), South Tongu District (west), and is flanked by the Gulf of Guinea to the south. Of its total land area spanning 446km^2, approximately 29.6% (132km^2) is aquatic, with the Keta Lagoon, measuring 12km at its broadest point and extending 32km, being the most expansive.

Topography and Drainage

The topography of Keta Municipality is characterized by a predominantly low-lying coastal plain, attaining an elevation of 53 meters above sea level near Abor in the northern region. Conversely, areas such as Vodza, Kedzi, and Keta townships exhibit elevations ranging between 1 to 3.5 meters below sea level. The hydrological network predominantly flows southwards, anchored by the River Tordzie, originating from the Togo Mountains and culminating in the interconnected Avu and Keta Lagoons. The basin also integrates streams and distributaries of the Volta River, including Angor, Avida, Awafla, Nukpehui, Tordzie, and Kplikpa. Key islands within this basin comprise Seva and Dudu, with partial habitation. Geographically, three distinct zones are discernible: the Narrow Coastal Strip, the Lagoon Basin, and the Northern Plains.

Coastal Strip

This zone, predominantly low-lying, has witnessed pronounced sea erosion and periodic inundation, though it presents substantial irrigation prospects. Dominated by sand bars interspersed with sporadic sea cliffs, areas such as Keta, Kedzikope, Vodza, Kedzi, and Horvi have benefited from the Keta Sea Defence Project, mitigating erosion impacts.

Lagoon Basin

Characterized by marshy terrains, the basin comprises lagoons and islands, with notable features including Atiavi, Seva, Anyako, and Dudu, primarily attributed to an underlying sandy-clay geological structure.

Northern Plains

The northern plains exhibit a gentle undulating topography with elevations peaking at around 53 meters above sea level.

Climatic Attributes

- **Rainfall**

  Keta Municipality is enveloped within the Dry Coastal Equatorial Climate regime, with an annual precipitation average below 1,000mm. Rainfall diminishes towards the coastal peripheries, registering approximately 800mm annually. Characterized by a bimodal rainfall distribution, the principal rainy phase spans March to July, while a secondary phase occurs from September to November, constraining year-round agricultural practices and emphasizing irrigation-dependent ventures, particularly in locales like Dzelukope.

- **Temperature**

  Elevated mean temperatures, averaging around 30°C, coupled with diminished relative humidity, intensify evapotranspiration rates. This phenomenon exacerbates water scarcity conditions, augmenting

salt production potential. Temperature patterns display a downward trajectory, characterized by uneven temporal distribution.

Biogeographical Characteristics

- **Vegetation**

  The municipality is situated within the coastal savannah biome, demarcated into four distinct vegetative zones. The northern sector is typified by towering grasses interspersed with medium-sized trees, whereas the central region features shorter grasses, diminutive trees, and sporadic occurrences of “Pamira” palm and baobab specimens. Notably, the prevalence of Cape St. Paul Wilt disease has adversely impacted coastal coconut tree populations, influencing regional precipitation patterns.

- **Fauna**

  The municipality hosts an array of biodiversity, including three endangered marine turtle species (leatherback, green, and olive-ridley), the Western Sitatunga antelope, fin fishes, manatees, primates, pythons, crocodiles, and a diverse avian migratory spectrum.

Pedological Characteristics

- **Oyibi-Muni Pedological Association**

  Situated along the coastal strip, the Oyibi-Muni and Keta Pedological Associations are distinguished by their predominantly sandy soil structure, often devoid of a discernible humus layer. This pedological framework is inherently conducive to coconut cultivation. However, with appropriate organic supplementation, it facilitates the cultivation of crops such as shallots, okra, peppers, and assorted vegetables. Notably, despite its relatively modest coverage, encompassing approximately 11% of the municipality’s terrestrial expanse (excluding aquatic bodies), this region stands as Ghana’s primary hub for shallot production. 67% of the shallot producers are men while 33% are women (Yeboah & Egyir, 2023). The subsequent figure delineates the pedological distribution across the municipality.

- **Ada-Oyibi Pedological Association**

  The pedological composition within the lagoon basin, characterized as the Ada-Oyibi Association, manifests as shallow soils superimposed upon a robust and compact clay substrate. Intrinsically alkaline in nature, this pedological association predominantly sustains mangrove ecosystems, alongside cultivation prospects for sugarcane and pasture grasses. Given the underlying clay stratum, this region is intrinsically prone to inundation events, rendering it unsuitable for extensive arable agricultural practices. Despite these limitations, it occupies a substantial portion, accounting for over 75% of the municipality’s terrestrial domain.

- **Toje-Alajo Pedological Association**

  Encompassing the Northern Plains proximate to Abor, the Toje-Alajo Pedological Association comprises a more profound soil profile, fostering the growth of staple crops such as cassava, maize, and leguminous plants. Occupying an approximate share of 14% of the municipality’s terrestrial area (excluding lagoonal regions), its pedological attributes are comparatively more amenable to diversified agricultural practices.

- **Administrative Structure**

  The Keta Municipal Assembly serves as the municipality’s paramount administrative and political entity. Composed of thirty-two members, it includes 22 elected officials and 10 governmental nominees, with

a gender imbalance notably affecting decision-making dynamics. Additionally, the Assembly includes a Municipal Chief Executive and a Member of Parliament, both non-voting constituents.

The Executive Committee, under the Municipal Chief Executive's stewardship, oversees administrative functions. This committee collaborates with specialized sub-committees—Development Planning, Justice and Security; Works, Finance and Administration; and Social Service—to deliberate on distinct policy domains. Recommendations from these sub-committees undergo vetting by the Executive Committee before reaching the General Assembly for approval.

Further organizational granularity exists through seven Zonal Councils, each delineated by specific geographic areas. However, these sub-district councils frequently underperform due to overarching constraints, notably financial, logistical, and human resource deficiencies. This operational shortfall underscores the imperative for targeted interventions to enhance their functional efficacy.

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5 Climate Change Vulnerability

The vulnerability to potential climate change impacts is determined based on sensitivity and adaptive capacity. The current vulnerability is characterised by both socio-economic conditions including the dependency on high-risk sectors such as agriculture, as well as the institutional capacity to manage and mitigate the potential for increasing climate change related risks including floods and droughts. The future level of climate change vulnerability will be determined based on the socio-economic developmentpathway as described in the previous section and summaries below in terms of future vulnerability.

5.1 Current Vulnerability - Sensitivity and Adaptive Capacity

Due to its location in the coastal Volta Region of Ghana, KeMA is highly vulnerable and exposed to climate risks, including extreme weather events, sea level rise, and flooding. Various factors, including economic, social, human, and political resources, influence KeMA's vulnerability to climate change.

5.1.1 Economic Vulnerability

The municipality is largely rural, with two-thirds of the population depending on small scale rain-fed agriculture, and a strong linkage between crop farming, livestock rearing, fishing and forestry. With limited livelihood diversification options, the municipality is well known for its vegetable production, especially shallot. The challenges of the farmers is heightened for the women and the youth, as the biggest portion of the economic gains are from the farm. Concurrently, a diverse spectrum of small-scale industrial operations has been identified within the municipality's economic fabric. The small-scale industries rely on climate sensitive raw materials such as cassava and sugarcane. In addition to these sectors, the KeMA holds significant potential as a tourism hub along Ghana's coastline and has key attraction sites. These facilities are located along the coastline and they are threatened by increased sea-level rise. The residual workforce is predominantly affiliated with service-oriented professions and artisanal trades.

5.1.3 Physical/Environmental Vulnerability

The municipality is ranked high in vulnerability to climate change and variability due to the increasing rate of sea level rise and widespread coastal erosion (GSS, 2014). Out of the total land area of 1,086 km2, water bodies cover approximately 362 km2 (about 30%), with the Keta Lagoon, which is about 12 km wide and 32 km long, being the largest in Ghana (Keta Municipal Assembly, 2018). Other lagoons include Angaw Agbatsivi, Logui, Nuyi and Klomi. Into these lagoons drain many streams (e.g., Angor, Avida, Awafla and Nukpehui) and some tributaries of the Volta River (GSS, 2014). Many of these streams are found in the municipality, although they are dwindling in size due to low rainfall, excessive evaporation and siltation. As a consequence, the quantity of water in the lagoons has considerably dwindled and tends to vary seasonally, leading to the emergence of islands in the Keta and other surrounding lagoons.

The coastal zone of Keta and the municipality in general are affected by human activities and geomorphological processes such as sea erosion and flooding which are upsetting the condition of the coastal wetland, the vegetal cover and other landscape features of the locality. Wetlands reduced

in coverage from 182.33 km2 to 135.11 km2 from 2005 to 2018 while farmlands showed a continuous increase in landmass. Increased anthropogenic activities such as urbanization, farming and geomorphic processes such as sea erosion and tidal inundation owing to climate change are the key drivers of the transformations of the landscape of the locality.

Erosion is having a huge impact on houses in the municipality as over 40% of houses are deemed bad or dilapidated due to erosion. Although the rate of erosion is considered reduced from initially predicted 2 m–1.5 m per annum (Adu-Gyamfi, Shaw and Yan, 2020) its impact on houses is highly fueled by the spatial coverage of the erosion (about 60% of the shoreline) and how the houses are spatially distributed near the shoreline.

5.1.4 Social Vulnerability and Adaptive Capacity

The most vulnerable groups within KeMA are women (elderly and orphans), children, people with disabilities and low-income individuals and households in both a rural and urban setting. These groups are disproportionately affected by the loss of services when infrastructure fails due to the impacts of climate change and environmental shocks. Often, it is these groups that bear the brunt of damages caused by natural disasters, as they may lack the resources to rebuild their homes, communities, and livelihoods, and who may be disproportionately affected by health and other impacts caused by disruptions to basic services (Adshead, et al., 2022). Households' dependent on primary economic activities such as small-scale fishing/fish processing and subsistence agriculture are the most vulnerable to the potential impacts of climate change as they are more directly exposed, and they have limited resources.

KeMA faces challenges in building its adaptive capacities and reducing vulnerability due to limited financial resources, inadequate infrastructure, and insufficient technical capacity and expertise to address the climate impact and related gender issues. However, by building on the existing strengths, include economic diversity, and addressing the challenges, the city can improve its adaptive capacity and build a more sustainable and resilient future.

A study revealed lack of knowledge/understanding of sea level rise, as the majority of household interviewees attributed the rise or fall in sea level to God[4][5] (Evadzi et al., 2018; Damptey and Essel, 2014).

5.1.5. Gender-Specific Vulnerabilities in Keta Municipality

Climate change impacts in Keta Municipality present distinct challenges that disproportionately affect various gender groups, particularly women, youth, and differently-abled individuals. These vulnerabilities are evident across key sectors such as agriculture, water resources, community health, and infrastructure, highlighting the need for targeted adaptation strategies to ensure inclusive and equitable resilience building.

Agriculture: In Keta Municipality, women predominantly engage in small-scale agriculture and fishing-related activities. Climate change impacts, such as unpredictable rainfall and rising temperatures, significantly affect crop yields and fish stocks. This places additional burdens on women who must spend more time on their fields and fishing activities to ensure food security for their families while managing household responsibilities. Women also face limited access to financial resources, credit, and improved agricultural technologies, which

4 Evadzi, P. I., Scheffran, J., Zorita, E., & Hünicke, B. (2018). Awareness of sea-level response under climate change on the coast of Ghana. Journal of Coastal Conservation, 22, 183-197.

5 Damptey, P. T. M., & Essel, A. K. (2014). Gender perspectives of climate change: Coping and adaptive strategies in Ghana. Kaduna, Nigeria: ABANTU for Development.

further exacerbates their vulnerability and hampers their capacity to adapt to changing climatic conditions.

Water Resources: Women and girls in Keta Municipality bear the primary responsibility for water collection. Climate change-induced water scarcity forces them to travel longer distances to find clean water, which poses significant health risks and limits their time for educational and economic activities. During dry seasons, women and girls may need to walk several kilometers to the nearest water source, increasing their exposure to potential dangers and reducing time available for other productive tasks.

Community Health: As primary caregivers, women in Keta Municipality are disproportionately affected by climate change-induced health risks. Increased prevalence of diseases like malaria, diarrhea, and respiratory infections due to changing weather patterns heightens the burden on women who care for sick family members. The youth, while generally healthier, are still vulnerable to health risks associated with outdoor activities. Differently-abled individuals face significant barriers in accessing healthcare, particularly during climate-induced emergencies, further exacerbating their vulnerabilities.

Infrastructure: Keta's infrastructure, including roads, bridges, and buildings, is highly vulnerable to extreme weather events such as flooding and coastal erosion. Women are often responsible for ensuring household safety during such events, increasing their burden. Poorly designed or maintained infrastructure also poses significant challenges for differently-abled individuals, making it difficult for them to access safe areas or evacuate during emergencies.

Table 4. Community-Specific Examples in Keta Municipality

Sector	Vulnerability	Impact on Women	Impact on Youth	Impact on Differently-abled	Specific Examples
Agriculture	Climate impact on crop yields	Increased workload and stress on dual roles	Uncertain job prospects and disrupted education	Accessibility barriers and need for adaptive technologies	Women in Keta working longer hours to maintain crop yields, youth facing limited agricultural employment opportunities
Water Resources	Water scarcity and contamination	Longer distances for water collection, health impacts	Diverted from education to water collection	Difficulty accessing clean water, heightened dependence	Women and girls walking several kilometers to find uncontaminated water sources due to pollution and scarcity
Community Health	Climate-induced health risks	Increased caretaker burden health risks.	Exposure to health risks, educational disruption	Exclusion from health services, increased vulnerability	Malaria, waterborne diseases, and respiratory infections straining women's caregiver roles and disrupting youth activities
Infrastructure	Poor resilience to extreme weather	Increased burden in securing family and community well-being	Limited engagement in recovery, lost opportunities	Increased risk of injury, lack of accessible escape routes	Flood-damaged roads complicating evacuation and rebuilding efforts, disproportionately affecting women and differently-abled during emergencies

These gender-specific vulnerabilities emphasize the need for targeted adaptation strategies that address the unique challenges faced by different gender vulnerable groups in Keta Municipality, ensuring inclusive and equitable resilience building.

5.2 National and Sub-National SSPs

A parallel study has considered the development of local level socio-economic development scenarios that can assist with evaluating the potential for future climate change risk and vulnerability under different future scenarios. These national and local level socio-economic development scenarios were developed out on four of the global Shared Socioeconomic Pathways (SSPs) as developed by O'Neill et al. (2015).

These four selected SSPs are summarized below:

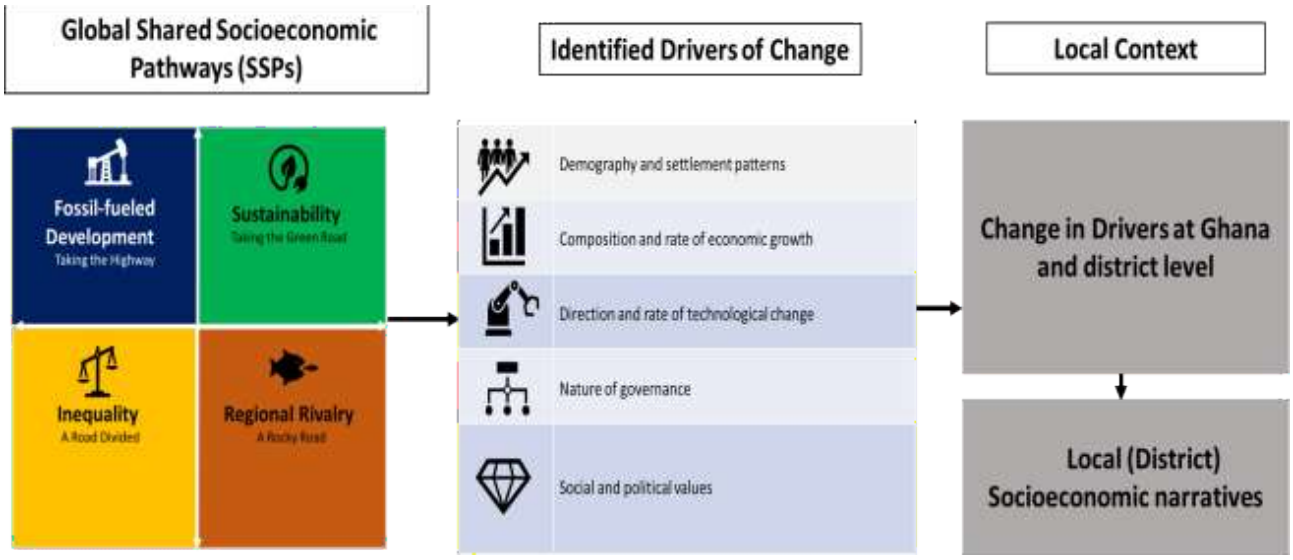
1. **Sustainability – Taking the Green Road:** This pathway is characterized by more inclusive global development and improved management of global commons, low global population growth and slower economic development, leading to relatively low resource and energy demand. Environmental technologies are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

The four selected SSPs have been applied in terms of identified key drivers of change at the national level for three key sectors (agriculture, energy, and health) and at the local level for KeMA. The specific details of these local level socio-economic development scenarios are still being finalised but have been assessed in the following section in terms of the potential impact that these alternative development scenarios will have on climate change vulnerability.

The key drivers of change used to define the SSPs are shown in Figure 12 and consist of the following:

(1) demography and settlement patterns, (2) consumption and rate of economic growth, (3) direction and rate of technology change, (4) nature of governance, and (5) social and political values.

Figure 10 I Adapted approach to develop local socioeconomic narratives.



5.3 Future Climate Change Vulnerability

Under the **Sustainability future scenario**, overall climate change vulnerability is reduced through investments in ecological infrastructure and pro-active urban planning. Improvements in agricultural practices and successful water resources development through the One Village One Dam have also reduced the sensitivity to drought and any potential impact of climate change on rainfall availability. In addition, the efforts made to reduce deforestation and to reduce plastic pollution have also reduce the potential risks associated with any possible increase in flooding risk. This is also as a result of improvedcollaboration between local government and national government around protecting critical infrastructure and the increased provision of basic services and improved health care facilities. For coastal communities increased investments in coastal defences and including the protection and rehabilitation of coastal wetlands and mangroves also help in addressing some climate related risks. The interventions should embrace equity by involving women, children, youth and differently abled persons.

Under this scenario, the KeMA would experience less climate change impacts especially from sea level rise and coastal erosions. This will lead to protection, promotion and development of tourism activities along the coast. It will result in a positive net-migration resulting from changes in the main economic activities in tourism sector leading to local economic development.

Under the **Fossil-fuel development scenario**, the potential impacts of climate change will be greater on the KeMA due to high dependence of livelihoods on climate sensitive sectors and the lack of national investment is measures needed to build resilience to climate change impacts. The KeMA has no oil exploration site and this requires that national earnings from oil explorations and investments in fossil fuel in other regions, is fairly distributed and invested in adaptation measures in places that directly do not benefit from fossil fuel investments This could include for example making investments in improved water supply infrastructure and improved stormwater management systems and providing social safety nets for the most vulnerable. If these pro-active investments are not made, then there is likely to be an increase in inequality which willresult in and overall increase in the vulnerability to climate change as well as other risk factors.

Under the **Inequality - Road Divided** scenario, the KeMA receives limited support from the central government and therefore have to solve most of their problems on their own and with limited resources. This could lead to innovative solutions and reduced climate change vulnerability, but it is more likely to driver inequality with

those who have the means being able to adapt to increase climate related risks by putting in their own water supply systems or flood protection, with the vast majority of the population becoming even more sensitive and vulnerable to climate impacts. Such inequality is also known to increase the gender divide.

Under the **Regional Rivalry – Rocky Road** scenario the world is characterized by competition, and a weakening of the structures for international cooperation. There is limited inflow of aid in all forms, and this reduces the availability of funds to undertake relevant projects. In the KeMA, the absence of international commitments will lead to a continued encroachment on the tropical forest and mangrovesincreasing the risk associated with both inland and coastal flooding. The KeMA will also lack the funds necessary to protect critical infrastructure such as the port, roads, power station, and coastal forts. This will have a significant negative impact on the local economy as the disruptions to services increase. Under this scenario, there is high probability of inconsideration for gender needs.

6 Observed Climate and Trends

6.1 Observed Climate

Ghana's climate is characterized by high temperatures and significant regional variability in rainfall. The country experiences a tropical climate with average annual temperatures ranging from 26°C to 29°C, with coastal areas benefiting from the moderating influence of the Atlantic Ocean. The southern part of Ghana experiences two distinct rainy seasons, from April to June and from September to November, while the northern region has a single rainy season from April to October followed by a prolonged dry season. Annual rainfall varies considerably, from about 1,100 mm in the north to over 2,000 mm in the southwest. Humidity levels are generally high, particularly in coastal and forest zones, although they drop during the Harmattan season in the northern regions.

Over recent decades, Ghana has observed significant climatic changes. Average temperatures have risen by about 1°C over the past 30 years, with an increase in the number of hot days and nights and a decrease in cold days and nights. Rainfall patterns have become increasingly erratic, with greater variability in both timing and intensity. This has resulted in a general decrease in annual rainfall in some parts of the country, particularly in the north, and has altered the onset and cessation of the rainy seasons, which poses challenges for agricultural planning and water resources management.

Additionally, Ghana has experienced a rise in the frequency and intensity of extreme weather events such as floods and droughts. Coastal areas are particularly vulnerable to storm surges and sea-level rise, leading to increased coastal erosion and flooding. The rising sea levels have also contributed to saltwater intrusion into freshwater systems, compromising water quality and availability.

These climatic trends have profound implications for Ghana's agriculture, which is a major component of the national economy. Shifts in growing seasons, reduced crop yields, and increased incidences of pests and diseases are notable impacts. To cope with these changes, farmers are increasingly adopting climate-resilient practices. Overall, the observed climate changes in Ghana necessitate adaptive strategies to mitigate adverse effects and enhance the country's resilience to ongoing and future climatic shifts.

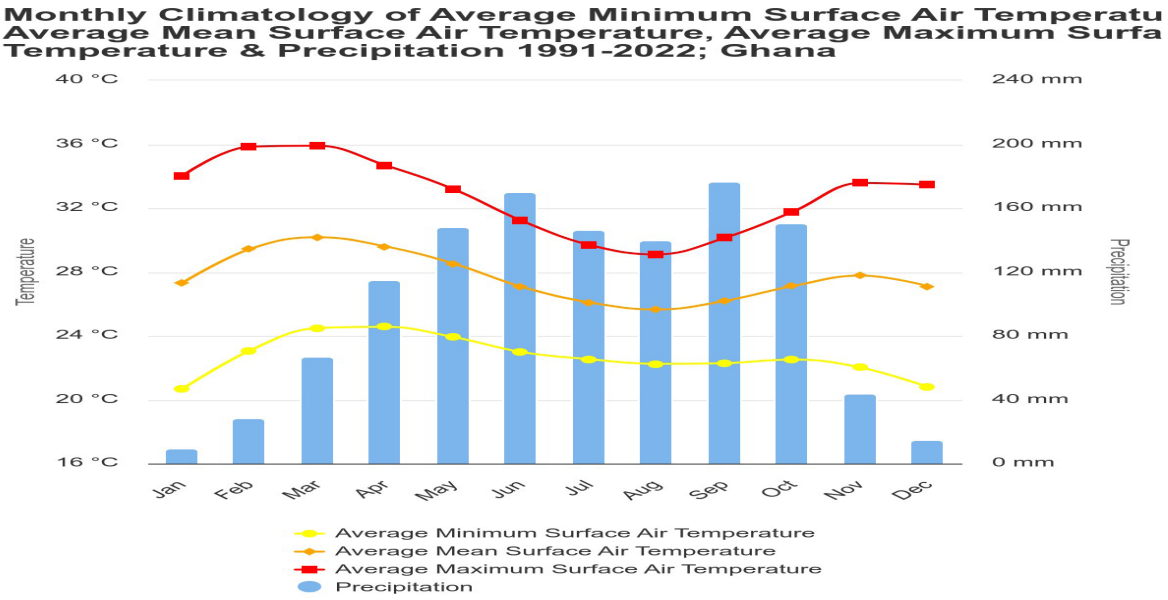
Figure 11 presents the monthly climatology of average minimum surface air temperature, average mean surface air temperature, average maximum surface air temperature, and precipitation in Ghana from 1991 to 2022. It reveals significant seasonal variations in temperature and precipitation. The average maximum surface air temperature peaks at around 35°C in March and April, with a secondary peak in November. The lowest maximum temperatures, around 31°C, occur in August. Similarly, the average mean surface air temperature follows this trend, reaching its highest at approximately 30°C in April and October and its lowest in August. The average minimum surface air temperature peaks at about 25°C in April and October, with the lowest values, around 22°C, in August.

Precipitation patterns exhibit a marked seasonal variation, with the highest rainfall occurring in June and September, reaching up to 200 mm. The dry season spans from November to March, with January and February

experiencing minimal rainfall, close to 0 mm. The wet season extends from April to October, characterized by significant rainfall, essential for agricultural activities and water.

Figure 11 I Monthly Climatology of Average Minimum, Maximum, and Mean Surface Air Temperature.

Monthly climatology of Average Minimum Surface Air Temperature, Average Mean Surface Air Temperature, Average Maximum Surface Temperature & Precipitation 1991 – 2022; Ghana



Source: Climate Change Knowledge Portal

6.2 Observed Climate Trends

There is evidence of a temperature increase over the past decades for Ghana. Mean annual temperature has increased by about 1.0˚C since 1960, an average rate of 0.21˚C per decade, with the strongest increase between April and July (+0.27 °C per decade). The rate of increase has been more rapid in the north of the country than in the south. Moreover, the number of 'hot'[6] days has increased significantly in all seasons except between December and February, and 'hot nights' has increased significantly in all seasons (by 13.2% and 20% respectively between 1960 and 2003), while the number of 'cold' days and 'cold' nights[7] has decreased (by 3.3% and 5.1% respectively over the same period).

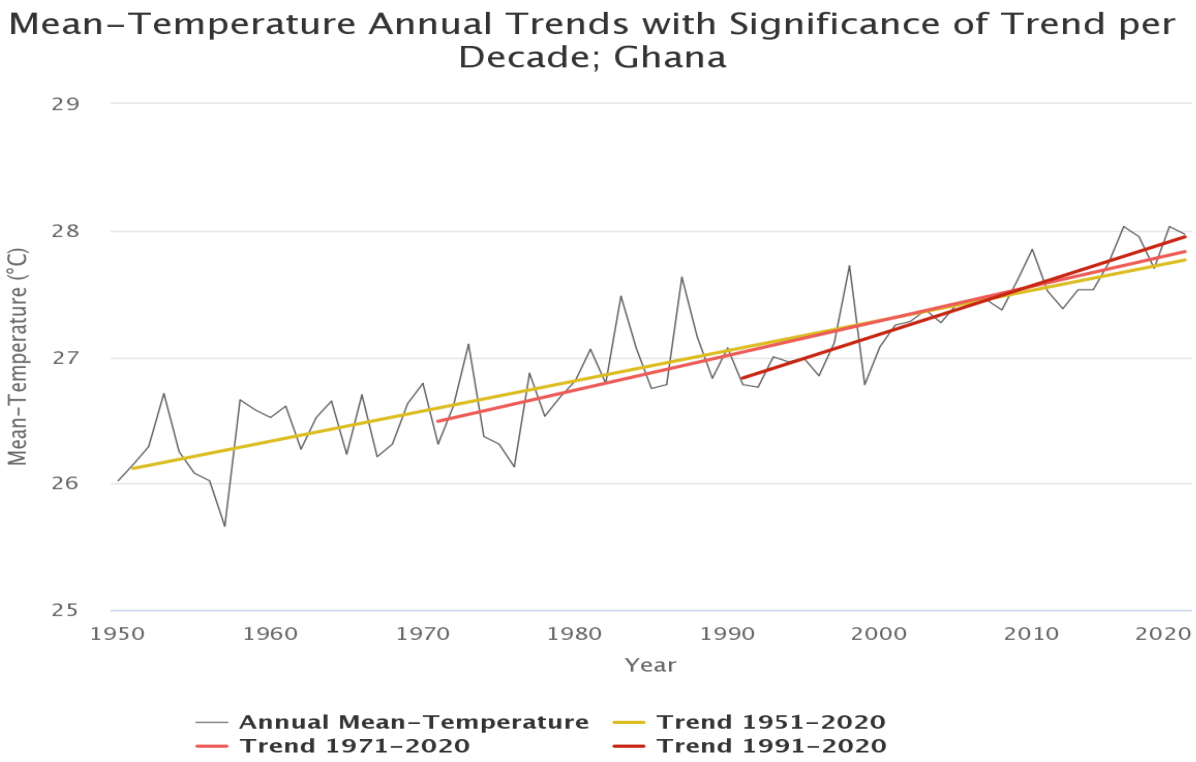
The increase in average annual temperature[8] is shown in Figure 12 while the increase in the number of days with a heat index of above 35°C are shown in 13. Each show increases that are significant.

6 'Hot' day or 'hot' night is defined by the temperature exceeded on 10% of days or nights in current climate of that region and season.

7 'Cold' days or 'cold' nights are defined as the temperature below which 10% of days or nights are recorded in current climate of that region or season.

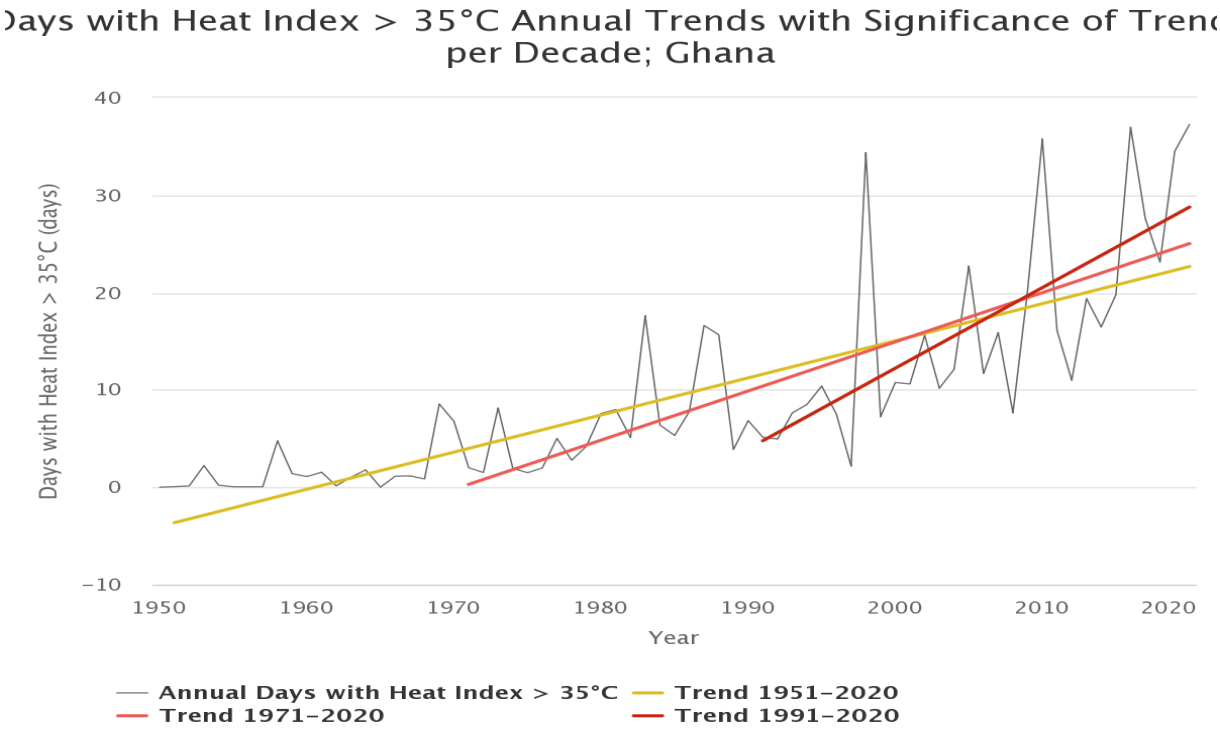
8 Data used is derived from the ERA5 reanalysis (here used at 0.5° x 0.5° resolution) and summarised for the whole of Ghana as part of the World Bank Climate Change Knowledge Portal (CCKP).

Figure 12 I Mean Annual Temperature trends for Ghana.



Source: CCKP.

Figure 13 I Days with Heat Index > 35 C trends for Ghana. Source: CCKP



The observed trends in mean annual precipitation for Ghana from the CCKP are shown in Figure 14 and while these do show slight negative trend over the long term it is not considered to be significant. It is also important to note that there has been a gradual increase in annual precipitation since around 2000.

These results seem to contradict previous studies which suggested “a well-defined cumulative reduction of 2.4 percent per decade” (USAID, 2017) and suggest even a possible increase in future rainfall. In contrast, the observed changes in maximum daily rainfall, shown in Figure 9 do show a significant increasing trend for Ghana from around 1990. This is an indication that even while there is uncertainty about overall rainfall, increasing rainfall intensity and flooding may become more significant for Ghana

Figure 14 I Annual precipitation trends for Ghana. Source: CCKP

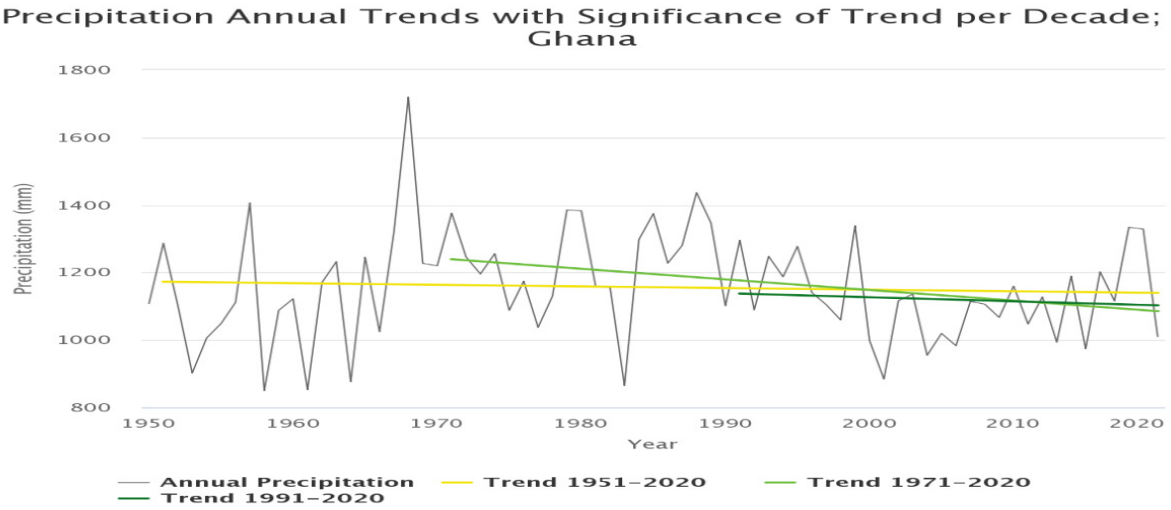


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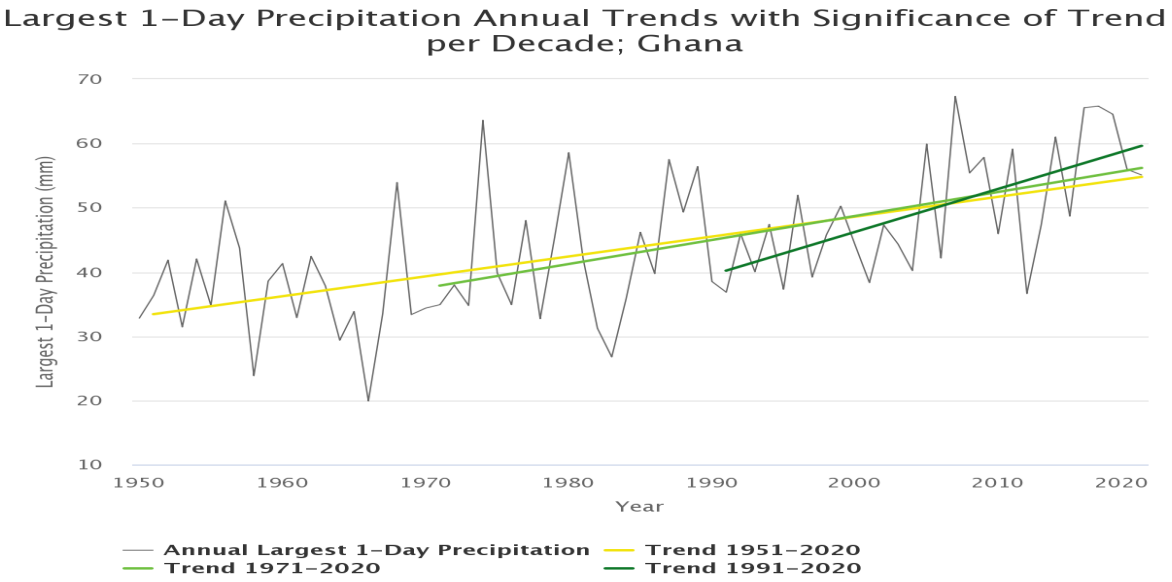
Figure 15 I Annual largest 1-day precipitation trends for Ghana. Source: CCKP



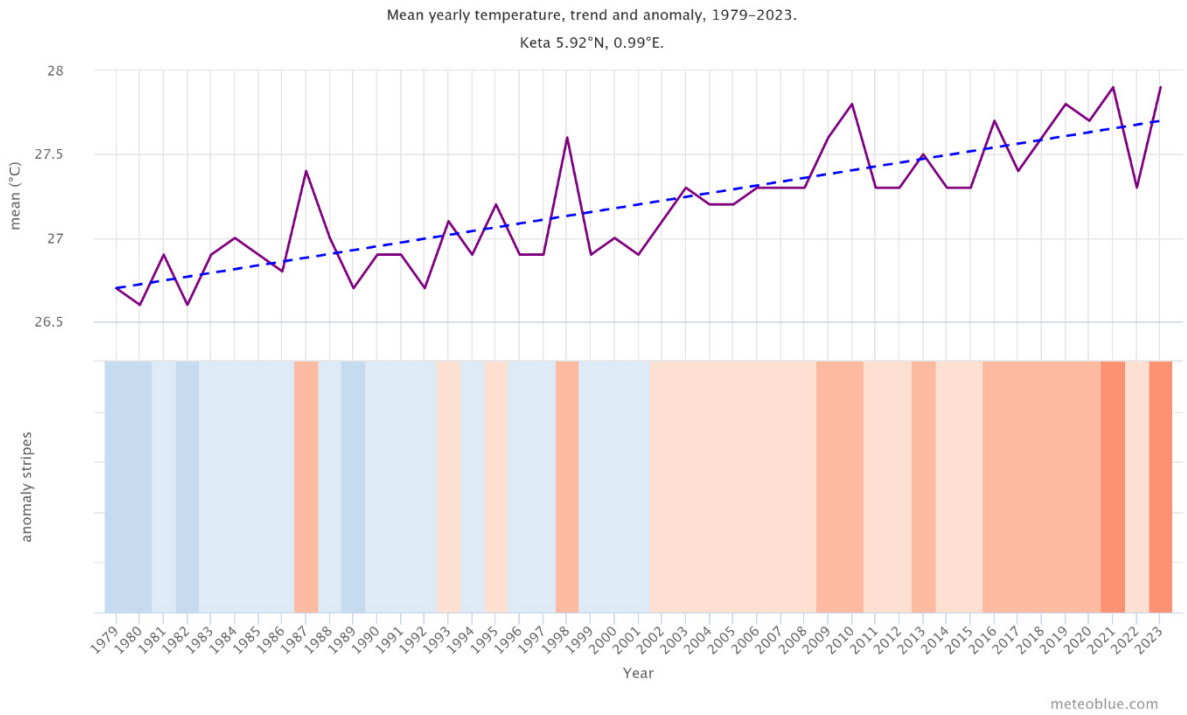
6.3 Local Level Observed Climate and Trends

The analysis of mean yearly temperatures in Keta, Ghana, from 1979 to 2023 reveals a clear warming trend (Figure 16). The data shows that the mean yearly temperature has increased from around 26.5°C in the early

1980s to approximately 27.5°C by 2023. This represents a significant rise of about 1°C over the 44-year period, highlighting the impact of global climate change on local temperature patterns.

The temperature anomalies further illustrate this warming trend. The early years of the dataset, from 1979 to the mid-1990s, are predominantly marked by blue stripes, indicating years with below-average temperatures. However, from the late 1990s onwards, there was a noticeable shift to red stripes, signifying years with above-average temperatures. This transition from cooler to warmer anomalies underscores the ongoing changes in the local climate.

Figure 16 I Mean yearly temperature, trend, and anomaly in Keta municipal.



Source: meteoblue.com, 2024.

The analysis of mean yearly precipitation in Keta, Ghana, from 1979 to 2023 indicates a stable overall trend in rainfall levels, with the annual precipitation consistently hovering around 900-1000 mm. The data, represented by a solid purple line and a dashed blue trend line, reveals no significant long-term increase or decrease in precipitation over the 44-year period. This stability suggests that the region's total annual rainfall has remained relatively constant over time.

Despite the stable long-term trend, the year-to-year variability in precipitation is notable. The lower section of the chart, which uses color-coded stripes to show precipitation anomalies, highlights this variability. Years with below-average rainfall are marked in shades of blue, while years with above-average rainfall are indicated in shades of brown and yellow. This pattern of alternating colors illustrates the significant fluctuations in yearly precipitation, with some years experiencing markedly higher or lower rainfall than the average.

From 1979 to 1990, the data shows considerable fluctuations in precipitation, with several years of below-average rainfall interspersed with years of above-average rainfall. The period from 1991 to 2010 continues to exhibit variability, although the deviations from the mean appear less extreme compared to the earlier years. In the recent period from 2011 to 2023, the variability persists, with notable fluctuations including consecutive years of below-average rainfall around 2012 to 2014.

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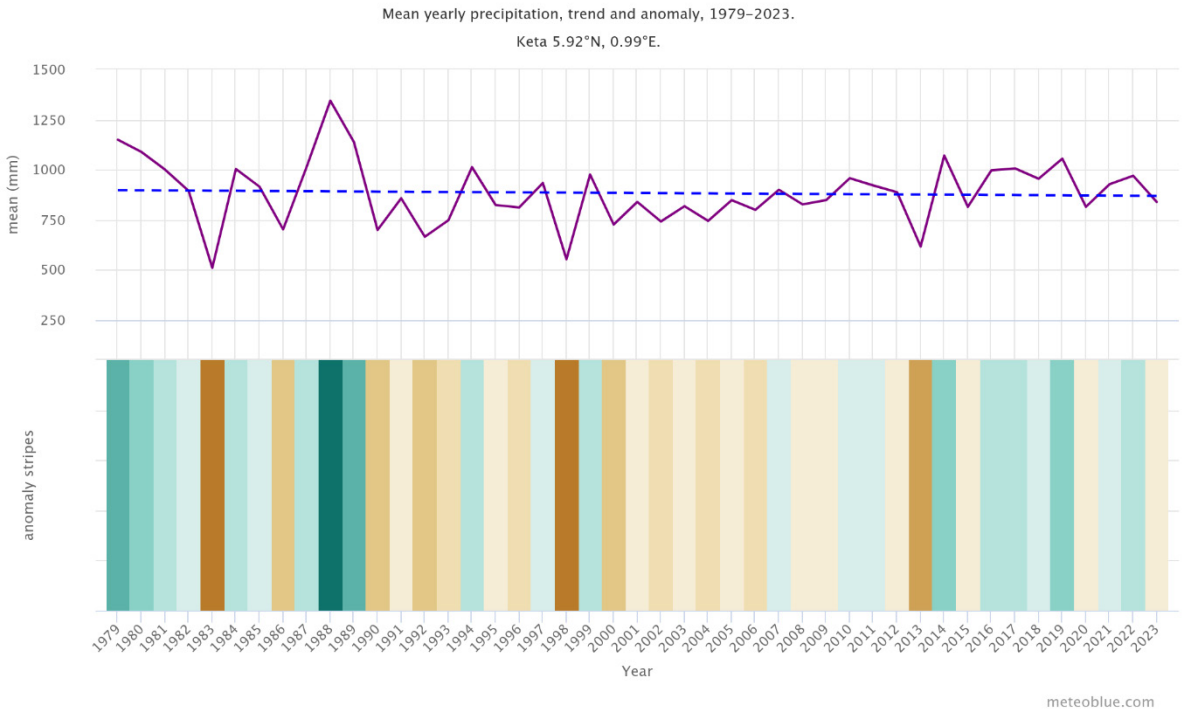
Figure 17 I Mean yearly precipitation, trend and anomaly in Keta municipal.

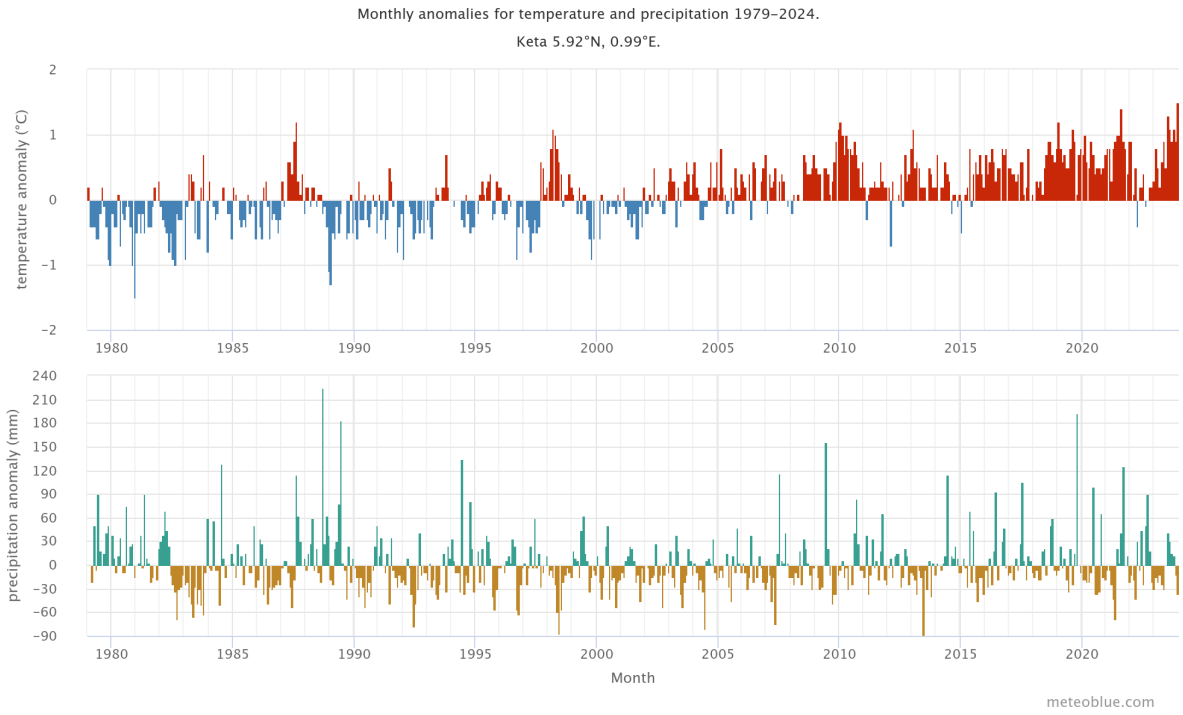


Source: meteoblue.com, 2024.

Figure 18 reveals monthly anomalies for temperature and precipitation in Keta, Ghana, from 1979 to 2024. The temperature anomalies, represented by red and blue bars, indicate periods of above and below average temperatures, respectively. From 1979 to the mid-1990s, there is a balanced distribution of positive and negative temperature anomalies. However, from the mid-1990s onwards, the data shows a clear shift towards more frequent and higher positive anomalies, suggesting a warming trend. This indicates that Keta has been experiencing more months with above-average temperatures, particularly after the year 2000, reflecting broader global warming patterns.

In contrast, the precipitation anomalies, depicted by green and brown bars, show significant variability without a clear long-term trend. Positive anomalies indicate months with above-average precipitation, while negative anomalies represent below-average precipitation. Throughout the observed period, there are alternating periods of wetter and drier months, with no consistent pattern emerging. Notable wet periods, such as the early 1980s and mid-1990s, contrast with significantly dry periods, like the late 1980s and early 2000s. This variability highlights the unpredictability of rainfall patterns in Keta.

Figure 18 I Monthly anomality's for temperature and precipitation Aowin municipal.



Source: meteoblue.com, 2024.

Analysis of drought conditions

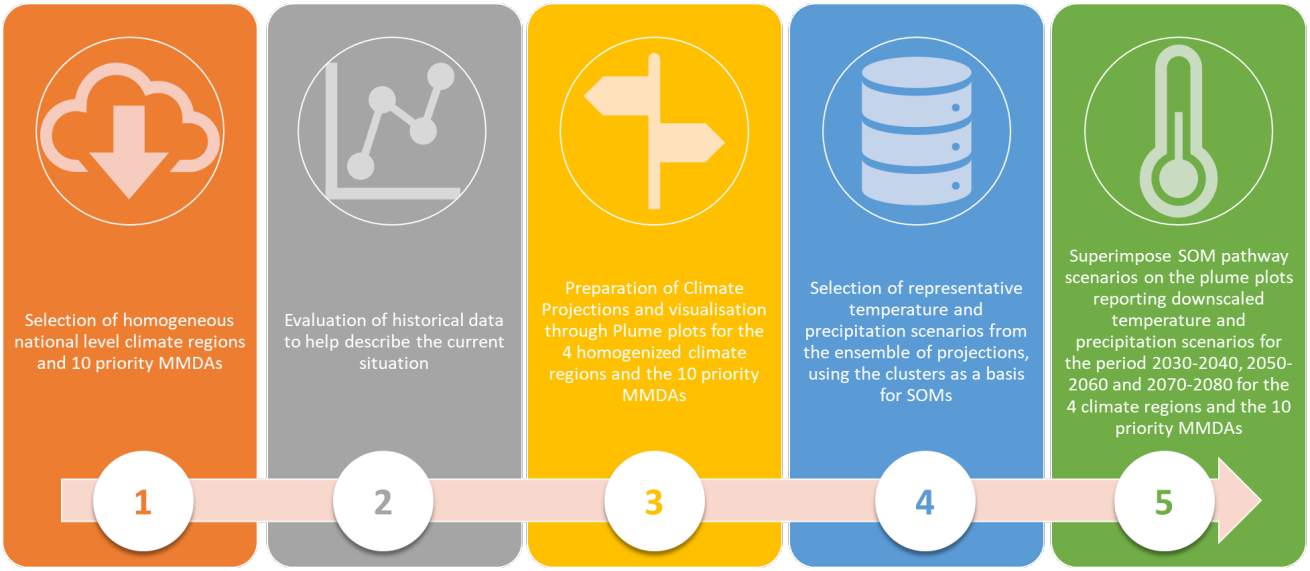
A study by Tettey (2012)[9] on the rainfall patterns in the southeastern coast of Ghana, which includes Keta, highlights the frequent occurrence of droughts. The research used Markov Chain analysis to predict dry and wet spells, emphasizing the high probability of dry days in Keta, indicating a susceptibility to drought conditions

6.4 Future Climate Change Projections

This assessment adopts the analysis of future climate change scenarios under the National Climate Change Risk Assessment by UNEP in Ghana.

The overall approach for the analysis of climate change scenarios is summarized below:

9 Tettey, M. (2012). Markov Chain Analysis Of Rainfall Pattern In The South Eastern Coast Of Ghana (Doctoral dissertation).



Clustering of current climate and expected changes in climate variables based on the downscaled climate scenarios from the CORDEX data set were used to identify four homogeneous climate zones. The district under consideration, Keta Municipal belongs to the coastal climate region/zone and projections in this region are therefore applicable to this region.

Overall trends in expected climate change for the remainder of the century are summarised in Figure 19 and in the table 5 below, based on CMIP5 ensemble mean results, in terms of the degree Celsius (°C) change per decade for annual average temperature and the percentage change per decade in annual rainfall, with significance at the 5% level in bold italics.

Table 5 I Overall trends in climate for the remainder of the century in °C/decade and %/decade

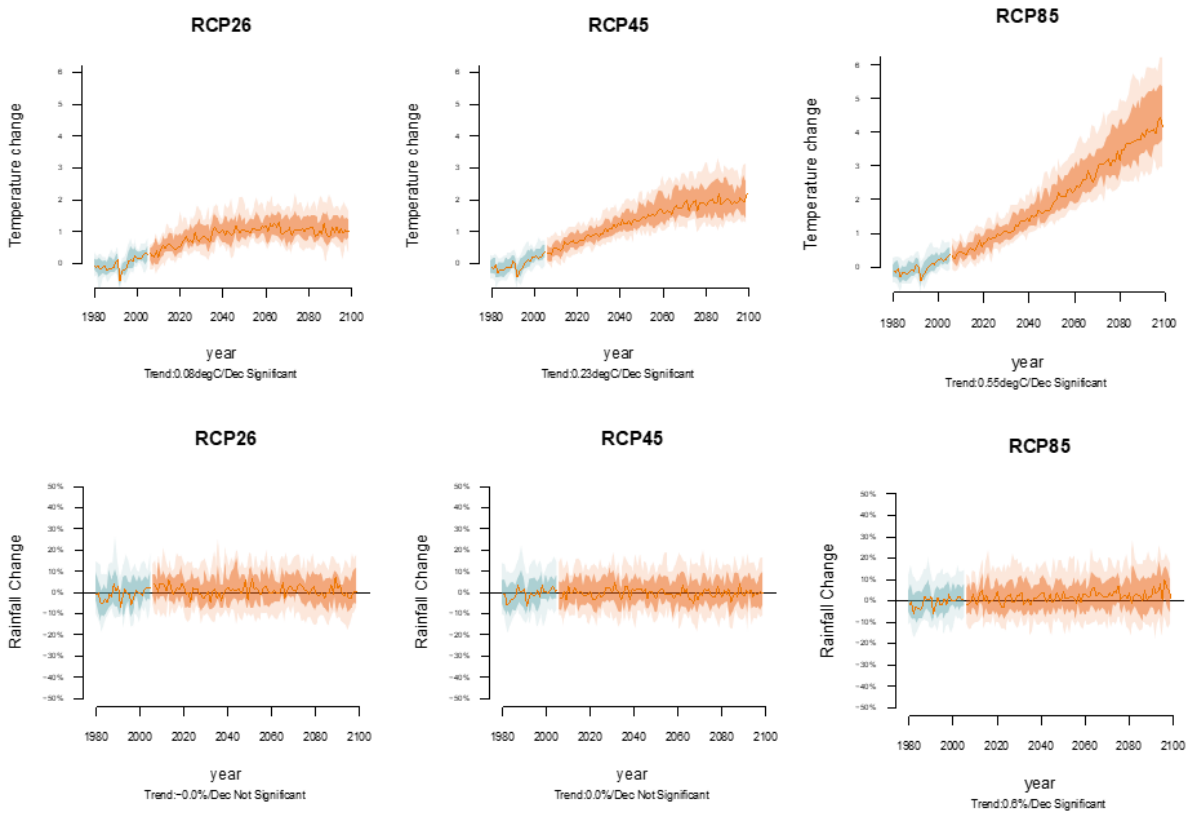
	Temperature °C/decade			Rainfall %/decade		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
North	***+0.09***	***+0.24***	***+0.57***	–0.1 %	+0.1 %	***+0.6 %***
Central	***+0.08***	***+0.23***	***+0.55***	–0.0 %	+0.0 %	***+0.6 %***
Southwest	***+0.08***	***+0.23***	***+0.52***	+0.1 %	+0.1 %	***+0.6 %***
Coastal	***+0.08***	***+0.22***	***+0.50***	–0.1 %	***+0.3 %***	***+0.8 %***

Note: Analysis based on average across all CIMP5 climate models, significance at the 5% level in bold and italics.

Temperature changes in all four zones are similar, with most trends, other than under RCP2.6, statistically significant. Under RCP2.6 the increases tend to plateau after mid-century; there is also some plateauing in the final two or so decades under RCP4.5 but temperatures increase throughout the century under RCP8.5, reaching an average rise of almost 4°C. Projected temperature trends are strongest in the North Zone, but only under RCP 8.5 with little difference for RCP 2.6 and RCP 4.5.

Only non-significant trends in changes in annual **rainfall** totals are present for most zones under RCP2.6 and RCP4.5, with statistically significant positive trends under RCP8.5 across all four zones. The strongest trends in rainfall are for the **Coastal Zone,** significant under RCP 4.5 and RCP 8.5.

Figure 19 | Time series of temperature (top) rainfall (bottom) changes across the coastal zone for RCP2.6. RCP4.5 and RCP8.5 up to 2100 using the full CMIP5 ensemble.



In terms of the results of the analysis of changes in extreme events:

- **Higher annual average temperature** values occur, as expected, with increasing emissions.
- There are **no clear trends in return values for the driest annual events**, suggesting limited, if any, change in drought occurrences and magnitudes, although when combined with an increasing trend in average annual temperatures, could result in an increasing risk of drought.
- There is a **possible trend, although not significant, towards increased return values for the wettest years**, *perhaps* indicating the prospects of increased flood risks.

Estimates have been made of the **changes in likelihoods of 2- and 3-year sequences** of average annual temperatures and rainfall totals exceeding certain thresholds, based on climate during the base period of 1986 to 2005. For temperatures, the thresholds are for 2- and 3-year successive breaches of 2 and 3 standard deviations defined annually historically. For dry events, the thresholds are the driest 10% and 25% of years historically. For wet events, the thresholds are the wettest 10% and 25% of years during the base period. The results are shown in Figure 20 and summarised below:

- In all zones, likelihoods under RCP 8.5 reach 100% by mid-century for 2-year sequences of temperatures above the 2 standard deviation thresholds, with 3-year sequences close behind. In other words, **the results point to certainty that there will be multi-year sequences with average annual temperatures of magnitudes currently in the warmest 16% and 2.5% of years.** Results are similar under RCP4.5 but reach 100%, or close by, only towards the end of the century. For RCP2.6 likelihoods approach around 50% in mid-century but reduce somewhat later. In summary, **it is certain that multi-year sequences with temperatures in the upper ranges of those currently experienced will occur, the more so with higher emissions.**
- For both the dry 10th and 25th percentiles there are **statistically significant positive trends**, indicating extended dry annual sequences, particularly for the 25th percentile metric (Note: the return values analysis suggested that overall, there is little risk of increased overall drought occurrences and magnitudes defined in terms of changes in mean annual precipitation only, but these results are not contradictory). **Positive trends** are present also for the wet 75th and 90th per-

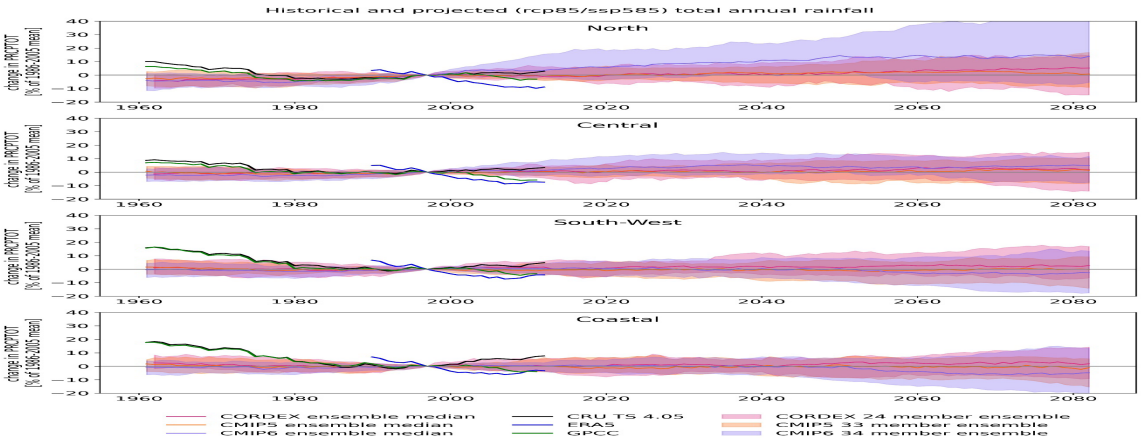
centile metrics, more so for the former. All trends are **most prominent under RCP8.5** and in the Southwest and **Coastal Zones**. **These results suggest a widening of the range of annual rainfall totals under climate change, more so towards wetter years than dry years.**

Summary of Results for the Four Climate Zones

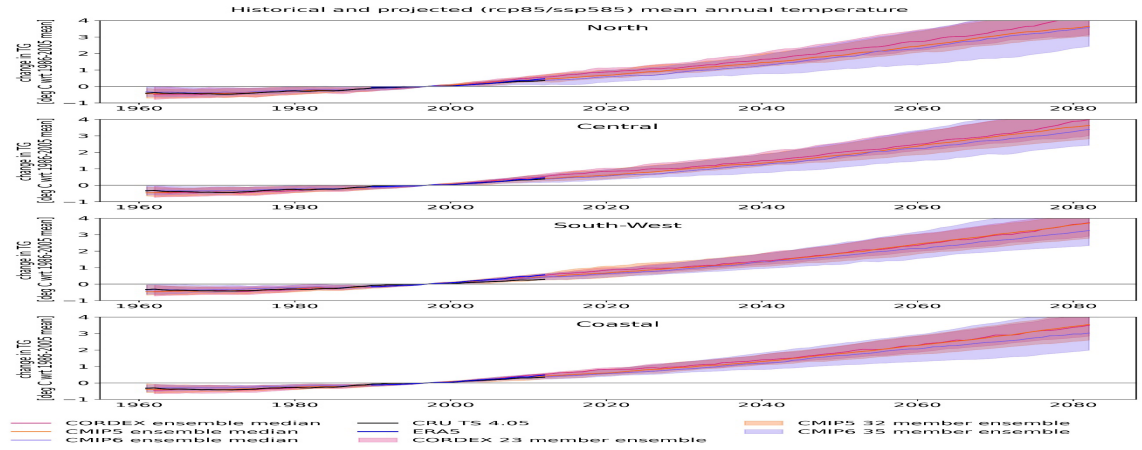
Individual SOMs analysis and the comparison of model projections using plume plots were undertaken for the four climate zones. Representative results for the comparison of the SSP5-8.5 model projections for the coastal zones is shown in Figures below.

Figure 20 | Projected change in mean annual temperature for all climate zones – RCP8.5/SSP 5 85

Historic and projected (RCP 8.5/ SSP5-8.5) mean annual temperature



Historic and projected (RCP 8.5/ SSP5-8.5) mean annual temperature



This zone will see **temperature** increases from between 1.5 °C under RCP 2.6 to 3 /4.5 °C under RCP 8.5 with RCP 4.5 suggesting a mid-point of about 2.0 °C. As usual RCP 8.5 represents step change in temperature. However, the plume plots particularly when incorporating CMIP 6 suggest an even greater increase of temperature of at least another 0.5 °C. In short there is a risk of significantly higher temperatures in the Coastal Zone even at lower GHG concertation scenarios under CIMP 6.

There is a roughly equal chance of small increases and decreases in annual average **precipitation** compared to the base years. Typically, around a 10% increase or decrease in mean annual precipitation (MAP). The extremes suggest that the change is possible of up to +/- 20% in MAP. The plume plots suggest there is a relatively good match in the precipitation scenarios and the plume plots suggesting that the scenarios do a relatively good job of capturing the possible variation at RCP 2.6 but not RCP 4.5 or 8.5 where there is chance of significant increases in rainfall - possibly 20-30% greater increases.

7 Potential Impacts for Priority Risk Domains

The potential impacts of climate change on the priority risk domains are described here, including:

- Water Resources
- Coastal Flooding
- Flooding
- Ecosystems
- Crop production
- Transport Systems
- Settlements
- Gender Implications
- Fisheries

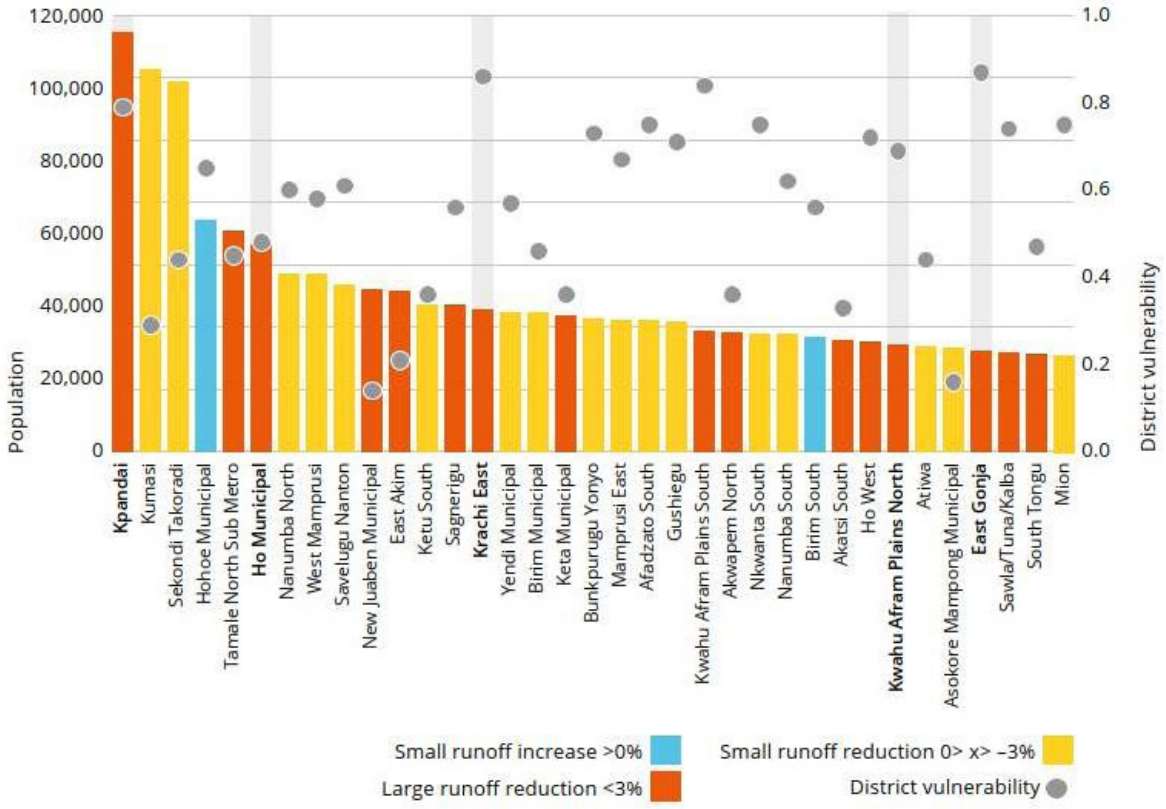
7.1 Water Resources

The main drainage basins are the lagoons. The major lagoons include Keta, Angaw, Agbatsivi, Logui, Nuyi and Klomi. Into these basins drains some streams and tributaries of the Volta River. In recent years the volume of water in the lagoons has drastically reduced leading to the emergence of several islands in the Keta, Angaw and Agbatsivi lagoons. The biggest among the islands are Seva and Dudu, which are partially inhabited.

Climate change is expected to contribute to a large reduction in runoff for the area around KeMA (Figure X). This is largely due to increased variability in rainfall and higher temperatures. Because the Keta Lagoon is largely river fed it is dependent on rainfall and changes in the human uses of water upstream. In the dry season the Lagoon shrinks significantly, and when there is severe drought, it may recede over 1 km (Damptey and Essel, 2014). Even with a potential increase in the likelihood of wetter climate scenarios, higher temperatures and associated increases in evapotranspiration will likely result in an overall reduction in mean annual runoff except during periods of very high flow which will causing increased risk of flooding. This will impact on local surface and ground water resources, but not necessarily on larger integrated water supply systems. Michael and Cobbina (2020) reported that many streams found in the municipality are dwindling in size due to low rainfall, excessive evaporation and siltation. More variable rainfall could contribute to an overall reduction in the availability of surface water (and potentially also groundwater) particularly if there is limited storage capacity or effective water resource management. As more intense rainfall increases the surface runoff increases too, contributing to erosion of the topsoil and sedimentation in the riverbeds. Reduced rainfall could limit ground water recharge and exacerbate saline intrusion and reduce of vegetation cover. Additionally reduced rainfall could also reduce dilution of contamination/pollution in the rivers thus worsening water quality. Reduced availability of potable water worsens the plight of the gender vulnerable groups.

The intrusion of seawater in the soil threatens biodiversity along with crop yields, and the leaching of salts from areas affected by these processes would increase the salinity of water bodies nearby, destroy infrastructure and the economy in the long run. Over the coming decades, changing climate, growing coastal population, and increased sea-level rise will raise the salinity of the coastal zone aquifers of Ghana, affecting in various ways its population (UNESCO-IOC, 2021).

Figure 21 I Climate change risk for water resource availability for selected MMDAs



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

7.2 Coastal Flooding

Globally, coastal flooding affects coastal areas due to sea level rise. Coastal areas serve as homes for about 2.4 billion people (40% of the world's population) (Braun, 2021), as well as provide high economic value to coastal countries. Over the 21st century, projections have shown that sea level rise would increase the rate of coastal flooding globally (Peter Sheng et al., 2022). This would possibly displace most people living in low-lying coastal zones and impact socio-economic and ecological systems of great importance, particularly in Africa (Dada et al., 2021). Like low-lying sandy coasts around the world, the Ghanaian coast is experiencing increasingly frequent coastal flooding due to climate change, putting important socioeconomic infrastructure and people at risk. The eastern coast of Ghana is known to be the most vulnerable coast in Ghana. It experiences coastal flooding not less than twice every year (Appeaning Addo, 2018).

In addition, the frequency and intensity of coastal flooding and erosion have increased. Over the past decade, the Volta Delta has significantly experienced coastal flooding events and duration. Some studies have attributed this to intensive rainfall, oceanographic conditions (waves, sea level rise, and tides), and human activities (watershed management) (Appeaning Addo, 2018). On the other hand, the construction of the Akosombo dam on the Volta River has been identified as a major cause of erosion and flooding problems in the Volta Delta region (Anthony and Patterns, 2015; Appeaning Addo, Brempong and Jayson-Quashigah, 2020). In

particular, the Keta District has been affected by coastal erosion and flooding. For this reason, one of Ghana's largest sea defenses was constructed from 2000 to 2004 to control coastal erosion and flooding. Persistent coastal erosion with erosion rates and sand deficit, estimated between 2 and 7 million of cubic meters of sand per year, led to a number of severe impacts such as the displacement of most coastal communities, gender vulnerable groups and destruction of commercial activities (especially as ships no longer docked at Keta), loss of educational, residential, historical, social and cultural edifices and the siltation of the lagoon basin[10].

Table 6 | The occurrence of coastal flooding was obtained from NADMO from 2002 to 2015. All data sets were collected by observing flooding and reporting by the NADMO office in Keta, Ghana.

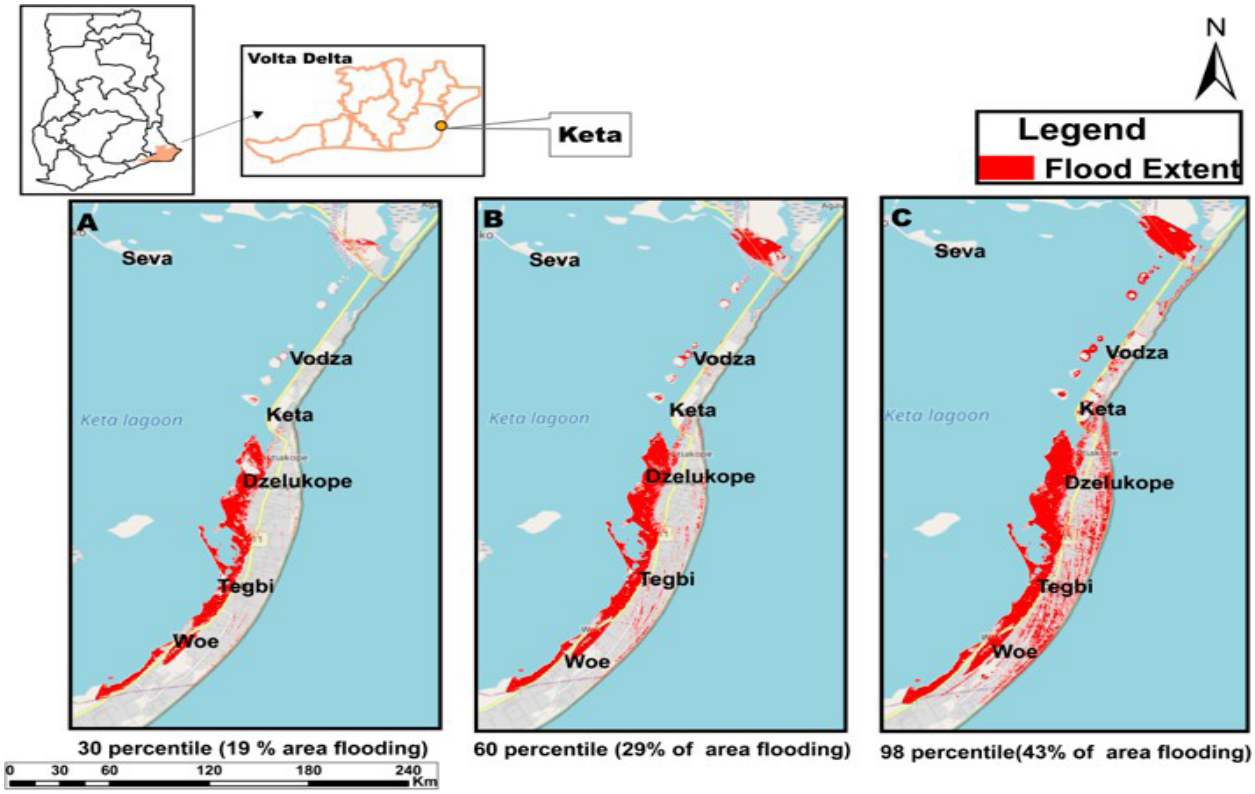
Year of Occurrence	Month of Occurrence
2002	August
2003	September
2004	July
2005	July
2006	September
2007	July
2008	August
2009	September
2010	August
2011	July
2012	June
2013	July
2014	August
2015	September

Adapted from Brempong et al., 2023.

A study by Brempong et al. (2023), mapped potential flood extent zones in Keta using the Pleiades satellite-derived digital elevation model topography. The results revealed that the highest percentage (43%) of the area flooded was recorded in the 98th percentile. The 30th and 60th percentiles showed that 19% and 29% of the area would potentially be flooded, respectively.

10 https://documents1.worldbank.org/curated/en/541981527661149414/pdf/Fighting-coastal-erosion-in-Keta-area.pdf

Figure 22 Mapped potential flood extent zones in keta using the Pleiades satellite-derived digital elevation model topography



7.3 Settlements

Coastal towns like Keta and Ada are being washed away by aggressive sea waves. A study revealed that erosion is having a huge impact on houses in the Keta municipality as over 40% of houses are deemed bad or dilapidated due to erosion. Women and children form the basis of every household; thus, this resettlement will impact them the most. The study revealed an annual erosion rate between 1986 and 2000 to be 5.0 m per annum with accretion of 7.0 m (Adu-Gyamfi, Shaw and Yan, 2020). However, the accretion rate is concentrated in specific areas representing just 15% of the shoreline. Areas along the 83rd transect experienced higher accretion and these extreme land gains may have contributed to the overall higher accretion rate. On the other hand, areas within the 40th transect experienced the highest erosion. The percentage of the shoreline experiencing erosion is 85. These areas are within Keta and Kedzi respectively. Although the rate of erosion is considered reduced from initially predicted 2 m–1.5 m pa (per this study), its impact on houses is highly fueled by the spatial coverage of the erosion (about 60% of the shoreline) and how the houses are spatially distributed near the shoreline. Aerial photo comparison between 2004 and 2016 also shows how closer the sea is getting to the communities with some houses in 2004 being abandoned in 2016. Rising sea levels as a result of climate change will continue to affect low-lying coastal settlements such as Keta.

Figure 23 I Aerial photo comparison between 2004 and 2016 that shows how closer the sea is getting to the communities.

Source: Adu-Gyamfi, Shaw and Yan, 2020

7.4 Flooding

The Keta municipality sandwiched between the Keta Lagoon and the Gulf of Guinea to the south experiences both floods from the lagoon and the sea as discussed in the section above. This section focuses on floods from Keta lagoon. The Keta Lagoon floods its banks and as a consequence leads to destruction of lives and properties. There are seasonal inflow of sea water during high tide from the Gulf of Guinea and regular inflow of rivers. The rivers which drain into the lagoon include the Aka, the Tordzi River and Belikpa stream which enter the lagoon from the north. The lagoon is surrounded by many settlements. The towns include Anloga, Woe, Keta and Kedzi to the south, Anyako and Anlo Afiadenyigba to the north, Kodzi, Alakple and Tregui to the west and Denu and Adina to the east. The drivers of lagoon flooding are both natural and human induced.

The first natural cause of lagoon flooding is the incidence of heavy rainfall (Anokwa, Martin, & Muff, 2005). This is a generally common cause of lagoon flooding. Heavy rainfall raises the water level of the lagoon beyond the carrying capacity of the channels subsequently leading to the overflowing of excess water first onto the immediate floodplains and later, beyond (Appeaning, Lloyd, Amisigo, & Ofori-Danson, 2011). This is a common cause of lagoon flooding in Ghana, and Keta to be specific. The Keta Lagoon which is a major water draining the town centre usually cannot contain all the water in its channel after a heavy downpour of rain thereby causing flooding. It is worth noting that this is reinforced by the influence of human activities.

The recent spillage from the Akosombo and Kpong dams that increased the volume of the Volta Lake and caused devastation at Mepe and other Tongu towns also increased the volume of the Keta Lagoon. This

resulted in flooding in the homes, farms and schools in Keta and surrounding areas[11]. In response, authorities in Keta have opened the Keta Lagoon floodgates to mitigate rising water levels that have caused flooding in parts of the town. The floodgates and a sandbar at Azizadzi were opened to allow excess water from the lagoon to enter the sea on Monday, October 23, 2023. The move was expected to also eventually mitigate the devastating flooding in Tongu towns following the spillage from the Akosombo Dam.

Secondly, the nature of relief is also a natural cause of lagoon floods. Flooding is prevalent in low lying areas or lowlands. Since rivers flow more slowly in such areas, if the water volume increases abruptly or suddenly, floods occur. In the Keta municipal for example, the terrain is generally not undulating flat land. Most communities along the Keta lagoon which get flooded lie in the Lagoon valley. Coastal Flooding occurs by virtue of the fact that the sea level at a point in time is higher than the adjoining coastal area. Thus, lagoon flooding occurs because land lying close to the sea can be submerged by sea water during high tides, tsunamis or storms. A typical example is that which occurred on the 5th of September, 2008 in parts of the Keta municipality in the Volta region of Ghana through high tidal waves (which is reinforced by rising sea levels). About 500 residents were displaced at Dzita and Atorko when the lagoon and sea water took over their homes leading to the eventual collapse of some houses.

Table 7. Records of flooding activities in Keta Municipality.

Date	Hazardous event	Impact	Reference
Oct, 2023	Akosombo and Kpong Dam spillage	Over 100 of residents rendered homeless	https://www.myjoyonline.com/akosombo-dam-spillage-keta-mp-threatens-legal-actions-against-vra/
Oct, 2023	Four hours of torrential downpour	Over 100 residents rendered homeless. Areas such as Vui, Tetekope, Abutiakope, Nukpesekope Kedzokope, among	https://gna.org.gh/2023/06/keta-hundreds-displaced-schools-homes-flooded-after-heavy-downpour/
Oct, 2018	Tidal waves leading to flooding	Over 5,000 Residents rendered homeless and disrupting economic and educational activities	https://www.modernghana.com/news/889320/keta-floods-renders-over-5000-residents-homeless.html
Nov. 2021	Tidal waves leading to flooding	Over 100 residences displaced.	https://www.youtube.com/watch?v=luUWzqyyNzI

11 https://yen.com.gh/ghana/244404-keta-lagoon-floodgates-opened-government-moves-prevent-flooding-part-volta-region/

Figure 24 I Aerial view of flood from Akosombo and Kpone village in Keta.

The surrounding wetlands of Lagoon are expected to play a critical role in flood management and mitigation through a combination of natural processes. They act as natural sponges, absorbing and storing excess rainwater and floodwaters, which helps to reduce the speed and intensity of floods downstream. However, human increasing exploitation of the lagoons and their resources has resulted in degradation and raised concerns about the long-term sustainability of these systems.

Projected climate change impacts, including erratic rainfall patterns, rainfall variability, and increased temperatures, pose significant challenges to the Keta Municipality, particularly in exacerbating flooding events from the Keta Lagoon. The expected increase in intense precipitation events can lead to more frequent and severe flooding, affecting surrounding settlements through the destruction of property and livelihoods. Simultaneously, higher temperatures may alter the lagoon's hydrology, leading to increased evaporation rates and potentially higher salinity, impacting biodiversity and water quality. Such climatic changes also threaten the degradation of natural flood defenses like surrounding wetlands, reducing their capacity to absorb excess floodwaters. Additionally, these changes are likely to affect agricultural productivity and food security, while increasing the risk of waterborne diseases and displacement due to flooding, thereby compounding the social and health challenges for communities in the Keta Municipality.

7.5 Ecosystem

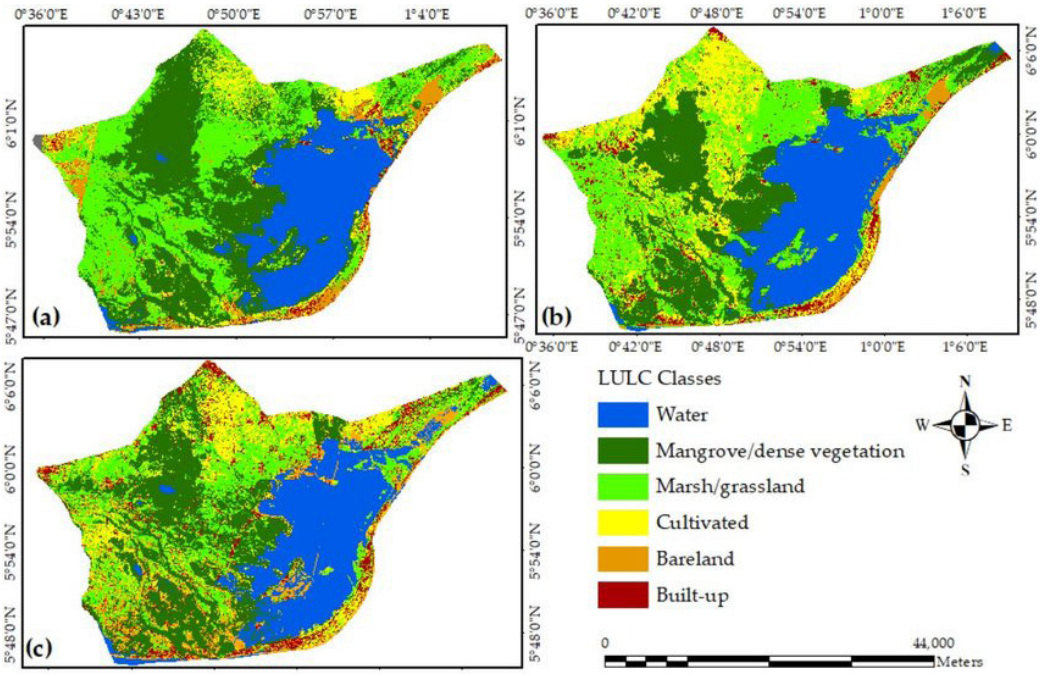
Biodiversity decline is a global phenomenon threatening the ability of ecosystems to provide the services on which humanity depends. Wetland fisheries are often considered a 'safety valve' for people who cannot access other sources of livelihood (Béné, 2006). Small-scale wetland fisheries provide nutritional security to poor households that lack adequate supplies of animal protein and sustain the livelihood of landless fishers who scarcely survive by fishing in depleted water bodies (Vass et al., 2009). Although wetlands provide habitat for 40% of all fish species, 20% of their biota fall under the most threatened components of global biodiversity, largely due to human-induced environmental degradation (Mattah et al., 2024). In Ghana, wetlands along the country's 550 km coastline form the basis for important small-scale fisheries. They serve as nursery grounds for some marine fishes, molluscs and crustaceans. Cichlid fishes of the genus Sarotherodon contribute significantly to the fresh and brackish water fishery of West Africa.

The Keta Lagoon Complex Ramsar Site (KLCRS) is the largest wetland in Ghana with a size of about 1010 km^2. The KLCRS stretches 40 km along the eastern coast of Ghana (Wiegleb et al., 2016) and across six districts and municipal areas with an estimated human population of about 900,000 in the last population census in 2021 (Ghana Statistical Service, 2021). The KLCRS covers part of the Volta River estuary, several small islands and a complex of lagoons, streams, rivers and creeks. The vegetation in the area is predominantly swamps, scrublands, and mangrove forests forming microhabitats for a variety of species. The Site supports 72 species of migratory and resident birds (Issaka, Makinde and Theuri, 2019) and provide habitat for Sitatunga (Tragelaphus spekii gratus), the only aquatic antelope in the world (McPherson et al., 2016). The sandy beaches of the Ramsar Site are also used as nest sites of various species of marine turtles [35]. The area is therefore one of the potential areas for ecotourism in Ghana (Brinks, 2017). The site is a biodiversity hotspot in Ghana, with records of sea turtles, shorebirds, reptiles, mammals, fish and macroinvertebrates (Boafo, 2023).

The lagoon complex supports livelihood opportunities for inhabitants, serving as considerable natural capital. Notable among the livelihood options are fishing, farming, mangrove harvesting and salt mining as the main occupations of inhabitants along the lagoon complex. However, the KLCRS is bedeviled with the natural threat of erosion and siltation, climate change in addition to anthropogenic threats to the environment and biodiversity. Within the economic sectors, there are differences in gender roles which lead to differences on the impact of these threats. For instance, the harvesting of mangroves is mostly done by the men while the women gather, arrange in canoe and sell the mangroves (The World Bank, 2023). Salt mining is largely undertaken by women (Brakopowers, 2021). Thus the variations on the impact of threats on economic activities influences the resilience of women and men differently.

The land use/land cover (LULC) map of KLCRS for three segment-years designed from the supervised classification of Landsat satellite images is depicted in Figure 25. The figure reveals dramatic changes in six major LULC categories of the KLCRS landscape during 1991–2007 and 2007–2020. However, the overall land change was slower in the first-time interval than in the second time interval. The intensive land transformation of the KLCRS landscape in the second time interval (2007–2020) is consistent with Ghana's economic and population growth rate, which has been well documented to be faster than Sub-Saharan Africa's average since 2007 (Aryeetey and Baah-boateng, 2016).

Figure 25 I LULC maps of Keta Lagoon Complex Ramsar Site for (a) 1991, (b) 2007, and (c) 2020.



Mangroves are at risk from climate change due to a variety of factors, as described in Duguma et al. (2022):

- **Rising sea levels** affect salinity and flooding of mangroves, which affect growth and survival
- **Extreme storms** can destroy canopies and uproot mangroves in extreme circumstances
- **Reduced precipitation** can lead to soil salinity increases beyond ranges healthy for mangroves
- **Increased temperature** alters the ability of mangroves to store carbon dioxide and affects photosynthesis and evaporation rates.

Further erosion may occur from higher precipitation events leading to stronger river flow upstream.

In addition to the challenges development pressures place on mangroves, much of the population associates wetlands with mosquito breeding and therefore is less inclined to participate in conservation efforts (Dadzie-Paintsil & Mensah, 2022). As climate change may also increase vector borne disease risk, this likely will continue to be a challenge.

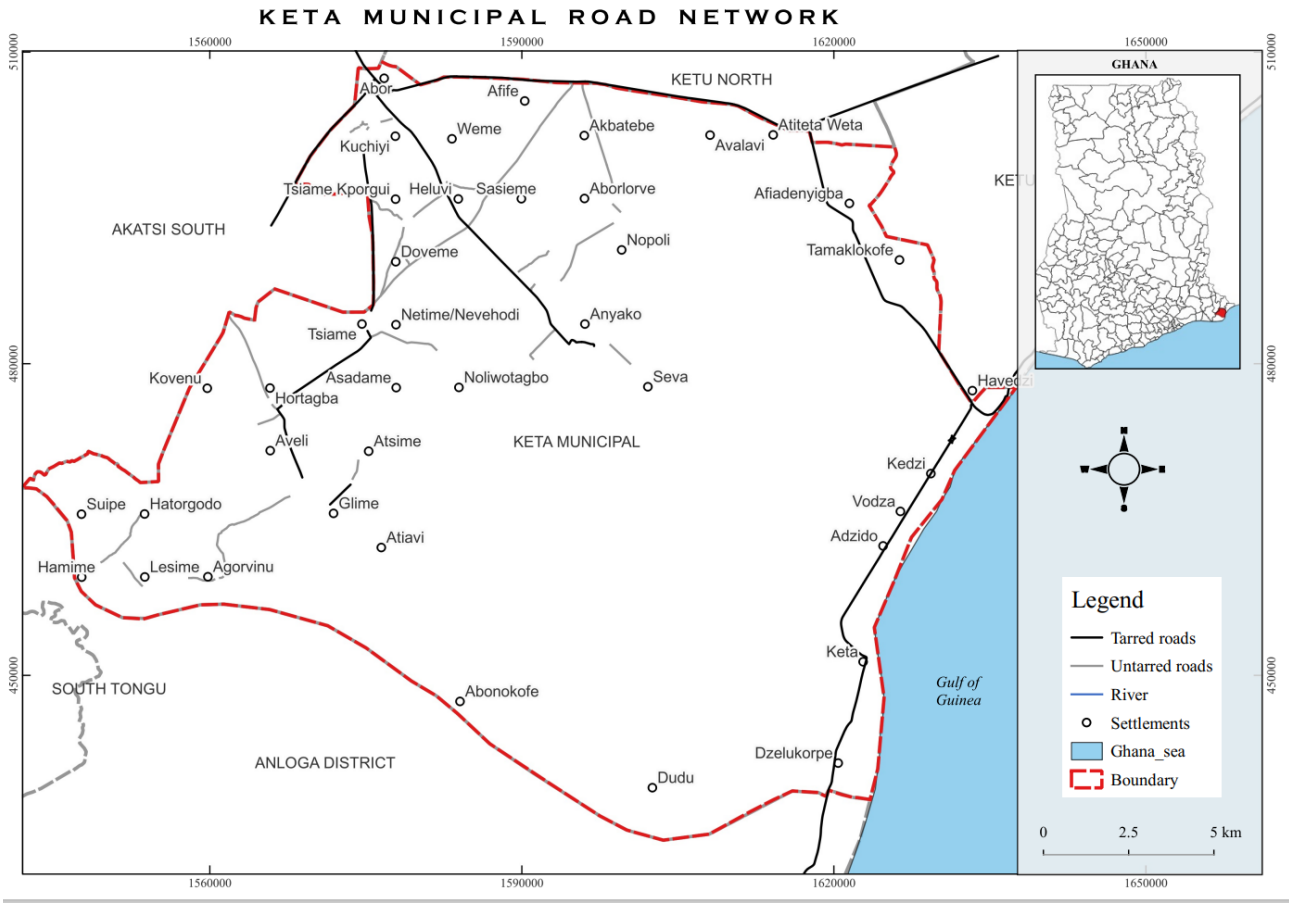
Marine ecosystems are also changing due to climate change due to rising temperatures, ocean acidification, and other effects.

7.6 Transport Systems

Transport infrastructures in the Municipality are mainly road and water. The first-class road (74.8km) traverses the coast from Havedzi through Keta-Anloga-Dabala to join the main Accra-Aflao road. The northern section of the Municipality between Abor and Anyako is accessible by second class road. The Keta-Aflao stretch of road which was completely destroyed by sea erosion between Keta and Horvi has now been constructed under the Keta Sea Defence Project by the Central Government. The complete destruction of the road halted affected mobility of children to schools, access to hospitals, markets and other social and economic amenities. Settlements in the north of the Municipality (Abor-Atiavi-Hatorgodo axis) are linked mostly by second class roads and are complemented by feeder roads. The middle and south western sections of the Municipality (Angaw and Klomi lagoon basin) are poorly accessible mainly by third class roads and footpaths. Generally, the Municipality is relatively more accessible as indicated by a relatively high road density of 194.7 meters/ km2.

This mode of transport is used for passenger and cargo services, passenger buses and mini-buses with a seating capacity of 16-40 are used for these services. Truck services are used to carry mainly tomatoes, shallots, salt and fish to outside the Municipality while manufactured goods and foodstuffs like rice, yams, maize and building materials are imported.

Figure 26 I Keta Municipal Road Network. (Source: KeMA MTDP, 2021)



7.6.1 Water transport

Lagoon transport, though important is poorly developed. In the case of water transport the services are privately owned. Non-motorized local canoes are used to transport goods and people across the lagoons. Another setback is the seasonal fluctuations in the water level, which render movement very slow and even cumbersome. The siltation of the lagoon has also generally reduced the water level. The major routes are Anyako/Seva-Anloga, Afiadenyigba-Keta-Anloga, Atiavi-Keta-Anloga, and Alakple/Kodzi/Fiahor-Keta-Anloga. The seasonal drying up of the lagoon makes water transport unreliable and time consuming as opposed to road transport (over 90 per cent of the population use road transport regularly). Increased temperatures coupled with variable and reduced precipitation could exacerbate challenges with lagoon transport.

Coastal and lagoon floods in the Keta Municipality significantly impact both paved and unpaved roads, leading to various forms of damage and disruption. Paved roads suffer from erosion and undermining as floodwaters erode their foundations, causing potential collapse. The surface of these roads can also be damaged by debris and sediment, while saltwater intrusion from coastal floods accelerates deterioration. Drainage systems may become overwhelmed, leading to waterlogging and further damage. Consequently, the lifespan of paved roads is reduced, necessitating increased maintenance and repair costs. Unpaved roads are especially vulnerable to washouts, with floodwaters sweeping away road materials and creating impassable gaps. These roads also experience compaction and rutting, making navigation difficult and hazardous. Erosion is a major issue, as the soil and gravel are easily displaced, and siltation from floodwaters can harden, creating uneven surfaces that complicate travel.

Overall, damage to transport infrastructure can increase traffic congestion and have other important socio-economic impacts (Cervigni, Losos, Neumann, & Chinowsky, 2016). Research by Twerefou et al. suggests that by 2100, damages to road infrastructure due to climate change could result in costs ranging from $4.7 million to $6.8 million for the country depending on adaptation responses (Twerefou, Chinowsky, Adjei-Mantey, & Strzepek, 2015). Additionally, an estimated 78,862 individuals could lose access to health care in the district due to the flooding of road networks (Adshead, et al., 2022).

Table 8 | Summary Description of Impacts of Climate Change on Roads

Road type	Climate stressor	Effect
Paved roads	Temperature	**Increased temperature leads to accelerated aging of binder**
		Increased temperature leads to rutting (of asphalt), andbleeding and flushing (of seals)
	Precipitation	**Increased precipitation leads to increased average moisture insubgrade layers and reduced load-carrying capacity**
	Flooding (in excess of designflood)	**Washaways and overtopping of road**
Unpaved roads	Temperature	**No effect**
	Precipitation	**Increased precipitation leads to increased roughness of the road surface, increased average moisture content in subgradelayers, and reduced load-carrying capacity**
	Flooding (in excess of designflood)	**Washaways and overtopping of road**

7.7 Fisheries

The Keta Municipality, with a vast coastline spanning over 60km, harbours rich aquatic resources, such as the sea, lagoons, and creeks, making it an ideal location for fisheries development. Historically, it boasted a diverse fish population, including species like sparidae, tuna, herring, tilapia, mullet, oysters, and shrimps. However, recent climatic changes and human activities have led to a decline in fish catches with a direct impact on the livelihood of fishermen, women (who are mostly into fish mongering and processing), and the youth who work for the fishermen and fish processors. In regions with significant lagoons like the Keta municipality, climate change impacts have altered freshwater flows, leading to increased saltwater intrusion into the lagoons. This, combined with changes in environmental factors like temperature, salinity, wind patterns, and ocean currents, has disrupted fish habitats and distribution (Urama & Ozor, 2010). Nii et al. (2020) noted that rising temperatures forced fish to move towards deeper waters, and the faster ice melting on fishing boats made it challenging to preserve freshly caught fish.

Mangrove forests, essential for fish habitats, are under threat from rising sea levels, which could submerge large portions of these vital ecosystems, endangering associated fisheries. The ongoing erosion of shorelines, as seen in Anyanui within the Keta coastal area, worsens this habitat loss (Awo et al., 2013). Unauthorized aquaculture, infrastructure development near wetlands, and the discharge of pollutants degrade wetlands, leading to a decline in fish stocks.

A study also found that most women involved in fisheries are poor and tend to manage large households (Okorley et al, 2006). More to the point, fish processing is now the province of an aging population of women and there is little evidence that the trade will be passed on to their children who show more interest in other economic activities. With the impacts of climate change, women who play an important role in the fishing industry either as intermediaries or through direct involvement with fishermen will see their income decrease significantly. As income levels for many involved in the fisheries sector decline (with the changes in the seasonality of fisheries and increased competition over resources from global players), so indebtedness is on the increase (Damptey and Essel, 2014). In some cases, this has led to the negative livelihood strategy of taking children from school and forcing them to work with their families. Taking into account the importance of the fishing industry to the economy, climate change impact will mean job losses and the increase in the price of fish generally, although local incomes from fishing will inevitably fall. (Nii et al., 2020). To rejuvenate the fisheries sector, comprehensive measures are essential, including restoring lagoons, promoting sustainable aquaculture, and implementing effective regulations to enhance fish yields and strengthen the sector's resilience.

7.8 Crop Production

The Municipality is one of the major vegetable producers in the Volta Region. It is well known for its shallots, which are produced in the flood plains along the Angaw and Keta Lagoons and streams. Maize and cassava are also grown as off-season crops, along the littoral but as main season crops in the northern parts of the Municipality. Coconuts are also grown in the inland parts of the Municipality around Afiadenyigba, Atiavi, Hatorgodo, Atsiame and Dorveme areas. Sugarcane is also a major crop extensively cultivated in the flood-prone mid-western parts of the Municipality, with the following major producing areas; Atiavi, Hatorgodo. Cowpea is also a major crop grown in the northern parts of the Municipality around Abor, Weme and other surrounding towns during the main cropping season. It is also grown along the littoral during off seasons as green manure. Sweet potato is one of the crops found all over the Municipality; however, the northern part of the Municipality grows it more extensively. The table 9 below presents details of the key indicators in the Agriculture Sector.

The key indicators highlight several climate change implications. The Keta Municipality's agricultural sector, characterized by the cultivation of vegetables, maize, cassava, coconuts, sugarcane, cowpea, and sweet potatoes, is particularly vulnerable to climate change due to its reliance on specific climatic and environmental conditions. The presence of flood plains, lagoons, and littoral zones amplifies these vulnerabilities. The limited number of extension officers exacerbates these vulnerabilities, reducing the community's ability to adapt to changing conditions. As climate change continues to affect the availability of arable land, water, and other resources, these indicators suggest that both exposure and vulnerability will likely increase, requiring targeted interventions to build resilience in the agricultural sector.

Table 9. Key Indicators in Agriculture

Indicator / Variable	Level of disaggregation	unit of measurement	2018	2019	2020	2021
Percentage of population in Agriculture (by sex)	Female	% (0-100)	26.09	26.09	10.16	10.68
	Male	% (0-100)	39.02	39.02	14.53	14.92
	Total	% (0-100)	65.11	65.11	24.69	25.6
Number of farmers	Female	Number	38515	38515	8011	8421
	Male	Number	57595	57595	11457	11763
	Total	Number	96110	96110	19468	20184
number of extension officers	female	Number	1	2	1	1
	male	Number	5	10	2	2
	Total	Number	6	12	3	3
Farmer - Extension Officer ratio	Ratio	Ratio	16018.33	8009.17	6489.33	6728.00
Proportion of arable land under cultivation	Percentage	% (0-100)	8.27	5.49	6.12	9.52
Number of Livestock Farmers	female	Number	9305	9305	6363	6363
	Male	Number	15845	15845	13524	13524
	Total	Number	25150	25150	19887	19887
Number of subsistence farmers	female	Number	36974	36974	7009	7306
	Male	Number	48114	48114	7989	8022
	Total	Number	85088	85088	14998	15328
Number of commercial farmers	Male	Number	1541	1541	1002	1115
	female	Number	9481	9481	3468	3741
	Total	Number	11022	11022	4470	4856

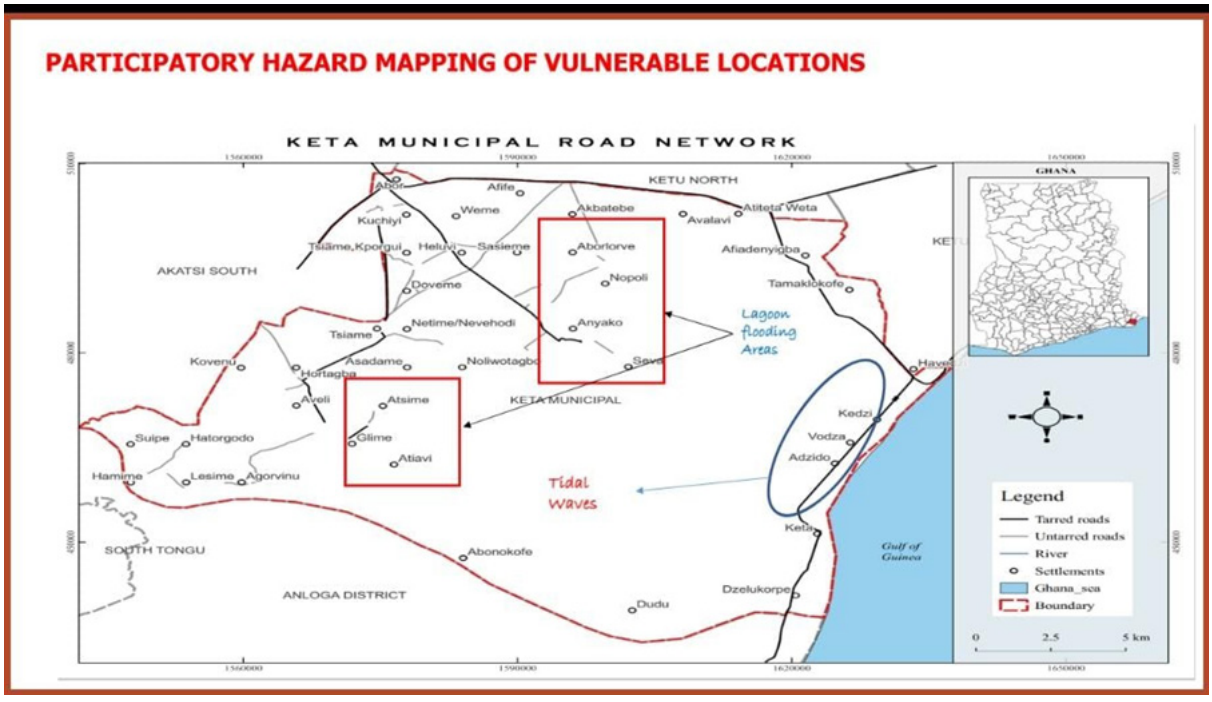
Source: KeMA, Department of Agriculture, 2021

Ankrah et al. (2023) found that temperatures in the coastal savannah agroecological zones of Ghana, including the Keta Municipality, have risen steadily over the past decades. This rise is accompanied by increased variability in precipitation patterns. Asare-Nuamah & Botchway (2019) confirmed that monthly rainfall has become more unpredictable. MacCarthy et al. (2015) pointed out that maize cultivation in coastal savannah areas is particularly affected by seasonal climate changes. Specifically, during the secondary growing season, which experiences prolonged droughts, yields become more unstable. They recommend that farmers prioritize the main growing season and adjust nitrogen fertilizer applications accordingly. The Keta Municipality's annual food production relies heavily on rainfall for both its major and minor seasons. Therefore, the observed climatic shifts, including rising temperatures and unpredictable precipitation, negatively impact agricultural output. Such environmental fluctuations introduce uncertainties for local farmers and, consequently, threaten food security in the Municipality. Again, the table shows a sharp decline in the population engaged in agriculture from 2019 to 2020, with the percentage of females engaged in farming lower than the males. The table also shows that more females are engaged in commercial farming and less in subsistent farming compared with the males.

7.9 Risk Mapping in Keta

Stakeholders during the consultation workshop were provided with printed maps that enabled them to map out hazards, exposures and impacts in the Keta Municipality. Figure 27 summarizes the hazards identified and locations or communities to be affected.

Figure 27 I Risk mapping in Keta



8 Climate Change Risk Assessment

8.1 Identify Critical Climate Related Hazards

Due to its location, KeMA is experiencing an increase in the frequency and intensity of extreme climatic events — particularly sea level rise, flooding, extreme heat, and changes in precipitation patterns. The climate analysis and baseline research (presented in previous chapters) revealed that current climatic events are likely to increase into the future.

Table 10 I Identified Climate change hazards in the Keta Municipality.

Systems and Assets Exposed to Hazard	Climate Hazard	Climate risk and potential impacts
Fishery Industries	Changes in sea temperaturesand acidification	The changes in temperature and PH level of the sea cause significant changes in the composition of fish populations, affecting the livelihoods of fishermen and the availability of seafood. The ocean's acidity can make it harder for some marine animals to build their protectiveshells or skeletons. The ocean's PH level can then impact the food chain and the economic viability of the fishery industries. Stakeholder's reported increase of alien species.
	Sea Level rise	The sea level rise may lead to the loss of coastal habitats such as wetlands and estuaries, reduce fish populations, and impact the economic viability of fishery industries. The wetlands and estuaries can be inundated,losing essential spawning and nursery areas for fish and other marine species.
	Extreme climate events	Extreme weather events, such as hurricanes, typhoons, and storms, can damage fishing infrastructure, affect coastal communities (safety) and disrupt fishing activitiesfor extended periods.
	Variable rainfall	Fishing patterns have changed, for instance, the Keta fishing industry has collapsed. Fishermen used to fish in wetlands or other areas which are now dry, affecting the livelihood of fishermen and fish processors.
Water Resources and Supply	Extreme Rainfall, Floodingand Storms	Extreme weather events, such as storms and floods can cause damage to water supply infrastructure and disrupt operations.
	Drought	Droughts and changing precipitation patterns can affectthe availability and the quality of the water for communities and businesses using both local sources and regional water sources.
	Drought	Prolonged dry periods can lead to lower river and stream flows.
	Flooding	Flooding causes erosion, and increased sediment loads in rivers leading to the contamination of water resources.

Systems and Assets Exposed to Hazard	Climate Hazard	Climate risk and potential impacts
Settlements and infrastructure	Sea Level rise	Sea level rise will cause coastal flooding, storm surges, high tides and coastal erosion and all these hazards will damage infrastructure and disrupt operations and business activities. During stakeholder's engagements communities reported that some coastal roads that usedto only occasionally (seasonally) be flooded and are nowflooded daily at high tide. • The Ghana gas pipeline is exposed in some areasdue to coastal erosion. • Many reports of beaches, houses and communitiesthat have been washed away. The increased sea-level heights impede drainage systemas there is more backwash.
	Flooding	Increased coastal flooding can damage critical infrastructure such as roads, bridges, gas pipelines andbuildings, disrupting transportation and business activities. Floods can also cause inundation of beach areas and ecosystems, landslides, and erosion, rendering roads impassable and difficult to access.
	Storms	Storm surges can damage or destroy roads, bridges, andother critical infrastructure along the coast, causing disruptions to business activities, transportation and access to essential services.
	High Temperatures	High temperatures can cause roads to expand and contract, leading to cracking, potholes, and other typesof damage.
Agriculture	Rising temperatures and more variable precipitation.	Rising temperatures, more extreme weather events, and changing precipitation patterns all have adverse effects on crop yields and livestock health. Crops fail due to floods, water logging, drought, extreme heat, and storms.Potential change in crop suitability.
	Changing precipitation patterns (more frequent dryspells and floods)	Heavy precipitation and increased frequency of floods can cause waterlogging and damage crops while dry spells and prolonged drought lead to water shortage andcrop failure
	Storms	Increased number of storms and lead to crop failure.
	Pests	Increasing temperatures and precipitation (i.e., more flooding) are likely to increase the risk of infestation ofpest and diseases leading to crop failure and reducedlivestock production.
	Hotter Temperatures	Hotter temperatures will reduce livestock productivity.
Health and sanitation systems	Changes in temperature andprecipitation	Changes in temperature and precipitation can alter the distribution and abundance of malaria-carrying mosquitos, leading to a potential for increased risk of malaria.
	Flooding and heavyprecipitation.	Flooding and heavy precipitation can increase the risk of waterborne diseases such as cholera, typhoid, and diarrhoea. Flooding can also damage critical health infrastructure and limit access to hospitals.
	Climate extremes	Floods, storms, and wildfires can lead to displacement,loss of property, and trauma, which can contribute to mental health issues such as anxiety and depression.

Systems and Assets Exposed to Hazard	Climate Hazard	Climate risk and potential impacts
Coastal Ecosystems	Sea Level rise	Sea level rise will cause coastal flooding, inundation ofcoastal habitats, saltwater intrusion, and changes in species distribution.
	Extreme weather events	Extreme weather events, such as hurricanes, storms, and tsunamis, can cause significant damage to coastalhabitats leading to loss of biodiversity, degradation andloss of ecosystem services along the coastline
	Changes in sea temperaturesand PH level	Changes in sea temperatures and pH levels can causechanges in the distribution and abundance of marine species
	Heatwaves	Extreme heat can cause coral bleaching, loss of seagrass beds and mangrove forests, distribution and abundance of marine species. Extreme heat also increases rate of evaporation causing the wetlands to dryquicker, impacting on fishing in the wetlands.
	Flooding	Flooding can lead to coastal erosion and the loss of land, which can significantly impact the livelihoods of communities along the coast and adversely affect ecosystem services. During the stakeholder's consultation Fishermen attested to the increased runoff from rivers into the ocean. The inlets affect the current and also release a lot more sediment into the ocean. This has impacted where the fishermen go to fish.
	Drought	Drought leads to reduced freshwater flow into estuaries, which can alter salinity levels and affect the distribution and abundance of plant and animal species. Wetlands have dried up due to drought and this has affected fishing that happens within the wetlands and related post-harvest fish processing and trading activities.

8.2 Impact Story Lines for Critical Assets and Risk Domains

Keta, like many coastal cities, is vulnerable to the impacts of climate change.

- To better understand the climate change related hazards, vulnerability and exposure for the critical assets, individual impact chains where developed. These were developed based on information obtained from desk review and was validated by the stakeholder for the following priority risks identified:
- Risk 1: Displacement and relocation
- Risk 2: Fisheries Impacts - Potential decline in fish population and increasing costs.
- Risk 3: Economic and social disruptions and loss of livelihoods
- Risk 4: Community health: Increase in spread of disease and loss of life.
- Risk 5: Decline in coastal ecosystems.
- Risk 6: Water security

Risk 1: Fishery- Potential decline in fish population

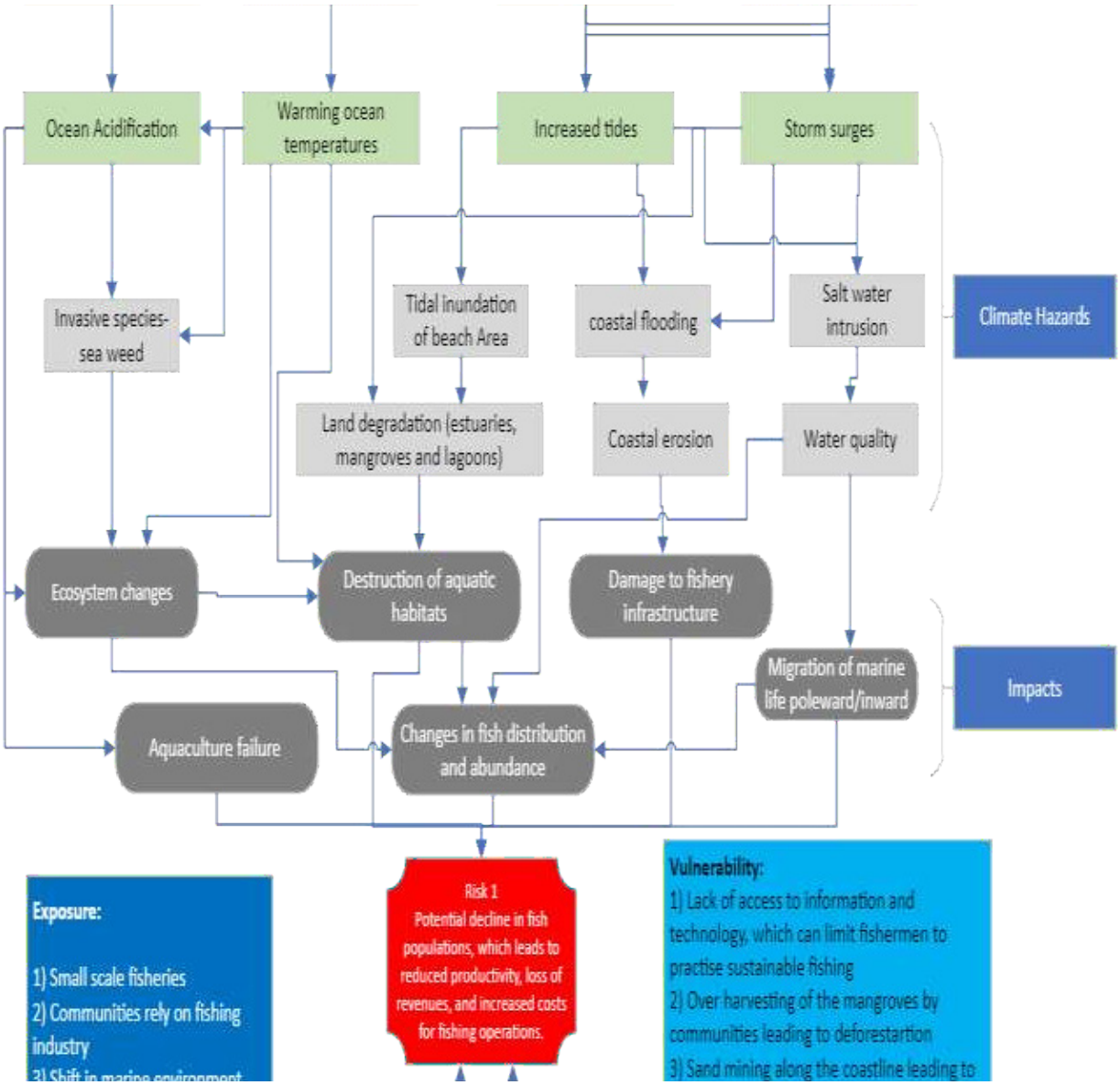
In Keta Municipal, the potential decline in fish populations is a significant climate risk, driven by several key climate hazards. Rising sea temperatures and ocean acidification directly impact marine ecosystems, causing shifts in fish species distribution and reducing the availability of key fish stocks. Increased storm intensity further exacerbates these risks by damaging marine habitats and disrupting fishing activities. These hazards create a cascade of effects that threaten the livelihoods of fishing communities in Keta Municipal, from fishermen to canoe owners, offloaders, traders, fish processors, carriers, fish arrangers for sale, amongst others loss their livelihood.

The exposure of Keta's fishing industry to these hazards is high, given the region's strong reliance on marine resources. Critical assets, such as fish stocks, fishing infrastructure (e.g., boats, gear, and landing sites), and coastal ecosystems, are directly exposed to the impacts of climate change. The sensitivity of the local population is also considerable, as a large portion of the community depends on fishing as their primary source of income and food. Overfishing and unsustainable fishing practices further amplify this sensitivity, as they reduce the resilience of fish populations to environmental changes.

Vulnerability in Keta Municipal is intensified by several factors. The local fishing communities often lack the resources and support necessary to adapt to these changes. Limited access to alternative livelihoods, coupled with poorly enforced regulations, makes it difficult for these communities to reduce their reliance on overexploited fish stocks. Furthermore, the absence of adequate early warning systems and lack of access to climate information limits the ability of local fishers to prepare for or respond to adverse climate events.

The impacts of declining fish populations in Keta Municipal extend beyond just economic losses. Reduced fish catches can lead to food insecurity and increased poverty within fishing communities. Socially, this can result in displacement of families, community conflicts over dwindling resources, and a potential increase in migration as individuals seek better opportunities elsewhere. Ecologically, the decline in fish populations could disrupt the balance of marine ecosystems, leading to a loss of biodiversity and degradation of coastal habitats, such as mangroves, which play a critical role in supporting fish populations and protecting coastlines. The climate change impact chains for the fisheries industry are shown in Figure 27.

Figure 28 | Fishery Impact Chain Diagram.



Source: Adopted from CCRA for Sekondi-Takoradi Metropolitan Assembly.

Risk 2: Economic and social disruptions due to critical infrastructural failure because of climate change

The municipality is particularly vulnerable to climate hazards, including rising sea levels, increased temperatures, changing precipitation patterns, and more frequent extreme weather events. These hazards lead to a series of secondary effects such as coastal erosion, flooding, and storm surges, which in turn cause severe disruptions to transportation, housing, and essential services.

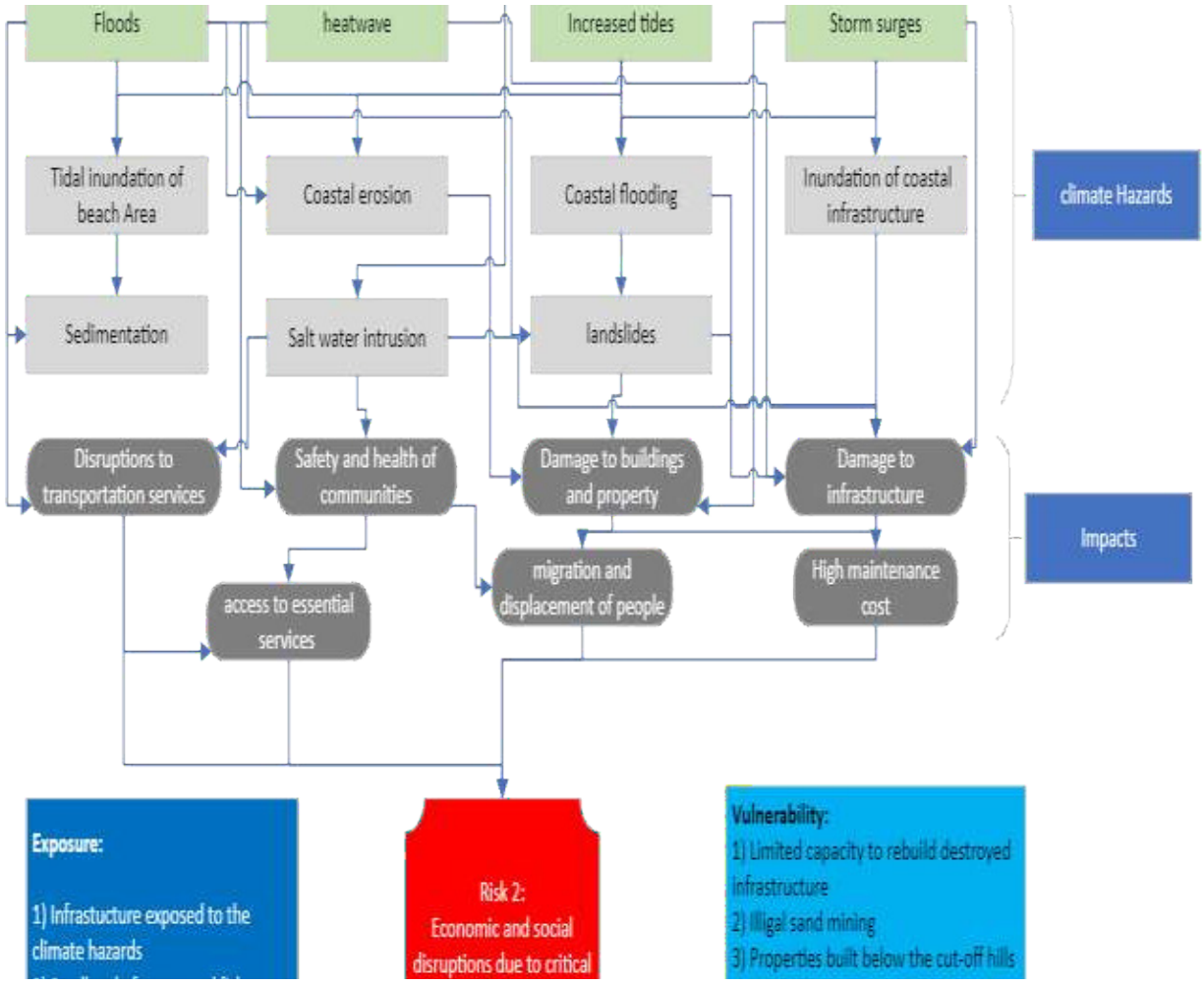
Floods and tidal inundation are particularly damaging in Keta Municipal, disrupting transportation networks and cutting off access to markets and social services. The buildup of sediment from these floods further exacerbates the situation by clogging drainage systems, leading to prolonged periods of inaccessibility. Coastal erosion and saltwater intrusion undermine the structural integrity of buildings and infrastructure, threatening the safety and health of local communities. These challenges are compounded

by the municipality's limited capacity to rebuild after disasters, exacerbating the impact of climate-related disruptions.

The social and economic impacts of these disruptions are far-reaching. Infrastructure failure often results in the displacement of people, as seen in recent events where tidal waves forced residents to abandon their homes[12]. Additionally, the destruction of key infrastructure such as roads and markets hampers economic activities, leading to increased poverty and food insecurity. The local economy, which heavily relies on agriculture and fisheries, is particularly vulnerable, as disruptions in infrastructure reduce access to markets and vital resources. Women and differently abled persons who cannot walk long distances are rendered vulnerable by unmotorable or non-existent roads.

Efforts to address these challenges must focus on building climate-resilient infrastructure, protecting and restoring ecosystems like mangroves that serve as natural barriers, and involving local communities in planning and adaptation strategies. Implementing early warning systems and ensuring adequate land-use planning are also critical to reducing the risks posed by climate change in Keta Municipal. The climate change impact chains for the fisheries industry are shown in Figure 28.

Figure 29 I Critical infrastructure Impact Chain Diagram.



Source: Adopted from CCRA for Sekondi-Takoradi Metropolitan Assembly.

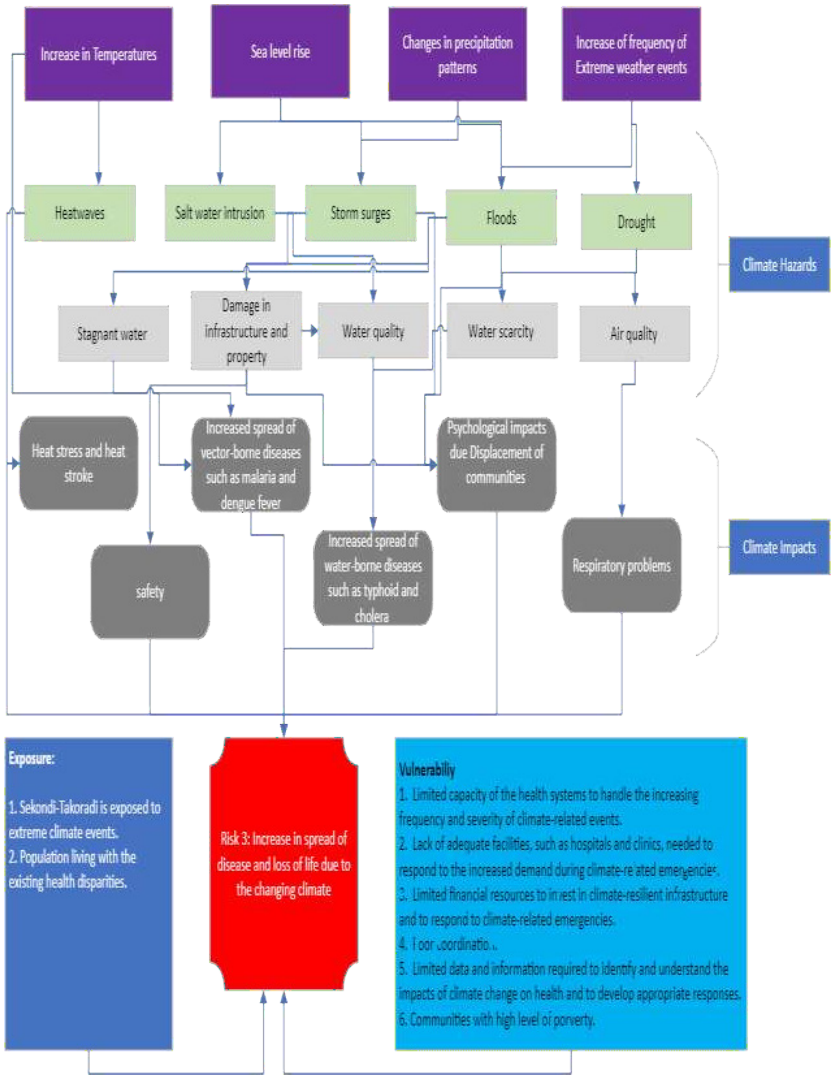
12 https://citinewsroom.com/2021/11/hundreds-displaced-as-tidal-waves-hit-some-communities-along-keta-aflao-stretch/

Risk 3: Community Health: Spread of disease and loss of life

The municipal's exposure to these hazards is compounded by its geographical location and socio-economic conditions. Communities in Keta Municipal often live in areas prone to flooding and water contamination, with limited access to clean water and sanitation facilities. These conditions create ideal breeding grounds for disease-carrying vectors and lead to the rapid spread of infectious diseases. Additionally, extreme weather events, such as floods and droughts, further degrade living conditions, leading to displacement and increased psychological stress among the affected populations.

The healthcare system in Keta Municipal is strained under the increasing demand caused by climate-related emergencies. The municipality lacks the financial resources to invest in climate-resilient health infrastructure, and there is insufficient coordination among health agencies to respond effectively to crises. High levels of poverty also exacerbate the situation, as many residents cannot afford adequate healthcare or preventive measures, leaving them more vulnerable to the impacts of climate change. All the climate change impacts in the form of flooding, sea level rise, reduced precipitation have consequent health implications; children, aged and persons with disabilities can easily be affected when exposed to these conditions.

Figure 30 I Health system Impact Chain Diagram. Source: Adopted from CCRA for Sekondi-Takoradi Metropolitan Assembly.



Risk 4: Decline in Coastal Ecosystems

Human activities such as encroachment, fill, illegal mining, and pollution, which threaten the coastal ecosystem, have destroyed habitats such as mangrove forests, wetlands, and coral reefs in the Keta Municipality.

One of the critical areas at risk is the Keta Lagoon Ramsar Site, a vital wetland that plays a crucial role in preventing coastal erosion, supporting biodiversity, and sustaining local livelihoods through fishing and agriculture. However, the lagoon and surrounding areas are under threat from pollution, unregulated sand mining, and over-exploitation of resources, which exacerbate the impacts of climate change. One study based on extensive interviews and observations, found that people have mixed views of coastal ecosystems: while they recognize their value, for example as fish breeding grounds, they also perceive them as a threat because of mosquito breeding[13]. They are often used as dumping grounds for solid waste because many residents perceive them as useless wasteland or as areas to be encroached for settlement. Climate change is adding pressure on the already fragile ecosystem by increasing the rate of loss of coastal ecosystems.

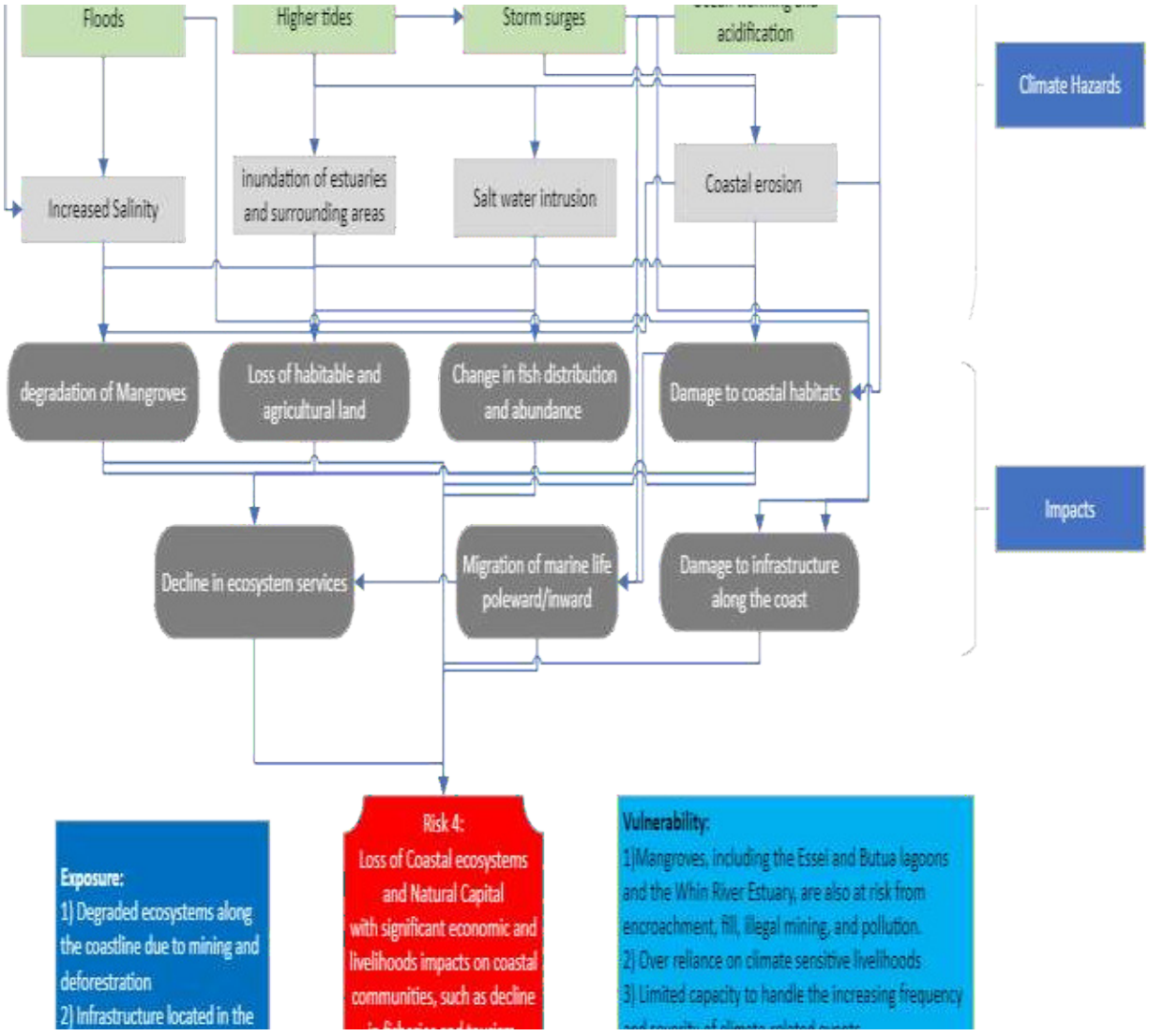
The degradation of these ecosystems leads to a decline in ecosystem services, such as water filtration and storm protection, further increasing the vulnerability of the local population to climate hazards[14]. Moreover, the loss of coastal ecosystems has severe economic and social implications. The over-reliance on climate-sensitive livelihoods, such as fishing, makes the community particularly vulnerable as fish stocks decline and tourism potential diminishes. Additionally, the limited capacity to manage and restore these ecosystems leaves the region exposed to further degradation, threatening the long-term sustainability of the local economy. There is a lack of resources and capacity to effectively manage and respond to the increasing severity of climate-related events. This limitation hampers efforts to protect and restore coastal ecosystems, further exacerbating the risks.

Many infrastructures, including homes, roads, and public facilities, are located in areas that are highly exposed to the impacts of sea-level rise and coastal erosion. This proximity increases the risk of damage and loss, both of which have cascading effects on the community's economy and social stability.

13 DADZIE-PAINTSIL, E. B. E. N. E. Z. E. R., & MENSAH, J. V. (2022). Effects of urbanization on coastal wetlands in the Se kondi-Takoradi Metropolis, Ghana. Indo Pacific Journal of Ocean Life, 6(2).

14 https://link.springer.com/article/10.1007/s11852-022-00928-6

Figure 31 I Coastal Ecosystem impact chain



Risk 5: Loss of Livelihoods

In Keta Municipal, many local communities rely heavily on fishing for their livelihoods. However, climate hazards such as sea-level rise, flooding, and coastal erosion increasingly threaten these traditional livelihoods. Other economic activities, including small-scale trade, agriculture, and tourism, are also affected by these climate impacts. The most vulnerable groups, including small-scale fishers, women and girls, and poverty-stricken communities living along the coastline, are particularly exposed to these climate hazards.

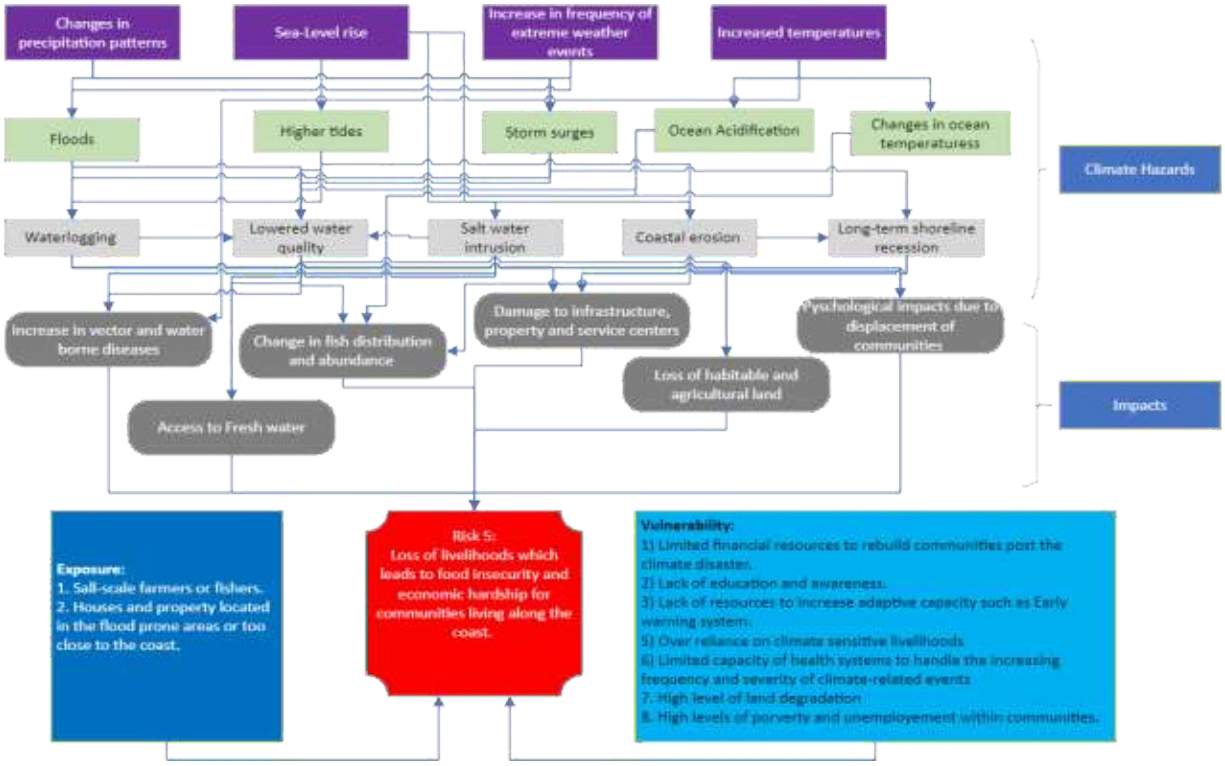
Flooding is a significant and recurring issue in Keta Municipal, exacerbated by factors such as unplanned urban expansion, deforestation, and the degradation of wetlands like the Keta Lagoon. These activities reduce the land's natural ability to absorb water, leading to more frequent and severe floods. Additionally, poor drainage infrastructure, building in low-lying areas, and siltation of water channels further increase the municipality's vulnerability to flooding. This situation is compounded by saltwater intrusion, which threatens both freshwater resources and agricultural productivity, critical to the livelihoods of local communities[15].

Climate change in Keta Municipal also manifests through coastal erosion, which is progressively eating away at habitable and agricultural land. This erosion, coupled with saltwater intrusion, reduces fish stocks and alters the distribution of some species, directly impacting the fishing community. The impacts of climate change also extend to increased water- and vector-borne diseases, damage to infrastructure, and disruption of services, which further weaken the resilience of communities dependent on climate-sensitive livelihoods.

These climate impacts disproportionately affect women and girls, who are often responsible for domestic and subsistence activities such as water collection, food production, and small-scale fisheries. Most often, women and girls to forgo productive and educational hours to search for water to keep the home running. The reduction in water availability and the rise in disease burdens increase their workload, limiting their opportunities for income generation and education. Women and girls in these vulnerable communities also face additional barriers, such as limited access to financial resources, technology, and decision-making power, which further hampers their ability to adapt to the changing climate and protect their livelihoods.

15 https://link.springer.com/article/10.1007/s11852-022-00928-6

Figure 32 Loss of Livelihoods Impact Chain Diagram



Risk 6: Water Security

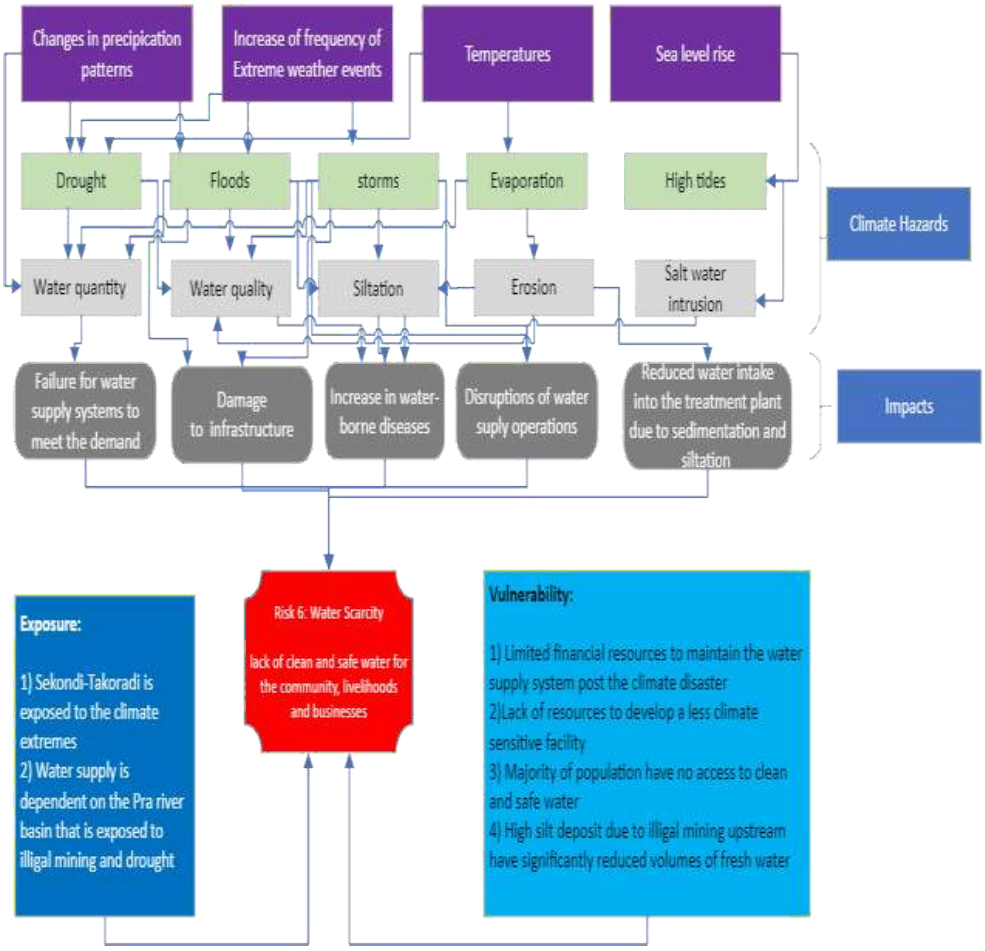
In Keta Municipal, climate change is expected to significantly exacerbate water scarcity. Droughts, rising temperatures, and changing precipitation patterns, along with siltation and sedimentation, can alter river flows and decrease the availability of fresh water for both human and ecosystem needs. This risk is heightened under all emission scenarios, particularly as future temperature increases and potential shifts in precipitation patterns are likely to worsen water scarcity. As discussed under the fossil-fuel development scenario, government would need to invest earnings made from oil exploration in other Areas such as Keta which would be impacted continuous GHG emissions. This could cover water supply infrastructure and improved stormwater management systems and providing social safety nets for the most vulnerable.

As urbanization continues and water supply from piped sources remains unmet, issues of water quality and security will be further exacerbated in Keta Municipal. The increasing frequency and severity of extreme weather events, such as floods and storms, will likely damage water treatment and supply infrastructure, leading to contamination of water sources. Flooding also increases the cost of treating water for drinking, placing additional financial burdens on the community.

These impacts will disproportionately affect women and girls, who are often responsible for domestic and subsistence activities, including water collection, food production, and small-scale agriculture. As water availability decreases, the workload of women and girls will increase, limiting their opportunities for income-generating activities and education. Additionally, women and girls in vulnerable communities face further barriers, such as limited access to finance, technology, and decision-making power, which restricts their ability to adapt to the impacts of climate change and secure resilient livelihoods[16].

16 https://link.springer.com/referenceworkentry/10.1007/978-3-031-25960-9_94-1

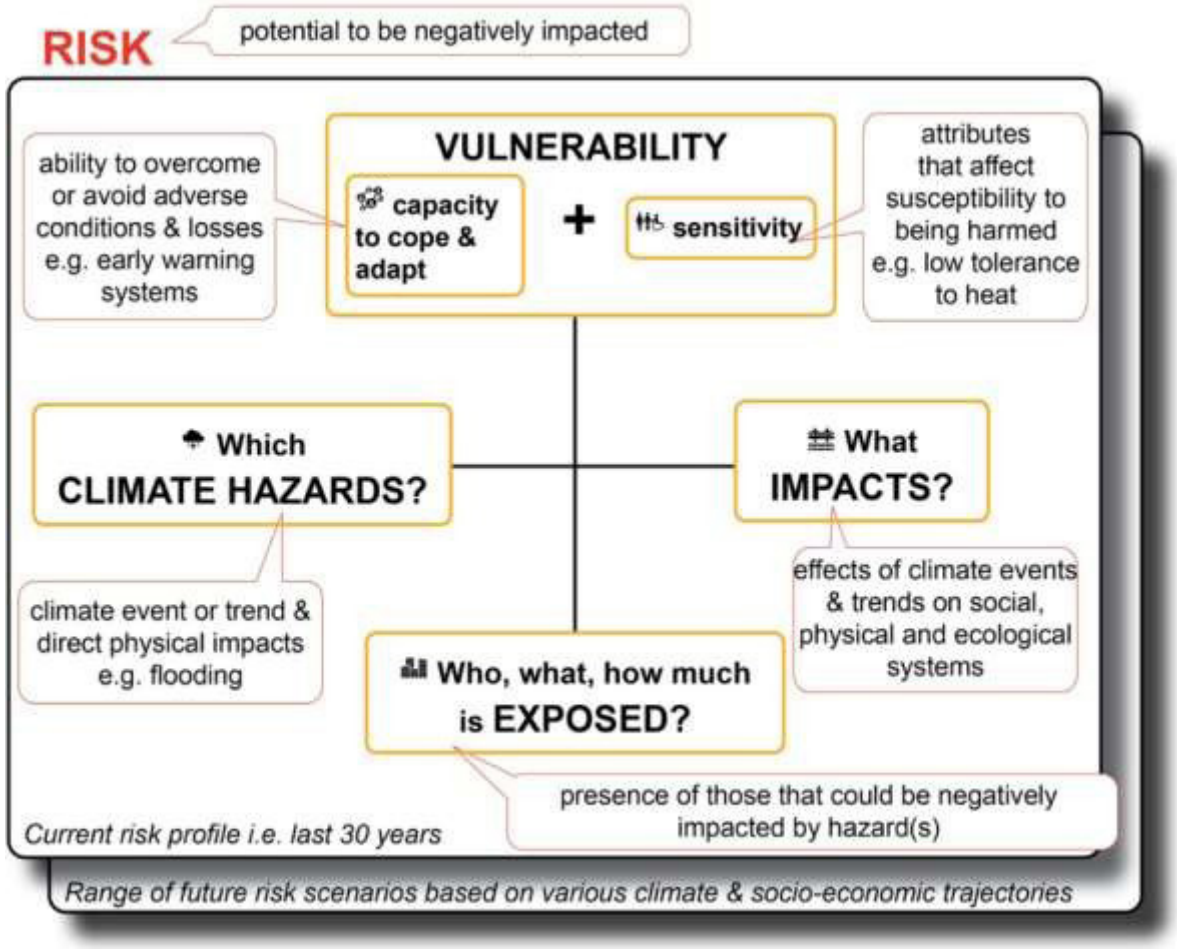
Figure 33 I Water Security Impact Chain Diagram



8.3 Risk Assessment Methodology

To assess key climate risks to the communities, a high-level, qualitative risk assessment was undertaken based on the understanding of risk as provided in the IPCC's Fifth Assessment Report from(AR5) (2014), where risk is a core concept, and vulnerability a component of risk. The key step in understanding risk is identifying who and what is exposed to the climate hazards and might therefore be potentially impacted or harmed, that could be adversely affected (Department of Environment, Forestry and Fisheries, 2020).

Figure 34 | The component of climate vulnerability and climate risk, adapted from IPCC AR5



Source: National Climate Risk and Vulnerability (CRV) Assessment Framework summary document, 2020

In this study, the risk is defined as a function of hazard, exposure and vulnerability and assessed as probable harm that can be caused to a biophysical or socio-economic system by an anticipated threat.

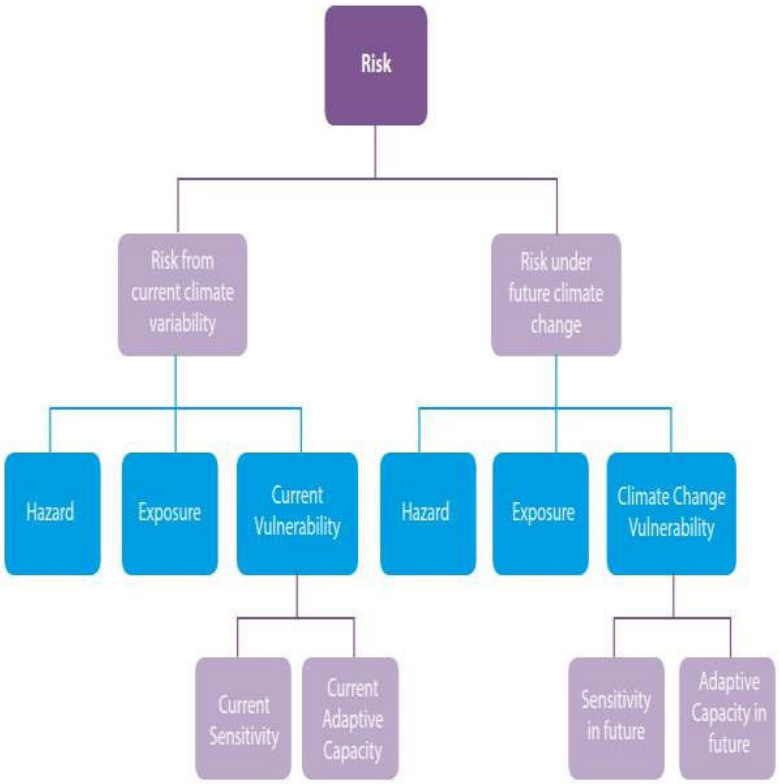
The vulnerability component of risk focuses on the sensitivity and adaptive capacity of those or that exposed to certain climate hazards. The approach to risk assessment involved collating and analysing information from the stakeholders' consultations and literature, considering the three elements that result in risk: exposure (E), hazard (H) and vulnerability (V).

Risk= f(H,E,V)

The assessment involved:

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

Figure 35 I Climate change risk assessment variables



8.3.1 Climate Change Hazard

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

The severity of potential impact is then characterised in terms of thresholds such as in Table 11.

Table 11 I Climate hazard thresholds to characterise the severity of potential impacts

Climate Hazard	Climate change parameter used	L[1]	M[1]	H[1]	VH[1]
Temperatures	Change in Mean Temperatures	0°C	+ 1°C	1.5°C	2°C
Precipitation	Change in Mean Annual Rainfall	100	50	0	-50
Droughts	Change in SPEI	2	1	0	-1
Floods	Change in maximum daily rainfall	-10%	-5%	0%	5%
Wildfires	Change in extreme temperatures	0%	10%	50%	100%
Agriculture	Change in crop suitability		-	-	--
Livestock	Change in heat index (HI)/max temperature	0%	10%	50%	100%
Human Health	Change in heat index (HI)/max temperature	0%	10%	50%	100%

Some of the values for the above variables can be derived directly from climate risk maps (for example changes in mean annual temperature or precipitation) or from derived hazard maps such as drought

hazard, water resource availability and crop suitability for primary crops under different climate change scenarios. The criteria to define the magnitude of the hazard is included in Appendix B.

8.3.2 Exposure

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

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

The criteria to determine the level of exposure is included in Appendix A.

8.2.3 Vulnerability

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

The purpose of this stage is to assess vulnerability conditions based on exposure, and the sensitivities and adaptive capacity. The vulnerability can be defined as a composite of two aspects of sensitivity and capacity. Sensitivity includes the physical environment and socio-economic or cultural dynamics.

The critical assets/sector within the district was profiled. The profiles revealed the general status quo including the biophysical and socio-economic status of the system. It is important to note that climate change vulnerability is not only dependent on climate- related hazards but, to a large extent, is dependent on socio-economic factors. It has been establishedthat climate change will exacerbate the existing socio-economic problems within the district.

The vulnerability of communities with in the KeMA was analysed using the feedback from the stakeholder engagement and review of published sources. Subsequently, the adaptive capacity was estimated by determining the abilities of the systems in place or missing to reduce or minimize the impacts of climate risks. Capacity aspects such as knowledge, technology, economy, and institutions directly or indirectly linked to climate risks will be considered in assessing the vulnerability.

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

The criteria to assess sensitivity and adaptive capacity respectively as well as the matrix used to assess and categorise the level of vulnerability for each system or assets are included in Appendix A.

8.3.4 Evaluating Risk

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

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

In Appendix C is the matrix used to rank the potential risks of the hazards associated with climate change on natural and human systems, based on exposure to identified climate hazards and the vulnerability of key natural systems, socio-economic sectors and local livelihoods

8.4 Risk Assessment Results

8.4.1 Current and Future Climate Related Risks

Understanding the risks at a local level requires an integrative approach that looks at both the physical climate hazards and social dimensions of vulnerability. The approach to identifying the critical assets and systems exposed to climate hazards was primarily desk review and will be shared with stakeholders during a validation workshop to receive their perspectives and experiences of the climate events that had adversely affected their systems of interests and challenges that they had to face as a result of such events.

The desk review revealed that the assembly seems to be more interested and aware of climate change issues and prepared for disasters as the following actions are already proposed in the Medium Term Development Plan and Annual Action Plan:

- Establish early warning systems to notify residents of upcoming disasters such as flooding could help increase adaptive capacity.
- Educate residents about areas of high risk in order to increase adaptive capacity.
- Embark on sensitization and farming education on Climate Change
- Procurement and distribution of Agriculture inputs
- Conduct pest and disease surveillance on livestock and poultry
- Sensitization on aquaculture and fisheries development as well as Pest and disease surveillance
- Train and supervise farmers on quality seed productions activities and farm /home visits by AEAs
- Carry out Modernization of Agriculture (MAG) projects/programmes
- Organize quarterly public awareness campaign on DRR and climate change activities within the municipality
- Capacity building for staff of NADMO on disaster prevention techniques at Keta

- Bituminous Pothole patching, sectional and edge repairs (1,100m3
- Construction of 1No. 14-Seater market shed
- Grading and Patching of 1km Gobah Beach Road
- Construction of feeder road at Glime
- Support the Parks and Garden Unit to undertake tree planning, beautification of the environment.
- Carry out 4. No sensitization programmes on the importance of biodiversity and wetland conservation in the Municipality
- Carry out Mangrove Restoration along the Coast and Lagoon (20 Hectares)
- Plant 2, 000 trees along the Lagoon and in other communities in the Municipality
- Capacity building for 400 youth in alternative livelihood programmes such as bee keeping, mushroom and vegetable production.
- Formalization of Farmer Based Organizations/Build capacity of 4 FBOs in FBS in the municipality
- Organize business counselling for clients and businesses
- Organize a two years Apprenticeship to Entrepreneurship program for employed youth

The discussions led to the results presented in the Table 12 and Table 13 below in terms of the current and potential future climate related risks. In addition, the outputs of climate models were used to inform the assessment of the future climate related risks, where the different scenarios were considered.

8.4.2 Adaptive Capacity and Residual Climate Change Risks

Keta is located in a region vulnerable to climate and weather extremes, including high sea level rise, floods and storms. Climate change projections for Keta suggests increasing average temperature from between 3 to 4.5 °C under RCP 8.5 with RCP 4.5 suggesting a mid-point of about 2.0 °C. The maximum temperatures and heatwave events are also expected to increase, thus increasing sea water temperatures and rate of evaporation. However, there is disagreement amongst climate models on future changes to seasonal and annual precipitation levels and intensity, suggesting a high level of uncertainty, with some models projecting increases and others decreases. Based on the analysis of current and future climate risks and qualitative considerations of the sensitivity, exposure and vulnerability, this CCRA has identified several critical climate-related risks for KeMA (see Table 12). The identified critical risks under the current and future conditions are rated high to extreme, but with the suggested risk mitigations measures, the level of risk is expected can be reduced.

The residual climate change risk assessment results are presented in Table 13, ranking current, future, and residual risks from Low to the Extreme. According to the results of the residual risk assessment, climate risk mitigation measures (adaptation) can reduce some elements of risk, such as sensitivity, and enhance adaptive capacity. Reducing risk requires modifying current policies and programs and implementing policies that explicitly consider climate variability and climate change.

The proposed adaptation measures listed below are initial recommendations and focus more on reducing the sensitivity and enhancing the capacity hence building a more resilient system. Further consideration should be given to the identification of priority adaptation responses that can then be included in the development of a specific climate change response plan for KeMA.

Table 12 | Assessment of current climate change risks

System	Hazard Description	H: Hazard	E: Exposure	H*E: Hazard x Exposure	AC: Adaptive Capacity	S: Sensitivity	V: Vulnerability = AC*S	Comment - Impacts (with Gender Consideration)	CCR: Climate Change Risk
Agriculture	Rising temperatures, unpredictable rainfall, and saltwater intrusion affecting crop yields and livestock health.	High	High	High	Low	High	High	Decreased crop yields, loss of livestock, food insecurity, women and men in agriculture face different impacts. With even more severe impacts on women who more often than not, take care of households.	High
Biodiversity	Habitat degradation and species displacement due to climate change and overexploitation of coastal wetlands.	High	High	High	Low	High	High	Loss of biodiversity, impacts on ecosystem services, gender roles in conservation and resource management affected.	High
Fishing Industry	Rising temperatures and saltwater intrusion disrupting fish habitats and causing economic losses for fishermen.	High	High	High	Low	High	High	Decline in fish stocks, loss of income, increased poverty, both men and women in fishing impacted.	High
Water Resources	Droughts, flooding, and pollution reducing water availability and quality, affecting domestic and agricultural use.	High	High	High	Low	High	High	Water scarcity, increased disease burden, women and girls face greater challenges in water collection and use.	High
Sanitation and Health	Rising temperatures and flooding increasing the spread of vector- and water-borne diseases, especially in vulnerable communities.	High	High	High	Medium-Low	High	High	Increased healthcare costs, reduced resilience, women and children face higher health risks.	High

Critical Infrastructure	Coastal erosion, flooding, and storms causing destruction of homes, schools, markets, and tourism infrastructure.	High	High	High	Low	High	High	Damage to critical infrastructure, displacement, economic losses, women's livelihoods disproportionately affected and limiting accessibility for differently abled persons.	High
Gender	Increased vulnerability of women and marginalized groups due to unequal access to resources, financial support, and decision-making.	High	High	High	Low	High	High	Increased gender disparities, women face barriers in adaptation and recovery from climate impacts.	High

Table 13 **| Assessment of future climate change risks**

Asset / System	Future Hazard Description	H: Hazard	E: Exposure	H*E: Hazard x Exposure	AC: Adaptive Capacity	S: Sensitivity	V: Vulnerability = AC*S	Comment - Impacts (with Gender Consideration)	CCR: Climate Change Risk
Agriculture	Increasing temperatures, more severe and unpredictable droughts, and rising sea levels leading to greater saltwater intrusion and further reductions in crop yields and livestock health.	Very High	High	Very High	Low	Very High	Extreme	Increased food insecurity, greater reliance on climate-resilient crops, women in agriculture face compounded challenges.	Extreme
Biodiversity	Accelerated habitat loss and species extinction due to intensified climate change effects, including more frequent extreme weather events and rising sea levels.	Very High	High	Very High	Low	Very High	Extreme	Further degradation of ecosystems, loss of biodiversity, gender roles in conservation and resource management increasingly impacted.	Extreme
Fishing Industry	Ocean warming, acidification, and altered marine ecosystems leading to further reductions in fish stocks and greater economic strain on fishing communities.	Very High	High	Very High	Low	Very High	Extreme	More severe economic impacts on fishing, increased poverty, both men and women in fishing face reduced livelihood opportunities.	Extreme
Water Resources	More frequent and severe droughts combined with increased saltwater intrusion and pollution further reducing water availability and quality.	Very High	High	Very High	Low	Very High	Extreme	Worsening water scarcity, higher risk of water-borne diseases, women face even greater challenges in water collection and use.	Extreme

Sanitation and Health	Increased temperatures and more intense flooding events leading to a higher incidence of vector- and water-borne diseases, exacerbating health challenges in vulnerable communities.	Very High	High	Very High	Low	Very High	Extreme	Significant increase in healthcare needs, women and children remain disproportionately affected by health risks coupled with increased cost of health care	Extreme
Critical Infrastructure	Intensified coastal erosion, more frequent and severe storms, and flooding causing even greater destruction of homes, schools, markets, and tourism infrastructure.	Very High	High	Very High	Low	Very High	Extreme	Extensive damage to critical infrastructure, higher displacement rates, women's security, livelihoods increasingly threatened.	Extreme
Gender	Worsening gender disparities due to increasing climate impacts, with women and marginalized groups facing even greater barriers to adaptation and recovery.	Very High	High	Very High	Low	Very High	Extreme	Intensified gender inequalities, women continue to face significant challenges in adapting to and recovering from climate impacts.	Extreme

Table 14| Assessment of Future Residual Risk after implementation of adaptation measures

Asset / System	Measure Type	Adaptation Measures	Residual Risk Assessment				
			Residual Adaptive Capacity	Sensitivity	Exposure	Vulnerability	Residual Risk
Agriculture	Nature-Based Solutions (NBS)	• **Improve Vegetable Cultivation in Oyibi-Muni Soil Type:** to enhance vegetable cultivation in this soil type, incorporate organic manure to support shallots, okra, pepper, and other vegetables. This enriches soil nutrients, boosts crop growth, and reduces reliance on synthetic fertilizers.	High	Medium	High	Medium	High
		• **Organic Mulching for Soil Improvement:** Use coconut husks and organic materials as mulch to retain soil moisture, suppress weeds, and improve soil fertility in Oyibi-Muni. This practice conserves water, enhances soil structure, and promotes sustainable agricultural productivity.	High	Medium	High	Medium	High
	Policy/Institutional/Social Measures	• **Climate-Resilient Agriculture:** Train farmers to prioritize the main growing season and optimize nitrogen fertilizer application during this period. This measure improves crop yields and resource use efficiency.	Very high	Medium	High	Low	Medium
		• **Improving Farmers' Access to Climate-Related Information:** Enhance farmers' capacity to access and utilize climate-related information. This should be target the communication channels used by female and male farmers. Equip agricultural extension services and other intermediary organizations to integrate climate information into their interactions with rural communities. This effort should be supported by the development of interactive communication channels such as mobile phones,interactive radio programming, and dissemination on women platforms at convenient times.	Very high	Medium	High	Low	Medium

		• **Research and Development on Resilient Crop Varieties:** Focus R&D efforts on identifying and promoting resilient crop varieties suited to local climatic conditions. Encourage the cultivation of climate-resilient crops that tolerate specific environmental stressors, such as fire and salt-tolerant varieties tailored to saline-prone environments. Promote the adoption of crop varieties resistant to prevalent pests and diseases to enhance overall crop resilience.	High	Medium	High	Medium	High
		• **Early Warning and Response Mechanisms:** Develop and improve early warning and response systems for farmers. Ensure these systems are accessible and understandable to all community members, including persons with disabilities	High	Medium	High	Medium	High
		• **Diversification of Livelihoods:** Promote the diversification of livelihoods to reduce the sensitivity of agricultural communities to climate risks. This measure helps to build economic resilience against climate-induced shocks.	Very high	Low	High	Low	Medium
	Technological/ Engineering Measures	• **Upgrade weather forecasting infrastructure:** upgrade localized stations and models, while increasing financial support and technical training for experts. This real-time data will enable farmers to adjust practices based on accurate forecasts, reducing vulnerability to climate risks.	High	Medium	High	Medium	High
		• **Irrigation Systems:** Implement irrigation systems in Keta that optimize water use efficiency and integrate the nexus between food production and energy.	High	Low	High	Low	Medium

Biodiversity	Nature-Based Solutions (NBS)	• **Mangrove Restoration:** Engage in large-scale planting and replanting of mangrove trees and wetland vegetation. Use native species that are well adapted to the local environment to ensure higher survival rates and ecological compatibility.	High	Low	High	Low	Medium
	Policy/Institutional/Social Measures	• **Community-Based Management of Wetlands and Mangroves:** Promote and improve community-based management of wetlands and mangroves by providing training and resources to local communities to enhance their capacity to manage wetlands and mangroves.	Very high	Low	High	Low	Medium
		• **Community workshops**: Organize community workshops to train farmers and fisherfolks on sustainable fishing, farming and forestry practices, and the benefits of conservation. The trainings should be gender sensitive and target farmers and fishers from the various gender groups.	High	Low	High	Low	Medium
		• **Collaboration for Biodiversity Conservation**: Liaise with specialized research institutions, NGOs and universities to undertake comprehensive biodiversity assessments to identify species at risk and implement tailored integrated conservation practices to protect them effectively.	High	Low	High	Low	Medium
	Technological/ Engineering Measures	• **Protect wetlands and forests by enforcing regulations and monitoring of forest resources:** Ideally, technologies like satellite imagery and drone surveillance are recommended for detecting illegal activities. However, in local areas where advanced tech is scarce, local volunteers are trained to patrol and monitor wetlands, mangroves, and coastal areas. Provide incentives and equip volunteers with tools to record and report incidents, thereby ensuring community-led conservation efforts in the Keta area. Lastly, improve incentives and other measures to encourage users of environmental resources to adopt less exploitative and non-degrading practices in agriculture.	Very high	Low	High	Low	Medium

Fishing Industry	Nature-Based Solutions (NBS)	• **Mangrove and Wetland Rehabilitation**: Engage in large-scale planting and replanting of mangrove trees and wetland vegetation to enhance fisk stock. Use native species that are well adapted to the local environment to ensure higher survival rates and ecological compatibility. The restored mangroves and wetlands create a more supportive habitat, promoting the breeding, growth, and survival of various fish species.	High	Low	High	Low	High
	Policy/Institutional/Social Measures	• **Diversification of Livelihood sources:** Diversification of livelihood sources among fishing communities will reduce their vulnerability to climate change impacts. This may involve providing training and resources for alternative income-generating activities, such as eco-tourism, or small-scale agriculture.	Very high	Low	High	Low	Medium
		• **Financial Assistance Programs for Fishing Industry:** Establish financial assistance programs tailored to the fishing industry can help mitigate the financial impacts of boat damage or loss. Providing financial support for boat repair, replacement, or recovery efforts alleviates the economic burden on fishermen.	Medium	Medium	High	Medium	High

		• **Effective regulations and local enforcement of bye-laws:** This effort will protect Keta's wetlands and mangroves from harmful practices like unauthorized harvesting of mangroves, pollutant discharge and encroachment of wetlands by business investors which destroy the natural habitat of fishes. The use of incentives and disincentives to discourage the unsustainable exploitation of mangroves would lead to net social benefits.	High	Low	High	Low	Medium
		• **Phase out or Improve Fishing Methods:** Fishing methods practised in keta include beach seines, Ali, Polo, Watsa, Set nets, and drift gill nets. Regulate and prioritize the phasing out or improvement of fishing methods which have proven to be inappropriate or unsustainable. • **Improve fish processing methods:** the Chokor fish smoker is the most widely used fish smoking technology. This can be replaced with more fuel efficient fish smokers being promoted by the Fisheries Commission.	High	Low	High	Low	Medium
	Technological/ Engineering Measures	• **Promote sustainable aquaculture development:** To promote sustainable aquaculture and enhance fish stocks in Keta's coastal waters, establish a laboratory facility where mature sparidae and other cultivable species can be brought from the wild and induced to spawn under controlled conditions. Develop protocols for spawning and rearing fingerlings in the laboratory setting, ensuring they are then stocked in floating cages offshore to grow to table size sustainably. Leverage successful technologies and practices from other countries to adapt and implement these methods locally, thereby contributing to food security in the region	Very high	low	High	Low	Medium

Water Resources	Nature-Based Solutions (NBS)	• **Promote Rainwater Harvesting Systems in Keta-Implement measures for water conservation and management:** Encourage the installation of rainwater harvesting systems in households to collect and store rainwater for various uses in order to reduce drought induced water scarcity. These systems capture and store rainwater during peak rainfall periods, ensuring a reliable water supply during dry spells or drought seasons. This reduces the need for women to travel long distances for water, improving accessibility and enhancing community resilience against climate change-induced water challenges.	Medium	Medium	High	Medium	High
		• **Restoration of natural drainage systems:** Restore natural drainage systems like wetlands and estuaries, which absorb and filter excess water, acting as buffers during heavy rainfall	High	Low	High	Low	Medium
	Policy/Institutional/Social Measures	• **Inter-Agency Coordination:** Promote collaboration between various government agencies involved in water management, such as environmental protection agencies, public health departments, and agricultural departments. Establish a central coordinating body to streamline efforts and share information.	High	Medium	High	Medium	High
		• **Community Education and Involvement:** Conduct gender inclusive community workshops to educate local residents on the importance of water quality and conservation practices. Topics should include proper sanitation, pollution prevention, and the safe use of water resources.	Very high	Low	High	Low	Medium
	Technological/ Engineering Measures	• **Construct and improve drainage systems:** Construct and upgrade drainage systems in Keta communities to channel polluted rainwater away from lagoons into appropriate systems.	Very High	Low	High	Low	Medium

		• **Monitor and improve water quality and salinity control:** Regular water quality testing is key for maintaining optimal conditions. Implement a monitoring program to regularly test for key parameters like pH, dissolved oxygen, nutrient levels, and contaminants. Engage local communities in monitoring efforts to enhance data collection and raise awareness about the importance of clean water bodies and plastic waste management to prevent pollutants from entering lagoons through rainfall-induced flood.	Medium	Medium	High	Medium	High
		• **Manage water levels and address lagoon siltation**: Regular dredging of lagoons removes accumulated silt in order to maintain adequate water depth. This will also improve water transportation by ensuring navigable waterways, reducing the risk of vessels getting stuck, and facilitating smoother movement for fishing and transport boats. The major routes are Anyako/Seva-Anloga, Afiadenyigba-Keta-Anloga, Atiavi-Keta-Anloga, and Alakple/Kodzi/Fiahor-Keta-Anloga. It will also improve tourism by since the lagoons provide calm waters for cruising and other water sports (Dragon boat).	High	Low	High	Low	Medium
		• Increase Access to Potable Water Supply and Sanitation Services:	High	Medium	High	Medium	High
		• **Expansion of Mechanized Boreholes:** Expand the construction of mechanized boreholes to improve access to clean water in Keta. Mechanized boreholes use pumps to extract groundwater, ensuring a reliable and continuous supply of potable water, thereby reducing women's burden of obtaining potable water for households.	Very high	Low	High	Low	Medium
		• **Development and Upgrading of Small-Town Water Systems:** Develop and upgrade small-town water systems to provide clean water to larger communities. These systems typically involve the installation of a centralized water treatment plant that sources water from rivers, lakes, or underground aquifers. The water is then treated to remove contaminants and distributed through a network of pipes to households and public facilities.	Very high	Low	High	Low	Medium

Sanitation and Health	Nature-Based Solutions (NBS)	• **Restoring Wetlands and Floodplains:** Restoring wetlands and floodplains in flood-prone areas can reduce flood risks by absorbing excess rainfall like a sponge. Additionally, wetlands slow down water flow, allowing it to seep into the ground gradually, which in turn reduces the amount of water entering lagoons, thereby reducing the risk of lagoon flooding that can overflow sewage and pollutants into water sources, spreading diseases like cholera and typhoid fever.	Medium	Medium	High	Medium	Medium
	Policy/Institutional/Social Measures	• **Public health regulations:** Enforcing public health regulations can ensure that water and sanitation infrastructure are properly maintained and managed. Through regular water quality testing, and sanitation facility inspections.	Medium	Medium	High	Medium	High
		• **Public health education campaigns and awareness creation:** Public health education campaigns should be conducted continuously to emphasize the importance of hygiene practices, particularly during climate-related emergencies like floods and droughts. These campaigns should educate communities on the proper handling and disposal of waste, the safe use of water sources, and the importance of personal hygiene practices like handwashing with soap.	High	Low	High	Low	Medium

	Technological/ Engineering Measures	• **Develop and strengthen existing health facilities and emergency preparedness:** Health facilities must be developed and strengthened to handle the increased burden of climate-related illnesses. This includes upgrading infrastructure, equipment, and personnel capacities. Healthcare workers must be trained on climate-sensitive health issues, and emergency response teams should be established to rapidly respond to outbreaks and disasters. Emergency preparedness plans should be developed and regularly drilled to ensure readiness for extreme weather events.	Very high	Low	High	Low	Medium
		• **Expansion of Drainage Systems:** Improve and enlarge drainage systems to better handle heavy rainfall and prevent flooding. Make sewage systems stronger to stop waste from flowing into water sources during floods, keeping water clean and safe for people. This will help prevent waterborne diseases and keep communities healthy.	High	Low	High	low	Medium
		• **Improve Early Warning and Response Mechanisms for Disaster Management:** Early warning systems are critical for reducing the impact of extreme weather events. Improved weather forecasting and monitoring can provide timely warnings, enabling evacuations and preparedness measures. Response mechanisms should be developed to quickly provide medical aid, food, and shelter to affected communities, especially for local communities that are usually ravaged by tidal waves. Community-based early warning systems can also be established to enhance local resilience.	High	Low	High	Low	Medium
		• **Need to reconsider the design and resilience of sanitation infrastructure:** Sanitation infrastructure must be redesigned and strengthened to withstand extreme weather events. This includes building flood-resistant latrines, improving wastewater management systems, and ensuring access to safe water sources. Communities should be engaged in the design and implementation process to ensure culturally appropriate and sustainable solutions.	Medium	Low	High	Medium	High

Critical Infrastructure	Nature-Based Solutions (NBS)	• Enhancement of Berms: Plant vegetation such as salt-tolerant grasses and shrubs on berms to help stabilize the soil and reduce erosion. The roots of these plants will bind the soil, preventing it from being washed away.	Medium	High	High	High	High
	Policy/Institutional/Social Measures	• Implement new architectural designs, update building codes, and ensure climate-informed planning: Building codes should be updated to enforce these resilient designs. Urban planning processes need to prioritize climate resilience through revised zoning regulations, land-use planning, and the strategic placement of critical infrastructure away from vulnerable areas.	High	Low	High	Low	Medium

		• **Infrastructure Audit and Reinforcement:** Conduct detailed assessments of all critical infrastructure, including markets, schools, roads, bridges, water systems, and public buildings, to identify vulnerabilities and prioritize areas requiring immediate attention.	Medium	Medium	High	Medium	High
		• **Inspection and Maintenance Culture:** Establish regular maintenance schedules for all key infrastructure including the regular inspection and maintenance and of high-tension electric cables and water supply systems to identify and address weaknesses before rainstorms occur.	Medium	Medium	High	Medium	High
		• **Community Engagement and Awareness Programs in flood prone communities in Keta:** Implement initiatives to educate the community on flood risks, prevention measures, and emergency response plans specific to lagoon flooding, rainfall flooding, and tidal surges. This involves conducting gender inclusive public awareness campaigns, workshops, and training sessions to empower women, differently abled and other residents to proactively prepare for and respond to flood events.	High	Low	High	Low	Medium
	Technological/ Engineering Measures	• **Extension and elevation of the sea defence wall at Keta:** Extend and elevate the sea defence wall at Keta along coasts where its structural integrity has been compromised to provide continuous protection along the entire vulnerable Keta coastline. Raising the wall's height will future-proof it against anticipated sea-level rise and intensified wave action driven by climate change.	High	Low	High	Low	Medium
		• **Construction of Resilient Market Structures and Schools**: Market structures and school buildings must be constructed or rehabilitated using materials and designs capable of withstanding high winds, severe storms, and flooding.	High	Low	High	Low	Medium

		• **Construction and expansion of drainage systems:** Protection of critical infrastructure in Keta requires the construction and expansion of drainage systems within local communities. These systems will efficiently divert surplus rainwater into designated water bodies, effectively reducing the potential for flooding and water-induced destruction to settlements and public facilities. Moreover, the restoration of natural drainage systems, including wetlands are also necessary. These ecological systems serve as buffers during periods of intense rainfall by absorbing and purifying excess water.	Very high	Low	High	Low	Medium
Gender	Nature-Based Solutions (NBS)	• Incorporate native tree planting to augment the shaded rest area and provide natural shade and cooler air. This integrated approach will reduce heat stress among fisherfolk, offering comfortable resting spaces while blending harmoniously with the coastal environment to support local ecosystems.	Medium	Medium	High	Medium	High
	Policy/Institutional/Social Measures	• **Enhancing Healthcare Access for Pregnant Women:** Strengthen healthcare access, particularly prenatal care, for pregnant women to better adapt to climate change impacts and improve maternal health outcomes.	High	Low	High	Low	Medium
		• Supporting Women's Climate Resilience: Provide increased financial and technical support to empower women in adapting to climate change impacts, enhancing their resilience and participation in sustainable development efforts.	High	Low	High	Low	Medium
		• **Climate Educational Programs for Heat Stress Management:** Implement climate educational programs focusing on heat stress management practices, including proper hydration, rest intervals, and utilization of protective clothing, to safeguard vulnerable populations from climate-related health risks.	High	Low	High	Low	Medium
		• **Gender Mainstreaming in Disaster Risk Reduction:** Promote gender mainstreaming in Annual Action Plans to prioritize women's empowerment across all aspects of disaster risk reduction and management, ensuring inclusivity and resilience in community responses.	High	Low	High	Low	Medium

		• **Gender Sustainable Livelihood Programs**: Develop sustainable livelihood programs for women, youth and other gender vulnerable groups. The programs can include training in sustainable fishing/fish processing practices, alternative livelihoods (e.g., beekeeping, eco-tourism, handicrafts), and marine nursery protection. These initiatives aim to empower the youth and women economically, enhance sustainable fishing practices, diversify income sources, and promote marine conservation and resilience.	Very high	Low	High	Low	Medium

Table 15 | Climate change risk assessment results matrix and short narrative explaining the risk

Critical Asset / System	Risk description	Current Risk	Future Risk	Residual Risk
Agriculture	• Rising temperatures and increased variability in precipitation patterns affect crop yields: temperatures in the coastal savannah agroecological zones of Ghana, including the Keta Municipality, have risen steadily over the past decades. This rise is accompanied by increased variability in precipitation patterns. Maize cultivation in coastal savannah areas is particularly affected by seasonal climate changes. Specifically, during the secondary growing season, which experiences prolonged droughts, yields become more unstable. The Keta Municipality's annual food production relies heavily on rainfall for both its major and minor seasons. Therefore, the observed climatic changes, including rising temperatures and unpredictable precipitation, negatively impact agricultural output • In Keta Municipality, cereals such as maize, cowpea, and groundnuts are secondary staple crops that face significant impacts from climate change. Rising sea levels lead to saltwater intrusions into freshwater sources, contaminating agricultural lands and reducing soil fertility, resulting in decreased crop yields and land degradation. • Increased temperatures also create favourable conditions for bush fires, which can spread rapidly across farmlands, damaging crops and vegetation. These fires contribute to soil degradation, and thus compromise agricultural productivity. Climate change-induced warmer temperatures and rainfall patterns create conducive environments for pest and pathogens that damage crops, leading to yield losses.	High	Extreme	Medium
Biodiversity	• Keta's coastal wetlands, like many others worldwide, are in danger due to overexploitation, and climate change among others. These climatic and non-climatic factors contribute to habitat degradation and species displacement.	High	Extreme	Medium
Fishing Industry	• Rising temperatures disrupt fish habitats and distribution, hence, economic activities and livelihoods are disrupted. In areas with large lagoons like the Keta municipality, climate change impacts have changed freshwater flows, leading to increased saltwater intrusion into the lagoons. This, combined with changes hot temperature has disrupted fish habitats and distribution. Rising temperatures forced fish to move towards deeper waters. • Unauthorized aquaculture, infrastructure development near wetlands, and the discharge of pollutants degrade wetlands, leading to a decline in fish stocks. • Rain/windstorms destroy canoes/fishing boats: Strong winds, heavy rainfall, and rough seas during rain and windstorms can damage or destroy canoes and fishing boats. Intense precipitation reduces visibility and creates dangerous conditions for fishermen navigating on open waters. These storms generate large waves and choppy seas, posing serious risks to smaller vessels like canoes and fishing boats, which are vulnerable to capsizing or sinking due to their size and design	High	Extreme	Medium

Water Resources	• Heavy rainfall floods can pollute lagoon ecosystems by washing in pollutants and plastic waste from surrounding human activities. With barriers blocking most lagoon inlets, this contaminated runoff cannot flush out to sea, damaging water quality. • Climate change -induced drought disrupts water availability, quantity, and distribution, leading to reduced water levels in lagoons, and rivers, reduced groundwater recharge, and limited access to water for domestic consumption, agriculture, and industry in the Keta municipality.	High	Extreme	Medium
Sanitation and Health	• Rising temperatures and flooding put vulnerable communities at risk. Extreme heat increases heat-related illnesses such as heatstroke. Heatwaves can cause serious health problems, especially for older adults, children, and people with existing health issues. • • Flooding creates health risks by contaminating water sources with pathogens, chemicals, and other hazardous substances, leading to the potential for waterborne diseases. Inundation of sewage systems can release harmful pollutants into floodwaters, exposing people to cholera, skin infections among others. • • Lagoon flooding or tidal waves inflict damage on infrastructure, disrupt healthcare services, and precipitate displacement, leading to overcrowding in shelters, which creates an environment conducive to the outbreak of infectious diseases. • • Extreme weather can cause injuries and droughts can lead to malnutrition, especially for people who rely on farming. This can cause health problems like poor nutrition, weak immune systems, and increased risk of illnesses.	High	Extreme	Medium
Critical Infrastructure	• Coastal erosion, lagoon flooding, rainstorms, and bushfires are causing destruction in the Keta area, negatively impacting the following: • Settlements: Homes and buildings are being swept away by lagoon flooding, displacing residents. • Schools: Educational infrastructure is being destroyed, disrupting children's education and futures. • Markets: Local markets in Keta face severe impacts from rainstorms, which destroy commercial infrastructure, including market stalls. This impacts local businesses and livelihoods. • Tourism infrastructure: Historic sites like Fort Prinzenstein and beach resorts in Keta are vulnerable to tidal waves and erosion, damaging the local tourism industry and cultural heritage • High-tension electric cables and water supply systems are being destroyed by rainstorms.	High	Extreme	Medium

Gender	• Higher temperatures intensify health problems, particularly for pregnant women and older adults. As caregivers, women are disproportionately responsible for looking after these vulnerable groups, adding to their workload and stress levels. This increased burden can have negative impacts on women's physical and mental well-being, as well as their ability to care for others. • Women experience heavier impacts of climate change during extreme climatic events such as floods and rainstorms, especially impacting market infrastructure. These events directly impede women's income-generating activities, thus increasing their economic strain and livelihood vulnerabilities. • The rise in temperatures adversely affects men engaged in outdoor and offshore livelihood activities, such as agriculture and fishing, directly impacting their health and productivity. Long exposure to high temperatures leads to heat stress and other heat-related illnesses • Differently abled persons and many gender vulnerable groups will be impacted in many ways that other people will not.	High	Extreme	Medium

9 Conclusion and Recommendations

9.1 Overview of Future Climate Change Scenarios for Keta

Keta Municipal Assembly (KeMA) is at significant risk from the impacts of climate change, particularly due to its low-lying coastal location and dependency on climate-sensitive sectors like agriculture and fisheries. According to observed climate trends, average annual temperatures in Keta have risen by 1°C over the past 44 years, and precipitation patterns have become more variable. Projections indicate continued warming, with temperature increases between 1.5°C to 3.5°C by 2100 under various emission scenarios (RCP 2.6 to RCP 8.5). Sea level rise is projected to exacerbate coastal flooding and erosion, while increased rainfall variability and intensity are likely to heighten risks of lagoon flooding.

9.2 Priority Climate-Related Hazards and Risks

Coastal Flooding and Erosion:

Keta's location between the Gulf of Guinea and the Keta Lagoon makes it particularly vulnerable to coastal flooding. Coastal flood events are increasing in frequency, with records showing multiple incidents between 2002 and 2015. The coastline is eroding at a rate of 1.5 to 2 meters per year, endangering settlements such as Kedzi and Vodza. Sea level rise, driven by climate change, is expected to exacerbate these challenges, displacing coastal communities and damaging critical infrastructure. Historical data from NADMO shows frequent flooding in Keta, with the most recent occurring in 2023 due to the spillage of the Akosombo Dam, which further increased the water levels of the lagoon and caused significant inundation.

Lagoon Flooding:

The Keta Lagoon, which is an essential water resource, frequently floods its banks during periods of intense rainfall. The recent spillage from the Akosombo Dam led to the opening of floodgates to mitigate rising water levels, but this remains an ongoing risk. Lagoon flooding threatens agricultural land and infrastructure, with surrounding communities such as Anloga and Anyako being particularly vulnerable. The relief of the area, combined with human-induced changes to water flows, increases the risk of these flooding events.

Extreme Heat:

Observed data from 1979 to 2023 shows a rise in annual mean temperatures in Keta, leading to more frequent and intense heatwaves. Extreme heat events are particularly concerning for agriculture and public health, with the potential for heat stress to negatively impact crop yields and increase water demand. Projections indicate that Keta could experience an increase of up to 3.5°C by the end of the century under high-emission scenarios.

Water Scarcity and Salinization:

Increased temperatures and reduced rainfall are contributing to water scarcity in Keta. The Keta Lagoon and other water bodies have seen reduced water levels due to higher evaporation rates and erratic rainfall. Salinization from seawater intrusion further compounds the issue, degrading agricultural soils and reducing

the availability of potable water. This poses a major challenge for local communities that depend on agriculture and fishing for their livelihoods.

Wildfire Risk:

Although not traditionally a major hazard, the risk of wildfires is increasing due to prolonged dry spells and rising temperatures. Coastal vegetation, particularly in mangrove areas, is at risk of degradation from both wildfires and human exploitation.

9.3 Climate Change Risk Assessment Results

The risk assessment for Keta highlights the critical exposure and vulnerability of the municipality to these climate-related hazards. The area's economy, which relies heavily on agriculture, fisheries, and tourism, is particularly at risk. Without effective adaptation, climate change could result in significant economic losses, the displacement of communities, and the degradation of natural ecosystems. The lack of resilient infrastructure, combined with the increasing frequency of extreme weather events, further exacerbates these risks.

9.4 Potential Adaptation Options and Recommendations

To address the prevailing and future impacts of climate change, the following measures have been identified based on the findings from the study. A detailed list is also provided in table 14.

Coastal Defense and Erosion Control

- Building on the Keta Sea Defense Project, additional coastal defenses such as breakwaters, seawalls, and the restoration of mangrove ecosystems should be expanded. These measures can mitigate coastal flooding and erosion, protecting vulnerable communities and infrastructure from the impacts of sea level rise.

Lagoon and Water Resource Management:

- Implementing better management systems for the Keta Lagoon, including the regular opening of floodgates during peak water levels, will help mitigate the risk of lagoon flooding. Investment in rainwater harvesting, small-scale reservoirs, and improved irrigation infrastructure will also be crucial for managing water scarcity in the region.

Climate-Resilient Agriculture:

- Promoting climate-resilient agricultural practices, such as the adoption of drought-tolerant crop varieties and efficient water management techniques, is essential to maintaining agricultural productivity. Diversification of livelihoods, including eco-tourism and aquaculture, should be encouraged to reduce dependence on climate-sensitive sectors.

Infrastructure Development:

- Upgrading and retrofitting infrastructure to withstand extreme weather events is a priority. This includes strengthening roads, bridges, and public buildings to resist floods and erosion. Future urban planning must also avoid the development of high-risk areas along the coast and near the lagoon.

Public Health and Early Warning Systems:

- Improving healthcare services and establishing early warning systems for heatwaves and floods will reduce the health risks posed by climate change. Special attention should be given to vulnerable groups, such as the elderly and those with limited mobility, to ensure equitable access to emergency services and healthcare.

Restoration of Coastal Ecosystems:

- Restoring mangrove forests and other coastal ecosystems will provide natural defenses against flooding and erosion while enhancing biodiversity. These ecosystems also play a vital role in supporting fisheries and tourism, providing an additional buffer for local livelihoods.

Community Engagement and Capacity Building:

- Raising awareness about climate risks and promoting community-based adaptation strategies will empower local populations to take action. Workshops and training programs should be implemented to build the capacity of local stakeholders, particularly women and marginalized groups, to participate in decision-making processes related to climate adaptation.

Gender Mainstreaming:

- Women, children, aged, marginalized groups need to be put on top priority in the processes that entail solutions to the challenges. This is necessitated by the deep linkage between their vulnerability and these climate change manifestations.

By implementing these recommendations, Keta can build resilience to climate change impacts, safeguard its vital resources, and ensure sustainable development for future generations.

ADAPTATION ACTION PLAN FOR THE KETA MUNICIPAL ASSEMBLY (KeMA)

10

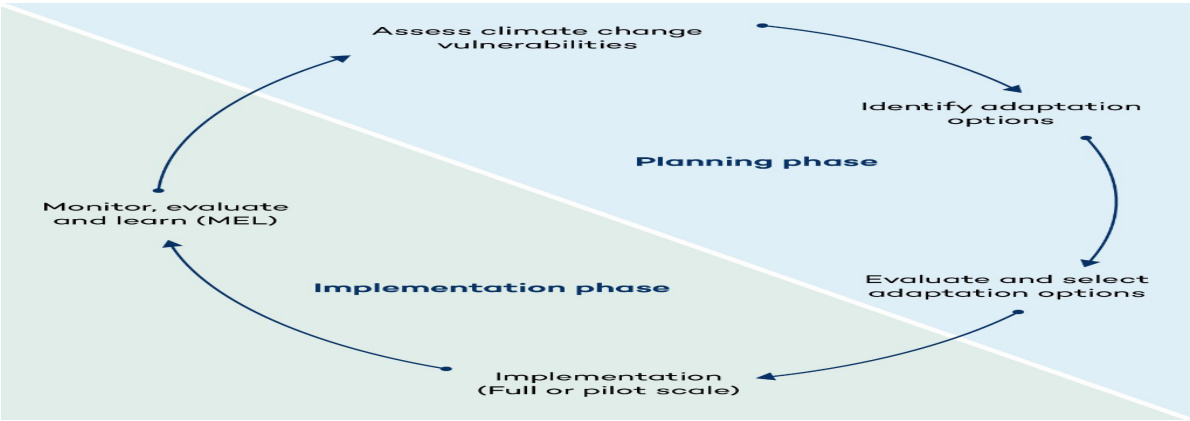
Adaptation action plan for the keta municipal assembly

10.1 Introduction

The Keta Municipal Assembly is committed to bolstering the resilience and sustainability of the municipality in addressing the challenges brought about by climate change. Adaptation Action Planning provides a comprehensive framework to tackle the unique vulnerabilities and risks posed by climate impacts within the municipality. This strategy seeks to embed climate adaptation into the municipality's core development agenda, ensuring that infrastructure, public services, and communities are better prepared to navigate the effects of climate variability and change. The Adaptation Action Plan for Keta prioritizes several fundamental areas.

- Risk Assessment and Vulnerability Analysis: Identifying critical climate risks and pinpointing the most vulnerable sectors within the municipality to guide targeted interventions.
- Stakeholder Engagement: Engaging local communities, government institutions, and other relevant stakeholders in the planning process to ensure adaptation strategies are inclusive, effective, and widely supported.
- Implementation of Adaptation Measures: Designing and carrying out targeted initiatives to address specific risks, such as upgrading drainage systems, expanding green spaces, and promoting sustainable practices in land use management.
- Monitoring and Evaluation: Creating robust systems to evaluate the progress and effectiveness of adaptation initiatives, allowing for regular updates and enhancements to ensure long-term success.

Figure 36 Approach to ADA adaptation planning



Identification and Compilation of Sector-Specific Adaptation Actions

The detailed climate change adaptation plan for the Keta Municipal Assembly identified and curated specific strategies tailored to the municipality's distinct requirements. This process allowed for a thorough evaluation of various adaptation options and the determination of the most effective measures. The planning team employed the methods detailed in the table below to select these adaptation actions.

Table 16 Methodology to identify adaptation options

Vulnerability assessment report recommendations	The climate change vulnerability assessment for the KeMA 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 optimal solutions and practices was conducted through a desk review of government documents, scientific publications, grey literature, and district reports. This process aimed to identify adaptation actions that address similar impacts and vulnerabilities effectively
Stakeholder consultation	Identified stakeholders in Keta were engaged and consulted through participatory workshops, enabling open and equitable discussions on adaptation options based on climate scenarios. These workshops focused on identifying current and future impacts and vulnerabilities. Sector-specific stakeholders were also consulted and organized into seven groups, each addressing a specific sector of concern. • Agriculture • Gender (cross-cutting sector) • Biodiversity • Water Resource • Health and Sanitation • Critical Infrastructure • Fishing Industry

Source: Author diagram based on the KeMA Adaptation Plan

A total of 50 adaptation measures were identified across six critical sectors in the Keta Municipal Assembly with gender being crosscutting. These measures were meticulously developed to address the unique vulnerabilities of the municipality while strengthening its resilience to the impacts of climate change. The agriculture sector accounted for the highest number of actions (9), underscoring its essential role in the local economy, livelihoods, and food security. Following this, the Critical Infrastructure and Water Resources sectors with 8 targeted actions each, aimed at addressing specific vulnerabilities such as infrastructure resilience to sea-level rise and ensuring sustainable access to water. The Health and Sanitation sector was addressed with 7 measures, focusing on enhancing public health systems and disaster preparedness. Adaptation measures tackling gender, drivers of inequality and risk and vulnerability of marginal groups accounted for 6 actions. Biodiversity and Fisheries accounted for 6 and 5 measures, respectively, emphasizing ecosystem restoration, sustainable practices, and livelihood diversification. In light of limited resources and various constraints, it is essential to prioritize adaptation actions to ensure their effective implementation. The sectors are ranked based

on their socioeconomic significance, the expected level of impact, and their alignment with the municipality's most pressing climate vulnerabilities.

Table 17 Distribution of adaptation actions by sector

Sector	Number of Adaptation actions	Rank
Agriculture	9	1
Fishing Industry	6	2
Health and Sanitation	7	3
Critical Infrastructure	8	4
Water Resource	8	5
Gender (cross-cutting sector)	6	6
Biodiversity	5	7

Evaluation and Prioritization of Adaptation Options

Based on the significant vulnerabilities and climate risks identified within the Keta Municipal Assembly, an extensive list of potential adaptation actions was compiled through a detailed desk review and consultations with key stakeholders. These actions were subsequently validated and refined during stakeholder workshops, where participants were grouped according to their expertise and interests to evaluate, prioritize, and rank the proposed adaptation measures. This exercise utilized clear criteria and comprehensive information to ensure robust decision-making. The prioritization process involved assessing the suitability of each adaptation option in the context of Keta, its capacity to enhance resilience, and its effectiveness in addressing the vulnerabilities identified in the climate risk assessment (outlined in Section A of this report). Additionally, the overall contribution of these measures to sustainable development was thoroughly evaluated.

This process was designed to enable informed decision-making and prevent maladaptation. To achieve this, diverse stakeholders were actively involved in the assessment, ensuring the selected measures were context-appropriate and free from potential negative consequences. Each of the six stakeholder groups—agriculture, fishing industry, health and sanitation, critical infrastructure, water resource, gender (cross-cutting sector), biodiversity —assessed the proposed actions using a Multicriteria Decision-Making (MCDM) Analysis. This method allowed for a nuanced evaluation of each measure, acknowledging that different actions may perform variably across multiple criteria and involve trade-offs.

Multicriteria Decision-Making (MCDM) Analysis is a systematic approach for assessing and prioritizing options based on diverse criteria. It entails identifying relevant factors, assigning importance weights to each, and scoring the options against these criteria. This approach facilitates well-informed and balanced decisions, particularly when addressing complex issues involving multiple stakeholders and competing priorities (Dixit & McGray, 2013). The criteria used to evaluate the climate change adaptation strategies are further detailed in Table 10.

Plate 1 Consultation with the sector stakeholders for the ranking and prioritization exercise

Table 18 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 indicators, appropriate weights were assigned to reflect their relative importance using an unequal weighting system (Zobeidi et al., 2024; Antwi-Agyei et al., 2013; UNFCCC, 2011). The sector stakeholders and experts ranked the indicators on a five-point Likert scale, with rankings based on their perceived significance. The frequency with which each indicator was mentioned helped determine its weight in the final system.

Ranking of adaptation options based

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

10.2 Adaptation Strategies

This section outlines the prioritized strategies for adapting to climate change, emphasizing the objective of each strategy, the rationale behind it, and key factors to consider. The prioritized adaptation actions for Keta Municipal Assembly focus on enhancing resilience to climate risks identified. These measures were validated by stakeholders and prioritized for implementation in the presented order.

10.2.1 Agriculture

Agriculture in KeMA faces significant challenges from a combination of lagoon and coastal flooding, which are exacerbated by climate change and human activities. The municipality's location between the Gulf of Guinea and the expansive Keta Lagoon exposes it to dual flooding hazards. Coastal flooding, driven by rising sea levels and intensified tidal waves, frequently inundates farmland, causing soil erosion and salinization. Lagoon flooding occurs when heavy rainfall or upstream dam spillage causes the lagoon to overflow its banks, submerging surrounding agricultural lands and settlements. These hazards disrupt agricultural productivity and threaten food security, particularly for farming communities situated in low-lying areas. Events such as the 2023 Akosombo Dam spillage underscore the compounded risks posed by human-induced upstream changes and extreme weather events

The impacts of flooding on agriculture in Keta are profound. Coastal flooding introduces saline water into soils, rendering them unsuitable for crop cultivation and reducing yields of staples like maize, cassava, and vegetables. Lagoon flooding results in waterlogging, sedimentation, and crop damage, further destabilizing farming livelihoods. Farmers in Keta are further constrained by their reliance on traditional rain-fed agricultural practices, limited financial resources, and inadequate access to climate-related information, leaving them ill-equipped to cope with these growing risks.

The 9 adaptation measures in the agriculture sector were focused on addressing the these risks and vulnerabilities thereby increasing resilience and promoting sustainable agriculture.

Table 19 Summary of the Adaptation Actions for the Agricultural Sector

Priority	Adaptation Actions	Objectives	Indicators of Success	Time Frame	Resources	Implementing Partners		Estimated Costs
						Lead	Collaborating	
#1	Diversification of Livelihoods	Promote alternative income sources to reduce reliance on climate-sensitive farming activities.	Percentage of farming households adopting alternative livelihoods; Increased household income diversification indices.	Medium-term	Finance, Technology, Human	KeMA	MoFA, NGOs, Private Sector	
#2	Organic Mulching for Soil Improvement	Enhance soil fertility and moisture retention using organic materials like coconut husks.	Percentage increase in soil organic matter; Reduction in chemical fertilizer use; improvement in crop yields per hectare.	Short-term	Human, Finance	KeMA	MoFA, Local Farmers, NGOs	
#3	Research & Development on Resilient Crop Varieties	Develop and promote salt- and drought-tolerant crop varieties to withstand climate stress.	Number of resilient crop varieties developed and adopted; Increase in crop yield per hectare under stress conditions.	Long-term	Technology, Finance, Human	KeMA	Research Institutions, MoFA, NGOs	
#4	Implementation of Irrigation Systems	Optimize water use for agriculture to reduce dependency on rainfall.	Increase in hectares of farmland under irrigation; Improvement in crop yield stability during dry seasons.	Medium-term	Finance, Technology	KeMA	MoFA, Development Partners, Private Sector	

#5	Improved Vegetable Cultivation Practices	Enrich soil nutrients and improve vegetable productivity in specific soil types using organic manure.	Increased yield of vegetables per hectare; Reduction in synthetic fertilizer application.	Medium-term	Finance, Human	KeMA	MoFA, Local Farmers, NGOs	
#6	Upgrade Weather Forecasting Infrastructure	Provide accurate and localized weather forecasts to aid agricultural planning.	Number of functional localized weather stations; Increase in farmers accessing and using forecasts for decision-making.	Short-term	Finance, Technology	KeMA	MoFA, GMet, Development Partners	
#7	Improving Farmers' Access to Climate-Related Information	Equip farmers with real-time climate information through interactive communication tools.	Percentage of farmers accessing and utilizing climate-related information; Reduction in crop losses due to climate variability.	Short-term	Finance, Human	KeMA	MoFA, NGOs, Media Organizations	
#8	Promotion of Climate-Resilient Agriculture	Train farmers on seasonal prioritization and efficient fertilizer use to enhance resource efficiency.	Percentage increase in crop yields during the main growing season; Reduction in fertilizer waste.	Short-term	Human, Finance	KeMA	MoFA, Agricultural Extension Services	
#9	Development of Early Warning and Response Mechanisms	Establish accessible systems to warn farmers of impending climate hazards.	Number of farmers receiving and acting on early warnings; Reduction in climate-induced crop losses.	Short-term	Finance, Technology, Human	KeMA	MoFA, Local NGOs, Community Leaders	

10.2.2 Fishing Industry

Fishing in Keta Municipal Assembly (KeMA) is heavily impacted by climate change, with key hazards including lagoon and coastal flooding, rising sea levels, and mangrove degradation. These hazards disrupt fish breeding habitats, reduce fish stocks, and increase the vulnerability of fishing communities. Coastal erosion and siltation of the lagoon further exacerbate these challenges, threatening the livelihoods of fishers who rely on the availability of stable aquatic ecosystems. Inadequate enforcement of fishing regulations and destructive fishing practices, such as overharvesting of mangroves, also contribute to habitat destruction, making the industry more susceptible to the impacts of climate variabilityin the fishing sector are compounded by socioeconomic challenges, such as limited access to alternative livelihoods, insufficient financial resources, and a lack of technical expertise for sustainable aquaculture. These challenges leave fishing communities ill-equipped to adapt to climate risks. Additionally, the encroachment of wetlands and inadequate wetland management practices reduce natural buffers against flooding and storm surges. Addressing these issues requires an integrated approach that includes mangrove restoration, regulation enforcement, and community-based management systems. The following table outlines prioritized adaptation measures validated by stakeholders to enhance resilience in Keta's fishing industry.

Table 20 Summary of the Adaptation Actions for the Fishing Industry

Priority	Adaptation Actions	Objectives	Indicators of Success	Time Frame	Resources	Implementing Partners		Estimated Costs
						Lead	Collaborating	
#1	Effective Regulations and Local Enforcement of Bye-Laws	Protect wetlands and mangroves from unsustainable practices and illegal activities.	Number of bye-laws enforced; reduction in illegal mangrove harvesting and wetland encroachment incidents.	Medium-term	Human, Finance, Technology	KeMA	Fisheries Commission, Local Communities	
#2	Mangrove and Wetland Rehabilitation	Restore degraded mangroves and wetlands to improve fish breeding habitats and biodiversity.	Area (hectares) of mangroves and wetlands restored; increase in fish populations in restored areas.	Long-term	Finance, Technology, Human	KeMA	EPA, Local NGOs, Fisheries Commission	
#3	Diversification of Livelihoods	Reduce over-reliance on fishing by introducing alternative income-generating activities for communities.	Percentage of fishing households adopting diversified livelihoods; increase in income from alternative sources.	Medium-term	Finance, Technology, Human	KeMA	Fisheries Commission, NGOs, Private Sector	
#4	Phasing Out or Improving Unsustainable Fishing Methods	Minimize environmental damage by encouraging sustainable fishing techniques and practices.	Percentage reduction in the use of unsustainable fishing methods; increase in adoption of approved fishing techniques.	Medium-term	Finance, Technology	KeMA	Fisheries Commission, NGOs, Fisher Associations	
#5	Financial Assistance Programs	Support fishers with funds for boat repair, replacement, and sustainable operations.	Number of beneficiaries receiving financial assistance; reduction in downtime due to equipment failure.	Short-term	Finance, Human	KeMA	Local Banks, Fisheries Commission, Development Partners	
#6	Promotion of Sustainable Aquaculture Development	Develop and promote sustainable aquaculture systems to supplement fish stocks.	Number of aquaculture facilities established; increase in fish production through sustainable aquaculture.	Long-term	Finance, Technology, Human	KeMA	Fisheries Commission, Research Institutions, NGOs	

10.2.3 Health and Sanitation

Health and sanitation in Keta Municipal Assembly (KeMA) face significant challenges from climate change, with key hazards including flooding, water scarcity, and rising temperatures. Flooding, exacerbated by sea-level rise and intense rainfall, overwhelms sanitation systems, leading to the contamination of water sources and an increased prevalence of waterborne diseases such as cholera and typhoid fever. Stagnant floodwater creates breeding grounds for mosquitoes, heightening the risk of malaria.

Rising temperatures also pose risks, including heat-related illnesses and the proliferation of temperature-sensitive diseases. Vulnerabilities in the health sector are further compounded by insufficient healthcare infrastructure, inadequate sanitation facilities, and limited access to clean water, leaving communities ill-equipped to cope with these hazards and sanitation are magnified by the municipality's reliance on aging drainage systems, unregulated waste disposal, and inadequate public awareness of hygiene practices.

Flood events often cause sewage overflows, polluting water sources and exacerbating health risks for vulnerable groups, including children and pregnant women. Climate variability also stresses the capacity of healthcare facilities, which are often ill-equipped to manage outbreaks of climate-sensitive diseases. To address these vulnerabilities, adaptation measures such as improving drainage systems, restoring wetlands, strengthening healthcare infrastructure, and enhancing public health education have been prioritized. These measures aim to build community resilience and safeguard public health in the face of increasing climate-related challenges.

Table 21 Summary of the Adaptation Actions for the Health and Sanitation

Priority	Adaptation Actions	Objectives	Indicators of Success	Time Frame	Resources	Implementing Partners		Estimated Costs
						Lead	Collaborating	
#1	Improve Early Warning and Response Mechanisms	Enhance disaster preparedness and response to minimize health impacts from climate hazards.	Number of functional early warning systems; reduced mortality and morbidity during disasters.	Short-term	Human, Technology, Finance	KeMA	MoH, GMet, Local NGOs	
#2	Restoring Wetlands and Floodplains	Reduce flood risks and water contamination by rehabilitating wetlands and natural drainage systems.	Area (hectares) of wetlands restored; reduction in flood-related disease outbreaks.	Medium-term	Human, Finance, Technology	KeMA	MoH, EPA, Local Communities, Development Partners	
#3	Public Health Education Campaigns	Raise awareness about sanitation, hygiene, and health risks related to climate change.	Number of campaigns conducted; percentage of the population adopting improved hygiene practices like handwashing.	Short-term	Finance, Human	KeMA	MoH, NGOs, Local Community Leaders	
#4	Enforcement of Public Health Regulations	Ensure compliance with sanitation and water quality standards to safeguard public health.	Number of inspections conducted; percentage reduction in non-compliance cases.	Medium-term	Human, Finance	KeMA	MoH, Environmental Health Officers	
#5	Redesign and Resilience of Sanitation Infrastructure	Strengthen sanitation facilities to withstand extreme weather events and flooding.	Number of flood-resistant latrines and improved wastewater systems constructed.	Medium-term	Finance, Technology	KeMA	MoH, Development Partners	
#6	Development and Strengthening of Health Facilities	Build capacity for health facilities to handle climate-induced illnesses and emergencies.	Number of upgraded health facilities; increase in trained health personnel and equipment for climate-sensitive illnesses.	Medium-term	Finance, Human, Technology	KeMA	MoH, Development Partners, NGOs	
#7	Expansion of Drainage Systems	Prevent waterborne diseases by improving drainage systems in urban and peri-urban areas.	Number of new or expanded drainage systems; reduction in flooding and waterlogging incidents.	Medium-term	Finance, Technology	KeMA	MoH, EPA	

10.2.4 Critical Infrastructure

Keta Municipal Assembly's critical infrastructure is increasingly vulnerable to the impacts of climate change, with hazards such as flooding, coastal erosion, and storm surges posing significant threats. Flooding caused by intense rainfall and rising sea levels disrupts roads, markets, and public facilities, hampering essential services and economic activities in the municipality. Coastal erosion, driven by strong wave action, endangers infrastructure along the shoreline, including buildings in low-lying areas. These hazards expose the municipality to heightened risks, including damage to critical facilities, displacement of communities, and interruptions in livelihoods. The inadequacy of drainage systems to manage heavy rainfall exacerbates these risks, leading to widespread water damage and rendering infrastructure increasingly unreliable.

The vulnerabilities in Keta's critical infrastructure are further amplified by systemic challenges such as insufficient funding, limited technical capacity, and poor maintenance of existing assets. The lack of regular inspection and upkeep of key infrastructure, including high-tension electric cables and water supply systems, increases their s=usceptibility to damage during extreme weather events. Additionally, issues such as land acquisition disputes and weak enforcement of building codes hinder the development of resilient infrastructure. Communities in flood-prone and low-lying areas are disproportionately affected, particularly those relying on markets and transportation networks for their livelihoods. Addressing these challenges requires comprehensive adaptation measures to ensure the resilience and functionality of critical infrastructure against climate risks.

Table 22 Summary of the Adaptation Actions for the Critical Infrastructure

Priority	Adaptation Actions	Objectives	Indicators of Success	Time Frame	Resources	Implementing Partners		Estimated Costs
						Lead	Collaborating	
#1	Extension and Elevation of the Sea Defense Wall	Protect coastal infrastructure and communities from coastal erosion and storm surges.	Length (meters) of sea defense wall extended and elevated; reduction in reported cases of coastal flooding.	Medium-term	Finance, Technology, Human	KeMA	MoF, Development Partners	
#2	Construction and Rehabilitation of Resilient Market Structures and Schools	Ensure critical facilities are designed or retrofitted to withstand climate hazards.	Number of market structures and schools built or retrofitted; improved safety and usability of these facilities during hazards.	Medium-term	Finance, Human, Technology	KeMA	MoE, NGOs, Development Partners	
#3	Community Engagement and Awareness Programs	Educate residents on climate risks and promote community participation in resilience planning.	Number of workshops conducted; increased community knowledge and participation in disaster management plans.	Short-term	Finance, Human	KeMA	Local NGOs, Community Leaders	
#4	Construction and Expansion of Drainage Systems	Mitigate flooding by improving stormwater drainage capacity in urban and peri-urban areas.	Kilometers of drainage systems constructed or rehabilitated; reduction in flood frequency and severity in key areas.	Medium-term	Finance, Technology	KeMA	MoW, Local Contractors	
#5	Enhancement of Berms with Salt-Tolerant Vegetation	Stabilize soil and reduce erosion by planting salt-tolerant grasses and shrubs along berms.	Kilometers of berms vegetated; reduction in soil erosion incidents along critical infrastructure.	Short-term	Human, Technology	KeMA	EPA, Agricultural Extension Services	
#6	Infrastructure Audit and Reinforcement	Assess vulnerabilities and strengthen critical infrastructure to improve resilience.	Percentage of infrastructure audited and reinforced; reduction in climate-related infrastructure failures.	Short-term	Finance, Human	KeMA	MoT, Development Partners	
#7	Inspection and Maintenance of Infrastructure	Establish regular inspection and maintenance schedules for critical systems like water and energy supply.	Frequency of inspections conducted; reduction in infrastructure failures caused by poor maintenance.	Short-term	Human, Finance	KeMA	MoW, Local Contractors	
#8	Implementation of New Architectural Designs and Building Codes	Ensure climate-resilient designs are adopted in all new constructions.	Number of new buildings adhering to climate-resilient codes; percentage compliance with updated building standards.	Medium-term	Finance, Technology	KeMA	MoW, Local Engineers, Architects	

10.2.5 Water Resource

Water resources in Keta Municipal Assembly are under significant threat from climate change, with hazards such as saltwater intrusion, flooding, and erratic rainfall patterns posing substantial challenges. Rising sea levels and coastal flooding exacerbate the salinization of water bodies and underground aquifers, rendering them unsuitable for drinking and agricultural purposes. Erratic rainfall patterns reduce the reliability of freshwater availability, intensifying water scarcity. These hazards compromise the quality and quantity of water resources, affecting the livelihoods of local communities dependent on agriculture, fishing, and domestic water supply.

The vulnerabilities in water resource management are further amplified by inadequate infrastructure for water storage and distribution, limited community awareness of sustainable water usage, and the degradation of natural water bodies such as wetlands and lagoons. Flooding events often introduce pollutants into freshwater sources, heightening public health risks and reducing water usability. Additionally, the lack of coordination among agencies responsible for water management hinders the effective implementation of resilience measures. Addressing these challenges requires targeted interventions to restore natural water systems, enhance infrastructure, and build community capacity for sustainable water resource management.

Table 23 Summary of the Adaptation Actions for the Water Resource

Priority	Adaptation Actions	Objectives	Indicators of Success	Time Frame	Resources	Implementing Partners		Estimated Costs
						Lead	Collaborating	
#1	Promote Rainwater Harvesting Systems	Enhance water conservation and reduce reliance on external sources during droughts.	Number of rainwater harvesting systems installed; volume of water harvested annually.	Medium-term	Finance, Technology, Human	KeMA	NGOs, Private Sector, Development Partners	
#2	Restore Natural Drainage Systems	Rehabilitate wetlands and estuaries to buffer against heavy rainfall and flooding.	Area (hectares) of wetlands restored; reduction in flood frequency and water pollution levels.	Medium-term	Human, Finance, Technology	KeMA	EPA, Local Communities, NGOs	
#3	Inter-Agency Coordination for Water Management	Foster collaboration between agencies for efficient water resource management and planning.	Number of coordination meetings held annually; percentage of planned actions implemented collaboratively.	Short-term	Finance, Human	KeMA	Water Resource Commission, NGOs	
#4	Community Education and Involvement	Promote water conservation and quality practices through public education and workshops.	Number of workshops conducted; percentage of community members adopting water conservation practices.	Short-term	Finance, Human	KeMA	NGOs, Educational Institutions	
#5	Monitor and Improve Water Quality and Salinity Control	Ensure water quality through regular testing and mitigate salinity issues.	Frequency of water quality tests conducted; reduction in salinity levels in key water sources.	Medium-term	Finance, Technology	KeMA	MoW, EPA, Local Water Boards	
#6	Manage Water Levels and Address Lagoon Siltation	Conduct dredging to improve water flow, reduce siltation, and maintain lagoon depth.	Volume of silt removed; improvement in water flow rates and lagoon navigability.	Medium-term	Finance, Human, Technology	KeMA	MoW, Development Partners	
#7	Expansion of Mechanized Boreholes	Increase access to potable water through mechanized boreholes in underserved areas.	Number of boreholes constructed; percentage increase in clean water coverage for households.	Short-term	Finance, Technology, Human	KeMA	NGOs, Private Sector	
#8	Development and Upgrading of Small-Town Water Systems	Provide centralized water treatment and distribution systems for growing communities.	Number of water systems upgraded; percentage of population with access to clean water.	Medium-term	Finance, Technology		MoW, Development Partners, Local Contractors	

10.2.6 Gender (cross-cutting sector)

Gender disparities in Keta Municipal Assembly amplify the vulnerabilities of women and marginalized groups to the impacts of climate change. Hazards such as flooding, drought, and coastal erosion disproportionately affect women, who often bear the burden of managing water, food, and energy resources for their households. Women are particularly vulnerable to the loss of livelihood opportunities caused by climate-induced disruptions in agriculture, fishing, and small-scale enterprises, which are critical sources of income. Additionally, extreme weather events such as flooding increase the burden of unpaid domestic work, including caregiving and collecting scarce water resources, limiting women's capacity to participate in community decision-making and resilience-building efforts.

The risks to gender equity in Keta are exacerbated by systemic challenges, including limited access to land, financial resources, and climate-resilient technologies. Social and cultural norms often restrict women's participation in planning and implementing adaptation strategies, leaving their perspectives and needs inadequately addressed. Vulnerabilities are heightened during disasters, as women and girls face greater risks of displacement and disruptions in access to healthcare and education. Addressing these issues requires targeted adaptation measures that promote gender-responsive planning, empower women through capacity building and livelihood diversification, and ensure equitable access to resources and decision-making platforms.

Table 24. Summary of the Adaptation Actions for the Gender (cross-cutting sector)

Priority	Adaptation Actions	Objectives	Indicators of Success	Time Frame	Resources	Implementing Partners		Estimated Costs
						Lead	Collaborating	
#1	Women's Sustainable Livelihood Programs	Empower women with alternative livelihood opportunities such as eco-tourism, beekeeping, and sustainable fishing practices.	Number of women trained in alternative livelihoods; percentage increase in household incomes led by women.	Medium-term	Finance, Technology, Human	KeMA	MoGCSP, NGOs, Local Communities	
#2	Supporting Women's Climate Resilience	Provide financial and technical support to help women adapt to climate-related impacts.	Number of women accessing financial support; increase in women-led adaptation initiatives.	Medium-term	Finance, Technology	KeMA	MoGCSP, Development Partners, NGOs	
#3	Climate Educational Programs for Heat Stress Management	Raise awareness about hydration, rest, and protective measures to reduce heat-related health risks.	Number of community workshops conducted; percentage decrease in heat stress-related health cases reported.	Short-term	Human, Finance	KeMA	MoH, NGOs, Educational Institutions	
#4	Gender Mainstreaming in Disaster Risk Reduction	Ensure inclusivity in disaster risk planning and decision-making processes.	Percentage of disaster risk reduction plans integrating gender considerations; number of women participating in planning.	Medium-term	Human, Finance	KeMA	MoGCSP, Local NGOs	
#5	Enhancing Healthcare Access for Pregnant Women	Improve access to prenatal care and health services during climate-related emergencies.	Percentage increase in prenatal care visits; number of healthcare facilities offering improved maternal services.	Short-term	Finance, Human, Technology	KeMA	MoH, Local Health Providers, NGOs	
#6	Incorporating Native Tree Planting	Establish shaded rest areas by planting native trees to reduce heat stress for fisherfolk and market vendors.	Number of trees planted; number of shaded rest areas created for vulnerable groups.	Medium-term	Finance, Technology	KeMA	Local Communities, NGOs	

10.2.7 Biodiversity

Biodiversity in the Keta Municipal Assembly is under increasing threat due to climate change and human activities. Key hazards include sea-level rise, coastal erosion, and flooding, which disrupt ecosystems and degrade habitats. Coastal wetlands, mangroves, and the Keta Lagoon Complex, which provide critical ecological services and support numerous species, are particularly vulnerable to saltwater intrusion and habitat loss. Extreme weather events such as storms further exacerbate the degradation of these habitats, threatening species that rely on them, including endangered marine turtles, migratory birds, and unique aquatic life forms.

The risks to biodiversity are compounded by vulnerabilities such as limited conservation funding, inadequate enforcement of environmental regulations, and the encroachment of urban development into critical habitats. Overexploitation of natural resources, including overfishing and unsustainable agricultural practices, further weakens the resilience of ecosystems. Local communities that depend on these resources for their livelihoods face diminished access to fisheries and other ecological goods, highlighting the need for urgent action to preserve biodiversity and maintain the ecosystem services critical for climate adaptation and community resilience.

Table 25 Summary of the Adaptation Actions for the Biodiversity Sector

Priority	Adaptation Actions	Objectives	Indicators of Success	Time Frame	Resources	Implementing Partners		Estimated Costs
						Lead	Collaborating	
#1	Community-Based Management of Wetlands and Mangroves	Train and empower local communities to manage wetlands and mangroves sustainably.	Number of community-based management programs established; area (hectares) of wetlands and mangroves sustainably managed.	Medium-term	Finance, Human	KeMA	NGOs, Local Communities	
#2	Mangrove Restoration	Restore degraded mangrove forests to enhance biodiversity and ecosystem resilience.	Number of mangrove trees planted; increase in mangrove forest cover; improved habitat for aquatic and terrestrial species.	Long-term	Finance, Technology, Human	KeMA	EPA, Local NGOs, Development Partners	
#3	Community Workshops on Sustainable Practices	Educate farmers and fisherfolk on sustainable practices and the benefits of biodiversity conservation.	Number of workshops conducted; percentage of participants adopting sustainable practices.	Short-term	Human, Finance	KeMA	NGOs, Educational Institutions	
#4	Collaboration for Biodiversity Conservation	Partner with research institutions, NGOs, and universities to identify and implement biodiversity conservation strategies.	Number of collaborative projects undertaken; improvement in the condition of key ecosystems and species.	Medium-term	Human, Finance	KeMA	EPA, Research Institutions, Development Partners	
#5	Protect Wetlands and Forests	Enforce regulations and monitor the use of resources using community patrols and modern technology like drones.	Number of patrols conducted; reduction in illegal exploitation of wetlands and forests.	Medium-term	Human, Finance, Technology	KeMA	EPA, Local Communities	

11

Framework for Adaptation Monitoring, Evaluation, and Learning

Monitoring, evaluation, and learning (MEL) play a key role in successful adaptation efforts in the Keta Municipal for several reasons:

- **Tracking Progress:** MEL systems enable ongoing monitoring of adaptation initiatives to ensure they are progressing towards their goals (European Environment Agency, 2024).
- **Evaluating Effectiveness:** By assessing the results of adaptation measures, MEL identifies what works, what doesn't, and why, allowing for adjustments to improve effectiveness.
- **Informed Decision-Making:** The insights from MEL activities inform future planning and decisions, ensuring that adaptation actions are evidence-based and more likely to succeed (NAP Global Network, 2024).
- **Continuous Improvement:** MEL encourages learning from past experiences, helping the Keta Municipal Assembly refine strategies and interventions over time.
- **Resource Efficiency**: Effective MEL identifies the most efficient use of resources, ensuring that investments in adaptation actions achieve optimal outcomes.
- **Stakeholder Involvement:** MEL processes engage various stakeholders, including local communities, building trust and ensuring that adaptation actions are inclusive and meet the needs of all affected groups.
- **Accountability and Transparency:** Regular monitoring and evaluation ensure accountability and transparency in the implementation of adaptation measures, which is crucial for maintaining public trust and securing continued support.

11.1 Leveraging Existing Structures for Mainstreaming in Keta

MEL can enhance mainstreaming efforts in Keta by integrating into existing systems and processes. For instance, MEL can be incorporated into Keta's current data collection and management frameworks to ensure that adaptation actions are based on accurate and up-to-date information, improving decision-making and resource allocation. It can also strengthen the capacity of local government staff through training, helping develop a skilled workforce for effectively implementing and monitoring adaptation measures. MEL can improve coordination across various departments and stakeholders by utilizing existing communication and collaboration platforms. Additionally, integrating MEL into Keta's reporting systems, such as annual reports and development plans, ensures that adaptation actions are regularly reviewed and adjusted based on performance and feedback. Local community engagement structures can be leveraged to involve residents in

the adaptation planning process, ensuring actions reflect the needs and priorities of Keta's residents. Finally, MEL can utilize knowledge-sharing platforms to promote the exchange of best practices and lessons learned from past adaptation efforts, fostering a culture of continuous learning and improvement. By building on these existing structures, Keta can effectively mainstream adaptation actions, contributing to more resilient and sustainable urban development.

11.2 MEL Framework

The MEL system in Keta is designed to achieve several key climate change adaptation goals:

- **Building Resilience:** MEL ensures that adaptation actions effectively strengthen the resilience of infrastructure, communities, and ecosystems against climate impacts.
- **Informed Decision-Making:** By providing ongoing feedback on the effectiveness of adaptation measures, MEL supports data-driven decision-making and allows for the adjustment of strategies based on real-time results.
- **Efficient Resource Use:** MEL promotes the efficient use of resources by identifying the most effective adaptation actions and reallocating resources to areas where they are most needed.
- **Stakeholder Involvement:** MEL ensures the active participation of various stakeholders, including local communities, in the adaptation process, ensuring actions are inclusive and reflect the needs of all affected groups.
- **Accountability and Transparency:** Regular monitoring and evaluation promote accountability and transparency in the implementation of adaptation measures, helping to maintain public trust and secure ongoing support.
- **Ongoing Improvement:** MEL fosters a culture of continuous learning, enabling Keta to refine and improve its adaptation strategies over time based on the lessons learned.

By achieving these goals, MEL supports Keta in effectively integrating climate change adaptation into its development plans, ensuring sustainable and resilient urban growth. Implementing the MEL system requires incorporating climate adaptation into municipal development plans and policies, such as the MTDP, and aligning these with the current monitoring and evaluation framework.

Table 26 Outline of approach to MEL of KeMA's adaptation actions

Steps	Indicative activities—to be led by the KeMA Planning Coordination Unit
1. **Monitoring the adaptation actions**	• Identify adaptation actions to be tracked using both qualitative and quantitative measures to assess progress toward adaptation goals. • Establish metrics and indicators to monitor the progress of the selected adaptation actions. • Gather data on the defined metrics and indicators throughout the adaptation process.

2. **Reviewing the adaptation process to assess progress, effectiveness, and gaps –** **Evaluation**	• Establish methods for measuring and communicating the effectiveness of adaptation actions, while identifying any gaps. • Collect insights from recent research and scientific advancements, alongside feedback and outcomes from ongoing adaptation initiatives, to assess and update the strategy or approach. • Update the adaptation activities based on evaluation findings and performance metrics.
3. **Iteratively updating the NAP** – **Learning**	• Revise adaptation activities using the collected information. • Record key lessons learned, including what was successful and what was not. • Establish criteria for success and failure. • Apply corrective actions where necessary. • Ensure that learning and corrective actions align with broader goals within the KeMA MTDP.
Steps	**Indicative activities—to be led by the KeMA Municipal Planning Coordination Unit**
4. **Communication Report progress, process effectiveness, outreach, and knowledge and information dissemination**	• Share adaptation documents and learning materials. • Include information in the KeMA annual progress report on the progress and effectiveness of the adaptation initiatives.

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

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Appendix A Risk Assessment Methodology

A1 I Determining the Magnitude of the Hazard

Table B. 1 present the criteria to define the magnitude of the hazard.

Table B. 1I Criteria for determining the magnitude of the hazard

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

A2 I Determining the Level of Exposure

Table B. 2 present the criteria to determine the level of exposure.

Table B. 2 I Criteria for assessing the level of exposure

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

A3 I Assessing the Systems' Vulnerability

Table B. 3, and Table B. 4 present the criteria to assess sensitivity and adaptive capacity respectively.Table B. 5 presents the matrix used to assess and categorise the level of vulnerability for each systemor assets.

Table B. 3 I Criteria to access sensitivity

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

Table B. 4 I Criteria to access adaptive capacity

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

Very Low	Lack of basic energy services, water supply to communities, etc. to address the potentialimpacts of climate change. Lack of knowledge and perception about the phenomenon ofclimate change and its effects on natural ecosystems and local livelihoods. Very limited and vulnerable means of survival and no alternative means.

Table B. 5 I Vulnerability Matrix

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

A4 I Evaluating Priority Risks

Table B. 6 presents the matrix used to rank the potential risks of the hazards associated with climate change on natural and human systems, based on exposure to identified climate hazards and the vulnerability of key natural systems, socio-economic sectors and local livelihoods.

Table B. 6 I Risk Matrix

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