Climate Vulnerability Assessment for the Cape Coast Municipal Assembly (CCMA)

March 2024 | Final Report

Climate Vulnerability Assessment
for the Cape Coast Municipal Assembly (CCMA)

Authors: Dr. Bob Manteaw, Dr. Yaw Agyeman Boafo, and Mr. Bernard Ayittah on behalf of Foresight Planners and Research Africa Limited

Environmental Protection Agency
Ministry of Environment, Science, Technology, and Innovation
Government of Ghana
Accra, Ghana
info@epa.gov.gh

Photo credit: BMA

Acknowledgements

The Government of Ghana, represented by the Environmental Protection Agency (EPA), expresses its gratitude to the different experts from the national government, municipal assemblies, civil society organizations, academia, the private sector, and all stakeholders who participated in various workshops to generate the needed information and knowledge to support this work. The EPA extends a special thanks to Dr. Bob Offei Manteaw, lead author and Principal of Foresight Planners and Research Africa Limited, for his coordinating and technical leadership roles. A special thanks also goes to Dr. Yaw Agyeman Boafo and Mr. Bernard Ayittah for their co-authorship roles in this work. Finally, we extend our warmest appreciation to Dr. Antwi Boasiako Amoah, of the EPA and NAP Project Coordinator, for his insightful supervision of this project.

The Climate Vulnerability Assessment for the Cape Coast Municipal Assembly (CCMA), as part of Ghana's NAP process, was prepared with financial and technical assistance from the National Adaptation Plan (NAP) Global Network Secretariat, International Institute for Sustainable Development (IISD) via the generous financial support of the Government of Germany.

NAP Global Network

This project is undertaken with the financial support of:
Ce projet a été réalisé avec l'appui financier de :

Secretariat hosted by:
Secrétariat hébergé par :

In partnership with Canada

Federal Ministry for Economic Cooperation and Development

Government of Ireland International Development Programme

IISD

Climate Vulnerability Assessment for the Cape Coast Municipal Assembly (CCMA)

March 2024 | Final Report

Foreword

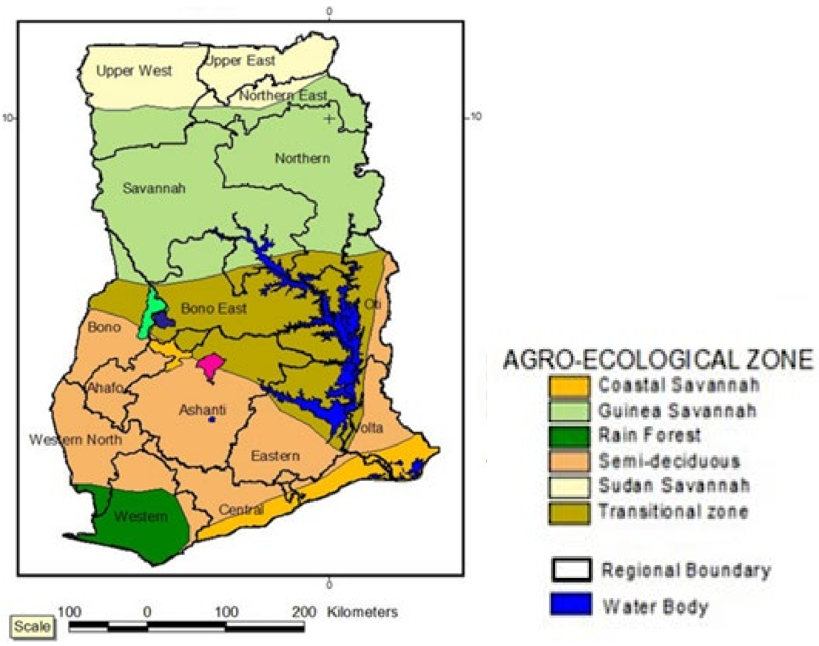
The Government of Ghana prepared six district-level climate vulnerability assessments, each for a municipal assembly located in one of the country's agroecological zones as part of the National Adaptation Planning (NAP) process. These vulnerability assessments aimed to improve the national and subnational governments' understanding of climate hazards, vulnerabilities, and risks both now and in the future to generate a knowledge base to guide adaptation planning and the identification of priority adaptation actions. They were also to provide a baseline against which progress in adaptation could be monitored and evaluated.

Vulnerability assessments were prepared for the following municipalities drawn from Ghana's six specific agroecological zones:

- Bekwai: Semi-Deciduous Forest
- Bibani-Anhwiaso-Bekwai: Rain Forest
- Cape Coast: Coastal Savannah
- Kassena Nankana: Sudan Savannah
- Kintampo: Transitional
- New Juaben South: Semi-Deciduous Forest

This vulnerability assessment was prepared for the Cape Coast Municipal Assembly (CCMA) and is representative of a district located in the Coastal Savannah zone of Ghana's agroecological zones (see Figure 1).

Figure 1. Regional and agroecological map of Ghana



Source: Hashmiu, I., Agbenyega, O., & Dawoe, E. (2022). Cash crops and food security: evidence from small holder cocoa and cashew farmers in Ghana. *Agriculture & Food Security 11:12*, Page 7 of 21.

Table of Contents

List of Tables

List of Figures

Abbreviations

CCMA	Cape Coast Municipal Assembly
CCVA	Climate Change Vulnerability Assessment
DACF	District Assembly Common Fund
EPA	Environmental Protection Agency Ghana
GCF	Green Climate Fund
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GMet	Ghana Meteorological Agency
IPCC	Intergovernmental Panel on Climate Change
MoFA	Ministry of Food and Agriculture
NADMO	National Disaster Management Organisation
NAP	National Adaptation Plan
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development

1.

1.1 Introduction

The impacts of climate change have become increasingly evident in recent years across key climate-sensitive sectors in Ghana such as agriculture, fisheries, forestry, water resources, mining, and health. Impacts such as drought, floods (both coastal and inland) and heatwaves have become common occurrences in many communities, with significant ramifications for Ghana's sustainable development goals. The Government of Ghana, working with development partners, have initiated various efforts, including the on-going National Adaptation Plan (NAP) process, to identify, quantify, and understand the mediating effects of both the social and physical environments on current and future climate change impacts and to respond with the appropriate adaptation measures.

As efforts intensify to understand climate change and its impacts across various sectors in Ghana, it has become urgent to assess current and plausible future climate vulnerabilities and to use such understandings to drive adaptation planning. Central to identifying, assessing, and appreciating the nature and distribution of vulnerabilities is the ability to understand the science and signs behind changing climatic conditions and the relative impacts of such changes on people, communities, and key sectors. It is critical to use such understandings to address uncertainties, as well as to make bold predictions upon which actionable climate adaptation decisions will be premised.

Climate change impacts are place- and context-specific, and as such adaptation planning should be context-responsive (Krause, Schwab & Birkmann, 2015). As Ghana's NAP process advances, it becomes vitally important that adaptation planning is driven by an appreciation of the geographical distribution of current and anticipated climate impacts. It is similarly important that such information is used to assess levels of climate vulnerabilities for effective and proactive adaptation planning.

Ghana's NAP process also emphasizes the importance of context-specificity and place-responsive approaches to adaptation planning. A central objective, as specified in Ghana's NAP Framework is to reduce vulnerability to adverse impacts of climate change by building adaptive capacity and resilience in local communities (Environmental Protection Agency [EPA], 2018). To achieve this, Ghana's NAP has adopted a district-focused adaptation planning process which uses district-level vulnerability assessments to ground adaptation planning for key climate sensitive sectors such as agriculture (fisheries, crops, and livestock), forestry, water, energy, gender, and health. The aim is to use information on district-level vulnerabilities and geographical considerations to develop standalone adaptation plans for each district in Ghana.

This vulnerability assessment was prepared for the Cape Coast Metropolitan Assembly and is representative of a district located in the Coastal Savannah agroecological zone (Figure 1).

1.2 Purpose and Objectives of the Vulnerability Assessment

The overarching objective of this vulnerability assessment (VA) process is to identify human and natural systems as well as economic sectors in the selected districts that are particularly vulnerable to climate variability and change and need special attention in terms of adaptation. This will help the government to take informed policy decisions when channeling funds for adaptation activities. The specific objectives are:

- To identify district-specific vulnerabilities and prioritize them in the Cape Coast municipality to inform district-specific adaptation planning and action under the NAP process.
- To inform the design of projects/programs to be implemented in the Cape Coast Municipal Assembly.
- To provide knowledge products that can be used for awareness creation and advocacy campaigns.

1.3 Scope of Vulnerability Assessment

The scope of the Cape Coast VA work is as follows:

- **Sectors:** As stipulated in the Ghana NAP framework, the VAs addresses a range of key sectors at risk from climate change impacts such as agriculture (crop and livestock), forestry (ecosystems and biodiversity), infrastructure, water, sanitation and health, and commerce. Impacts and vulnerabilities were assessed in individual sectors and complemented with cross-sectoral analysis that take into consideration the cascading nature of climate change impacts.
- **Geographic scope:** The objective of the district-specific VA for the six districts is to guarantee inclusion of various agroecological zones, and the Cape Coast Metro area was chosen to represent Coastal Savannah. The evaluation focused on the Cape Coast municipality, using individual townships as the fundamental analytical unit. Data on these townships was collected through individual household surveys.
- **Timeframe for analysis:** Given the long-term nature of climate change and its impacts, the VA examined current vulnerabilities as well as projected future impacts up until 2100. This approach, we believe, will provide important information for planning into the future.

1.4 Outputs of the Vulnerability Assessment

This VAs seeks to produce seven main outputs:

- Output 1: Development of climate projections and scenarios for each the Cape Coast Municipal Assembly (4.1)
- Output 2: Description and creation of representative district-level vulnerability narratives (3)

- Output 3: Projections and description of potential future vulnerabilities (4.1.6)
- Output 4: Analysis of pathways that link current vulnerabilities to the future (5.1)
- Output 5: Description of prioritized vulnerabilities in key climate-sensitive sectors (3.2.2)
- Output 6: Creation of a map of vulnerability hotspots in each district (3.3.2)
- Output 7: Identifying available options to help people and communities adapt to the effects of climate variability and change (5.2)

1.5 Guiding Principles

Development of the vulnerability assessment for the Cape Coast Metro was guided by the principles of the Ghana NAP process and the Least Developed Country Expert Group's technical guidelines for the NAP process. They included.

- **District-specific and needs-driven:** The assessment was tailored to identify specific vulnerabilities in specific districts to inform the development of district-specific adaptation responses. Cape Coast is in the Coastal zone and apart from inland climate risks. It also faces risks associated with sea level rise such as coastal erosion and inundation. The unique vulnerabilities and impacts in the district, such as the effects of sea level rise on agriculture and the drying of lagoons that support livelihoods demonstrate the importance of a district-specific and needs-driven approach.
- **Inclusivity:** The VA process made conscious efforts to identify, engage, and include all stakeholders from diverse places, institutions, sectors, communities, and groups (including women, youth, and marginalized stakeholder groups) who are currently impacted by or projected to be impacted by climate change both in the design and implementation of the assessment. Fifty-seven stakeholders, including 21 women and 36 men, were engaged from the institutions, groups and organization listed in Appendix 2.
- **Relevant to the NAP and national priorities:** This VA was aligned with and aimed to advance Ghana's NAP process, as well as other national and Cape Coast Metro's development priorities. The VA incorporated sectors and areas of developmental priority in Cape Coast Metro's Medium Term Development Plan (MTDP) and considered how the results of the VA could inform actions in such areas.
- **Utilize existing structures and resources:** The Green Climate Fund (GCF) NAP Readiness program has been running in Ghana for some time and has generated knowledge, and established stakeholder relationships and collaboration fora. The VA process utilized existing structures, such as subnational governance structures to engage local institutions and other stakeholders as identified in the NAP Framework (e.g., National Development Planning Commission [NDPC], Environmental Protection Agency [EPA], Forest Commission, and Fire Services). This approach saved time and costs and contributed to strengthening existing structures, whereby ensuring the sustainability of future vulnerability exercises.

- **Gender-sensitive approach:** The assessment process ensured that gender-sensitive vulnerabilities were captured and highlighted through (i) inclusion of women, men, youth, and other marginalized groups in the stakeholder engagement process; (ii) creation of subsections for gender vulnerabilities in the VA report; and (iii) discussing how sector impacts are linked to specific gender issues.

1.6 Definition of Key Terms

This VA Framework adopts definitions from the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC, 2022), listed below.

- **Adaptation** is defined, in human systems, as "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or take advantage of beneficial opportunities." In natural systems, adaptation is "the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects."

- **Exposure** is defined as "the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected by climate impacts."

- **Vulnerability** is "the propensity or predisposition to be adversely affected" and "encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt."

- **Sensitivity** is "the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise).

- **Adaptive capacity** refers to "the ability of a systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to the consequences" of climate change — including climate variability and extremes.

1.7 Methodological Framework for the Vulnerability Assessment Process

Cape Coast Municipal Assembly's vulnerability assessment adopted a blend of top-down and bottom-up approaches, also known as the hybrid approach. This approach is recommended by the LDC Expert Group's NAP technical guideline (LDC Expert Group, 2012). Top-down approaches focus mostly on the biophysical impacts of climate change but say less about why, which, and how people are vulnerable. Bottom-up approaches, on the other hand, mainly provide information about the vulnerability of different social groups and discuss the inherent characteristics of the system that make these groups and their context vulnerable to climate change. Comprehensively assessing vulnerability to climate change required an integration of both approaches.

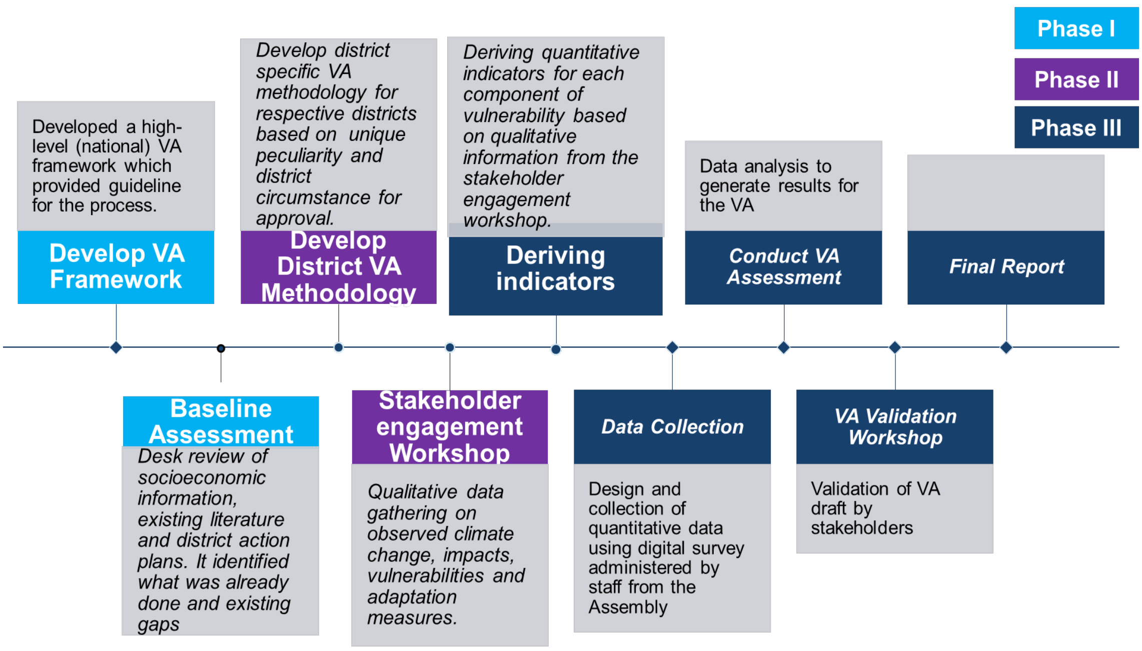
In this VA, climate modeling constituted the top-down approach. The bottom-up approach sought to answer the following questions:

- Who or what is vulnerable to climate and non-climate stressors?
- Where is someone or something vulnerable within the municipality?
- When is someone or something vulnerable?
- Why and how is someone or something vulnerable?
- How important are climate stressors relative to non-climate stressors?

The minimum mapping unit for the assessment was the household, which was aggregated into the village/town unit. The approach assessed vulnerability of the priority sectors indicated in the Ghana NAP Framework at the district level and zoomed in on agriculture and fishing at the town level. This assessment therefore adopted the Climate Vulnerability and Capacity Analysis tool developed by CARE International (2019), which provided a framework and instructions for the VA team to gather and analyze vulnerability information at the community level, to develop socio-economic and climate change scenarios. The VA team also carried out top-down vulnerability assessments in individual sectors (such as coastal resources, water resources, agriculture, and human health).

The VA process adopted a three-phase approach to deliver its expected outcomes. A report was prepared and submitted for each phase and the output informed the next phase. The activities in each phase are summarized in Figure 2 below.

Figure 2. The vulnerability assessment process



1.7.1 Institutional Arrangements and Stakeholder Engagement Plan

Climate change is an existential problem that affects people and systems differently. Addressing a problem of the magnitude of climate change requires collective action. It becomes imperative, therefore, that conscious efforts are made to engage relevant and diverse stakeholders. Such an approach seeks to deploy an engagement and consultation arrangement that not only serves the purpose of the VA, but also prepares all stakeholders to acquire the requisite knowledge to build adaptive capacity and participate fully and effectively in subsequent adaptation planning processes in the Cape Coast Municipality. The stakeholder engagement plan is strategically aligned to the Ghana NAP's institutional engagement plan, which aims to develop and cultivate local ownership of the adaptation planning process (EPA, 2018).

The stakeholder engagement process involved identifying key relevant stakeholders within the district, establishing their roles and responsibilities regarding climate action, and understanding their challenges or opportunities in engaging in climate actions. It also considered the best possible and most convenient approaches to engage all identified stakeholders. Working in close collaboration with the Local Government Team, especially the Planning Unit of the Municipality, various entities and interest groups within the district were identified and engaged in different ways (Appendix 2). Participatory workshops and consultations were used to engage stakeholders. This approach facilitated collaboration, ownership, learning, and knowledge refinement through dialogues. Stakeholders identified are the ones that will be affected (positively or negatively) by climate risk and impacts in the community.

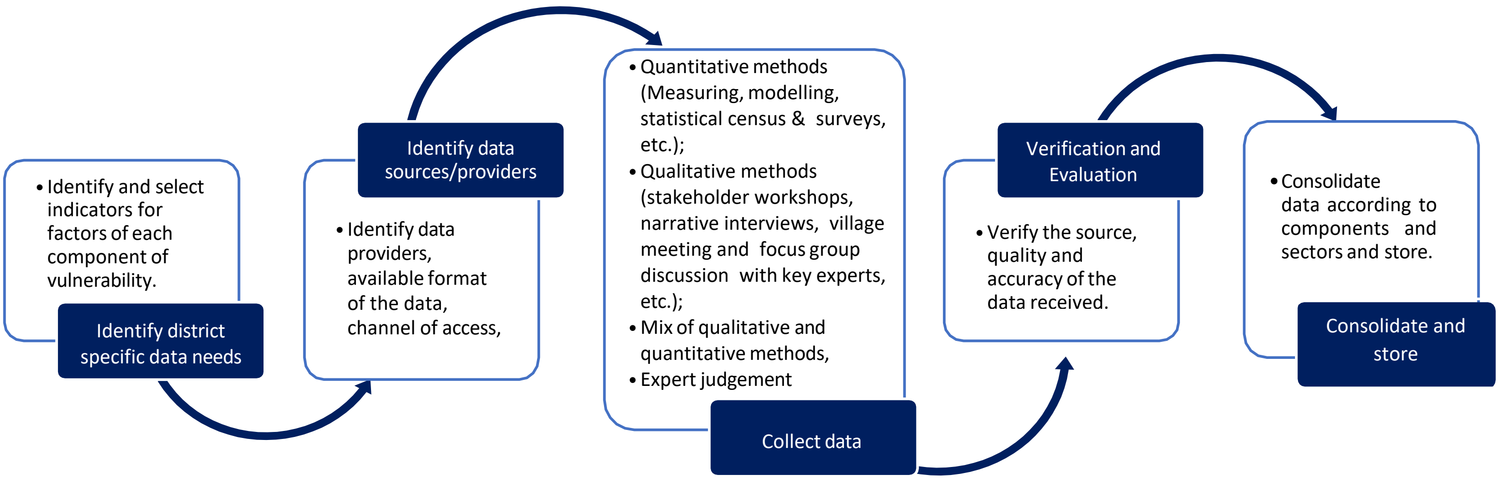
1.7.2 Ensuring Gender Responsiveness

The assessment process ensured that gender-sensitive vulnerabilities captured and highlighted through (i) inclusion of 21 women and 36 men in the stakeholder engagement process (ii) creation of subsections for gender vulnerabilities; and (iii) discussing how sector impacts are linked to specific gender issues.

1.7.3 Methodology for Data Gathering and Management

Key to the VA is data collection and management. Figure 3 summarizes the approach to data collection.

Figure 3. Data collection framework



The methodology for data collection entailed:

i. **Desktop review:** The review aimed to understand what information existed and where there were gaps. The initial desk review undertaken in Phase I provided a good overview of climate and vulnerability data in Cape Coast Municipality.

ii. **Stakeholders and experts' consultation:** Experts at the national, regional, district, and local level were consulted for information and data.

iii. **Stakeholder engagement workshop:** The initial stakeholder workshop was used to collect data on prevailing climate change, impacts and vulnerabilities. The validation workshop was used to validate the final vulnerability assessment report.

iv. **Household-level survey:** A digital questionnaire was administered to households by trained enumerators (primarily staff from the Municipal Assembly) to collect data for the indicators for the vulnerability assessment.

2. About the Cape Coast Metropolitan Assembly

2.1 Geographic Profile

The Cape Coast Metropolitan Assembly is located in the Central Region of Ghana and lies within latitudes 50.07' to 50.20' north of the Equator and between longitudes 1.11' to 1.41' west of the Greenwich Meridian. It covers a land area of 122 km^2 and is the smallest metropolis in Ghana. Located on the southern coast of Ghana, the metropolis is bounded on the south by the Gulf of Guinea, west by Komenda Edina Eguafo Abrem Municipal, east by the Abura Asebu Kwamankese District, and north by the Twifo Hemang Lower Denkyira District. It is divided into two administrative sub-Metropolitan Districts, i.e., Cape Coast North and South even though in geographic terms they share the same climate and ecological attributes (Cape Coast Metropolitan Assembly, 2017).

2.2 Population and Socio-Economic Profile

The total population of the Metropolis according to 2021 population and housing census was 189,925 in 2021 with 49% male and 51% female with a 1% annual growth rate (Ghana Statistical Service, 2021). The urban population was 76.7% while the rural was about 23.3%. About 65% of the population was engaged in agriculture. Commercial farmers comprised approximately 0.3% of the population and peasants comprised the majority at approximately 62% (Cape Coast Metropolitan Assembly, 2017). About 32.5% of the employed who are 15 years and older are service and sales workers.

The major tree crops cultivated in the area are oil palm, citrus, and coconut; while the main staple crops were maize, cassava, sweet potato, plantain, groundnut, tomato, pepper, eggplant, cabbage, lettuce, and carrots. Cattle, sheep, goats, pigs, and poultry dominate livestock production.

There are several private sector construction industries in the Metropolis which include block molding factories, brick and tile, mining and quarrying of chippings, sand and stone, and other related activities. These industries have significantly contributed to real estate development and road construction.

Tourism is an expanding sector in the Metropolis, with the Cape Coast well known as the hub for both the tourism and hospitality industry in Ghana. Its historical ties with early colonialism and slavery make the area particularly attractive to tourists. The area boasts significant scientific, historical, and aesthetic attractions, including the Cape Coast Castle, forts, historically significant tombs, ancient edifices within the town's older sector, and revered shrines. Notably, the Cape Coast Castle (see Figure 4) stands out as a prime example of Ghana's revered historic edifices; it has been included on UNESCO's esteemed list of 314 World Heritage monuments earmarked for preservation for future generations (Cape Coast Metropolitan Assembly, 2017). The area receives a significant percentage of tourist visits in Ghana due to these attractions and its beaches. The area also hosts the top brass of Ghana's universities and colleges, established in this area partly as a result of its colonial past.

Figure 4. Cape Coast Castle showing the bailey

Source: Y.A. Boafo, 2022.

2.3 Arable Land and Agricultural Land Under Cultivation

The metropolis has about 8,000 hectares of available land for agriculture production which reflects a potential for higher levels of production to meet both domestic and export market demand. About 3,500 hectares is currently under cultivation with landholdings of less than 1 hectare for most farmers.

2.4 Soil Type

Different classes of soil series are found in the metropolis as one moves from the coast towards the hinterland, with each type suitable for a specific kind of crop. For example, Chichiwere-Kakum is suitable for tree crops; Ayensu-Chichiwere is suitable for both tree and non-tree crops; and Achenfu-Kuntu-Asokwa-Suprudu mainly for non-tree crops.

2.5 Vegetation

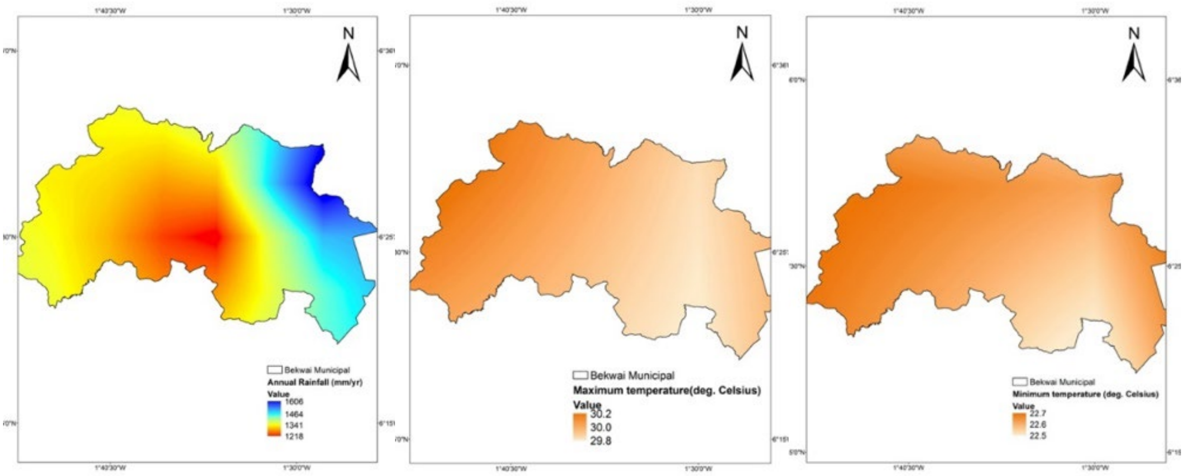
The Cape Coast Metropolitan Assembly, or district, belongs to the Coastal Savannah Agroecological zone. The zone is highly distinguished by its relatively low rainfall in two seasons, grassland savanna vegetation, high temperatures, and coastal geomorphology that includes tidal flats and lagoons. The main vegetation in the metropolis is secondary forest characterized by thickets and shrubs growing to an average height of 4.5 m. The metropolis stretches across a coastline which is about 13 km long.

2.6 Climate

Temperatures range between 24˚C to 32˚C with an average annual temperature of 26˚C. The hottest months are February and March, just before the main rainy season, while the coolest months are between June and August. There are two seasons of rainfall with peaks in May-June and October. The annual total rainfall is between 750 and 1,000 mm. Dry periods (harmattan) are experienced between November and February. Cape Coast is a humid area. Mean monthly relative humidity in the morning varies narrowly between 85% and 99%. Afternoon humidity varies considerably from around 50% in the dry months to the high 80s during the wet months, especially in May and June. The high humidity and sea breeze have negative effects on equipment and materials including vehicles and construction materials. The humidity also creates foggy conditions in the mornings, especially on coastal roads, reducing visibility appreciably and making driving somewhat hazardous.

0 illustrates a clear spatial variation of the climate of Cape Coast, particularly for rainfall.
The southern part of the municipality experiences less rainfall but the amounts increase toward the north. There is a spatial north-south contrast concerning day and night temperature. Temperature increases from south to north during the day but decreases with the night temperature.

Figure 5. Climate of the Cape Coast Municipal Assembly



Source: Asare and Klutse, 2023.

2.7 Administrative Structure

The availability of institutions that can implement climate change adaptation strategies is a measure of the level of adaptive capacity of the system/district. The Cape Coast Metropolitan Assembly has 16 Departments and other Units with Heads of Departments who all report directly to the Metropolitan Coordinating Director and ultimately to the Metropolitan Chief Executive (also referred to as the mayor). The General Assembly meetings are presided over by the Presiding Member. The General Assembly has 66 Members comprised of 41 Elected Members, 25 Government Appointees, 2 Members of Parliament, and the Metro Chief Executive who also chairs the Executive Committee.

In the performance of its functions, the Cape Coast Metropolitan Assembly works through 14 Sub-Committees. These Sub-Committees perform deliberative functions and submit recommendations to the Executive Committee for further deliberation and then to the General Assembly for final decisions and implementation. The 14 Sub-Committees include: Social Services, Finance and Administration, Development Planning, Revenue Mobilization, Justice and Security, Education, Works, Environment, Youth and Sports, Culture and Trade, Tourism and Industry, Disaster Management, Food and Agriculture, Health, and Women and Children. The existence of these institutional units and structures has the potential to facilitate effective climate change adaptation planning.

3. Vulnerability Assessment to Current Climate Change

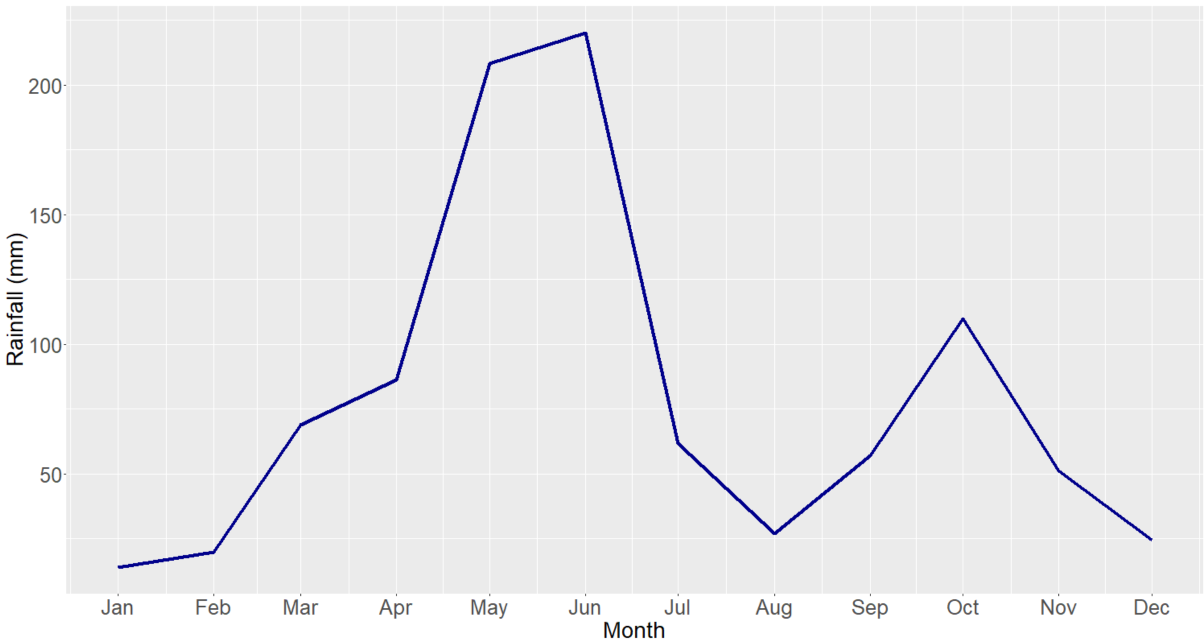
3.1 Analysis of the Observed Climate Changes

Developing adaptation strategies for community resilience requires understanding the past. Understanding the climate patterns of Cape Coast is essential in developing adaptation strategies and planning for the future since the livelihood activities of people are directly linked to the climate. This section of the report assesses the historical climate of the Cape Coast, reviewing trends in rainfall and temperature in Cape Coast over the past 40 years (1980-2020). These datasets help to identify evidence of climate change and variability and include useful information to inform decision making. Chapter 4 of this VA presents the future climate scenarios from 2021 to 2100. Climate change data was derived from the Ghana Meteorological Agency and was analyzed by the VA team to generate the various charts and figures in this section.

3.1.1 Rainfall Characteristics

The rainfall regime over Cape Coast is characterized by the North-South movement of the Inter-Tropical Convergence Zone. Therefore, the area is characterized by wet (March to October) and dry (November to December) seasons. Cape Coast experiences a bimodal rainfall regime, as depicted in Figure 6.

Figure 6. Monthly rainfall over Cape Coast



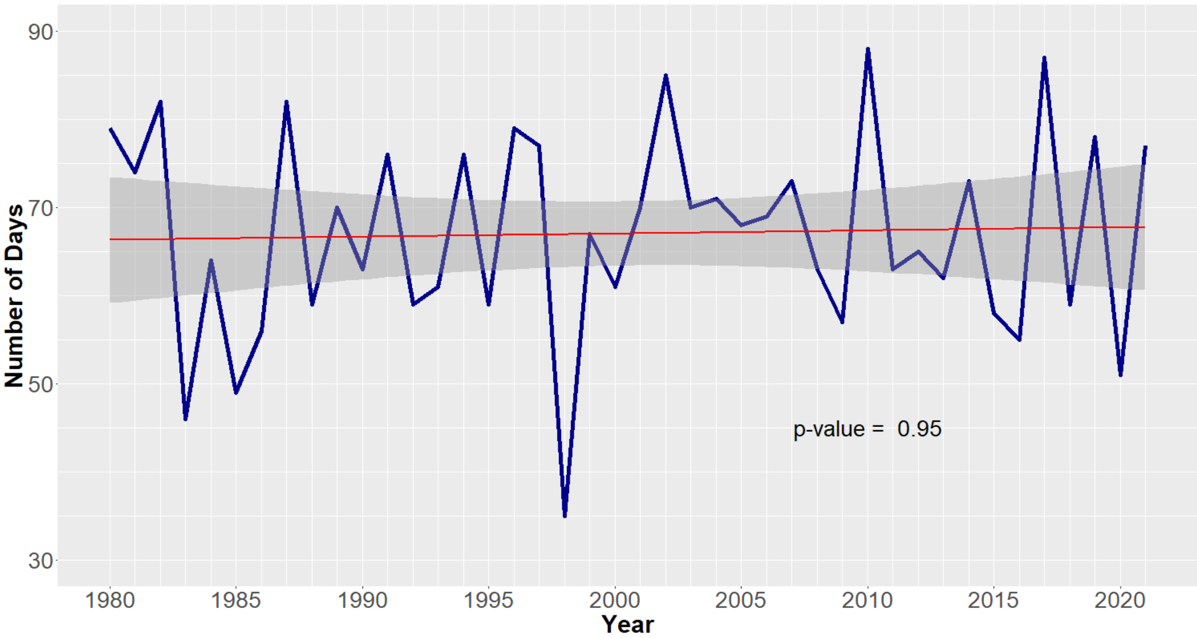
Source: Asare and Klutse, 2023.

The rainfall season begins in March and progresses as it reaches its peak in June, after which there is a decline until August when the first rainfall season ends. The second rainfall begins in September, peaks in October and then the dry season starts in November. Cape Coast receives rainfall for about 7 months of the year.

3.1.1.1 Annual Rain Days

The total number of days that it rains over Cape Coast remained variable. The number of days with rainfall events varied from year to year but does not show a long-term trend (Figure 7).

Figure 7. Rainfall events over Cape Coast



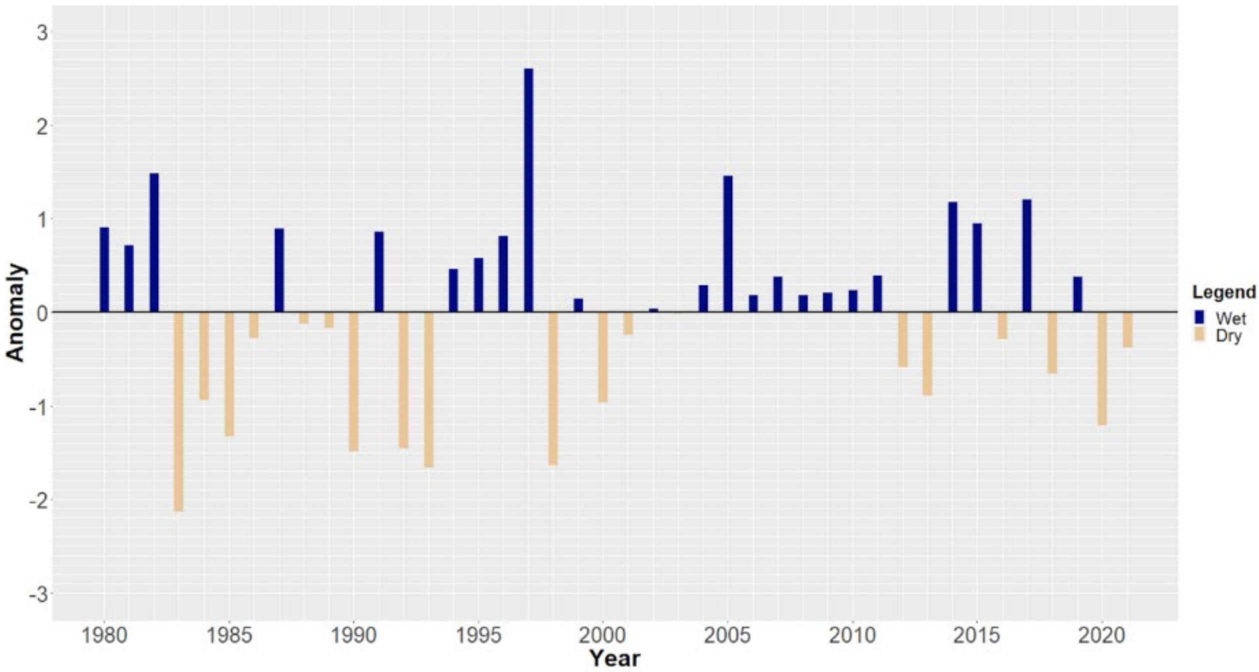
Source: Asare and Klutse, 2023.

Out of the 365 days in a year, days with rain accounted for less than 100. The year 2010 was credited with the highest number of rain days (88 days), while 1998 recorded the lowest (35 days). The frequency of rainfall events over Cape Coast had high inter-annual variability. The trend did not show a significant increase or decrease over the period. The mean number of heavy rainfall events was slightly higher from 1980 to 2020, but the difference was not significant, with high inter-annual variability. This means that rainfall distribution for 2010 was better compared to 1998. The year 2010 was good in terms of rainfall distribution for agriculture compared to 1998.

3.1.1.2 Annual Rainfall/Rainfall Anomaly

The mean annual rainfall over Cape Coast was 952 mm. Similarly, annual rainfall over Cape Coast remained variable without a consistent increasing or decreasing trend. The 1980s to the early 2000s had a fair balance of years of wet (Figure 8, blue bars) and dry (yellow bars). The period between 2001 to 2010 was consistently wet, but this has changed to more variable annual conditions in the recent past, as shown in Figure 8. The annual total rainfall over Cape Coast was marked by high variability. The year 1997 was the wettest year over the past 40 years, while 1983 was the driest.

Figure 8. Annual total rainfall and anomaly over Cape Coast

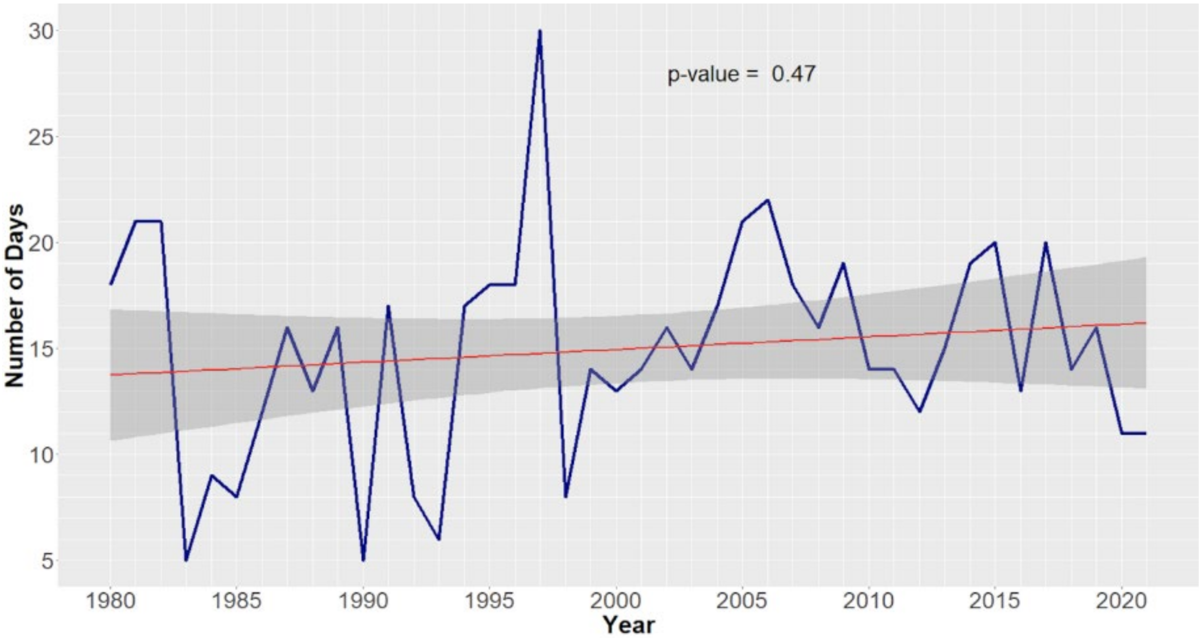


Source: Asare and Klutse, 2023.

3.1.1.3 Heavy Rainfall Events

Assessing the occurrence of heavy rainfall events (20 mm+) over the study area revealed an increasing but non-significant trend when the increase was compared to the long-term mean, as shown in Figure 9. This is important because it indicates a possible extreme event that could trigger flooding in Cape Coast. Generally, the increasing trend could best be described as variable. This means that the total number of days with heavy rain events per year differs yearly. The increased heavy rainfall indicated potential floods in the Cape Coast municipality in recent years, among other causative factors.

Figure 9. Heavy rainfall events over Cape Coast



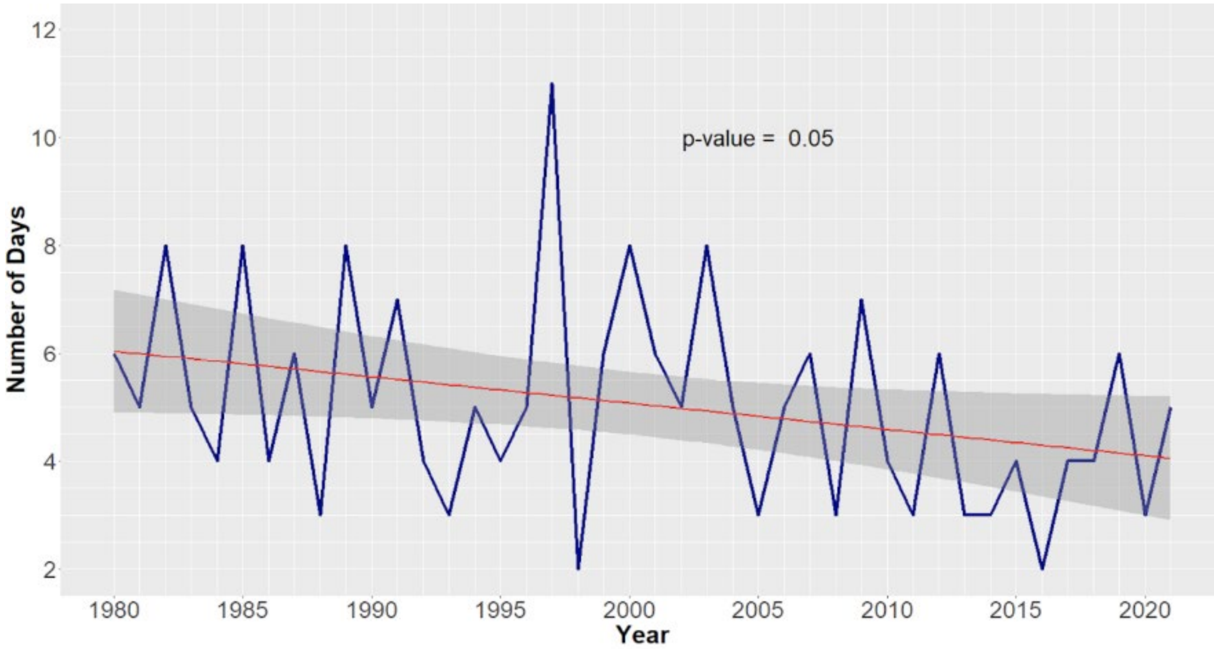
Source: Asare and Klutse, 2023.

3.1.1.4 Consecutive Wet Days

Continuous days with rainfall could also trigger floods within the Cape Coast Municipality depending on other factors like soil characteristics and adequate drainage system. An assessment of consecutive wet days over Cape Coast was conducted, and the results revealed a decreasing trend. The assumed decreasing trend has significantly changed (P-value = 0.005) compared to the long-term mean (Figure 10).

Embedded in the decreasing trend was inter-annual variation in the consecutive wet days. The year with the highest consecutive wet days was 1997 (11 days). Over the last 40 years, this year recorded the highest annual rainfall and heavy rainfall events. The year 1998 and 2016 also recorded the lowest number of consecutive wet days (2 days). Continuous days without rain could negatively impact the rainfall-dependent livelihood activities over Cape Coast. Drought is an extreme climate event which can disrupt livelihood activities within the study area. Therefore, continuous days without rainfall were assessed within the rainfall season for drought in Cape Coast.

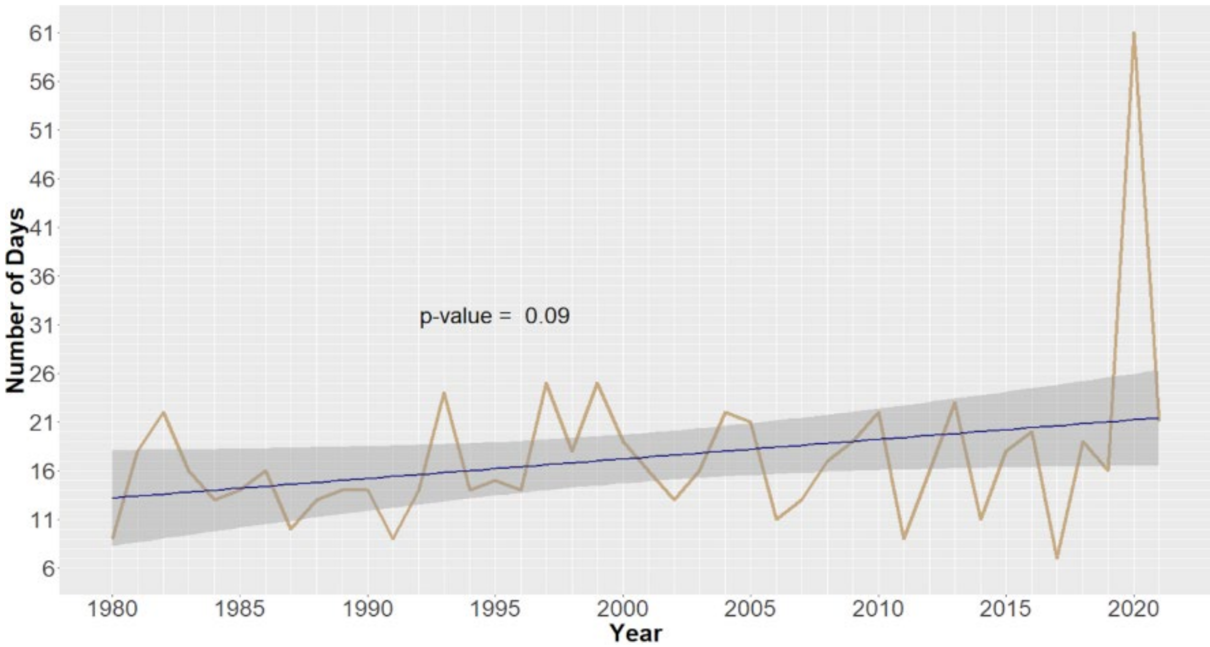
Figure 10. Wet spell duration over Cape Coast



Source: Asare and Klutse, 2023.

Figure 11 presented the lowest frequency in 2017 and a high of 61 days that occurred in 2020. Cape Coast experienced a slightly increasing trend with low variability in dry spell duration over the period. The year 2020 recorded an exceptionally high dry spell of 60 days. The occurrence of drought in Cape Coast could increase if the current trend persists, which calls for action.

Figure 11. Dry spell duration over Cape Coast

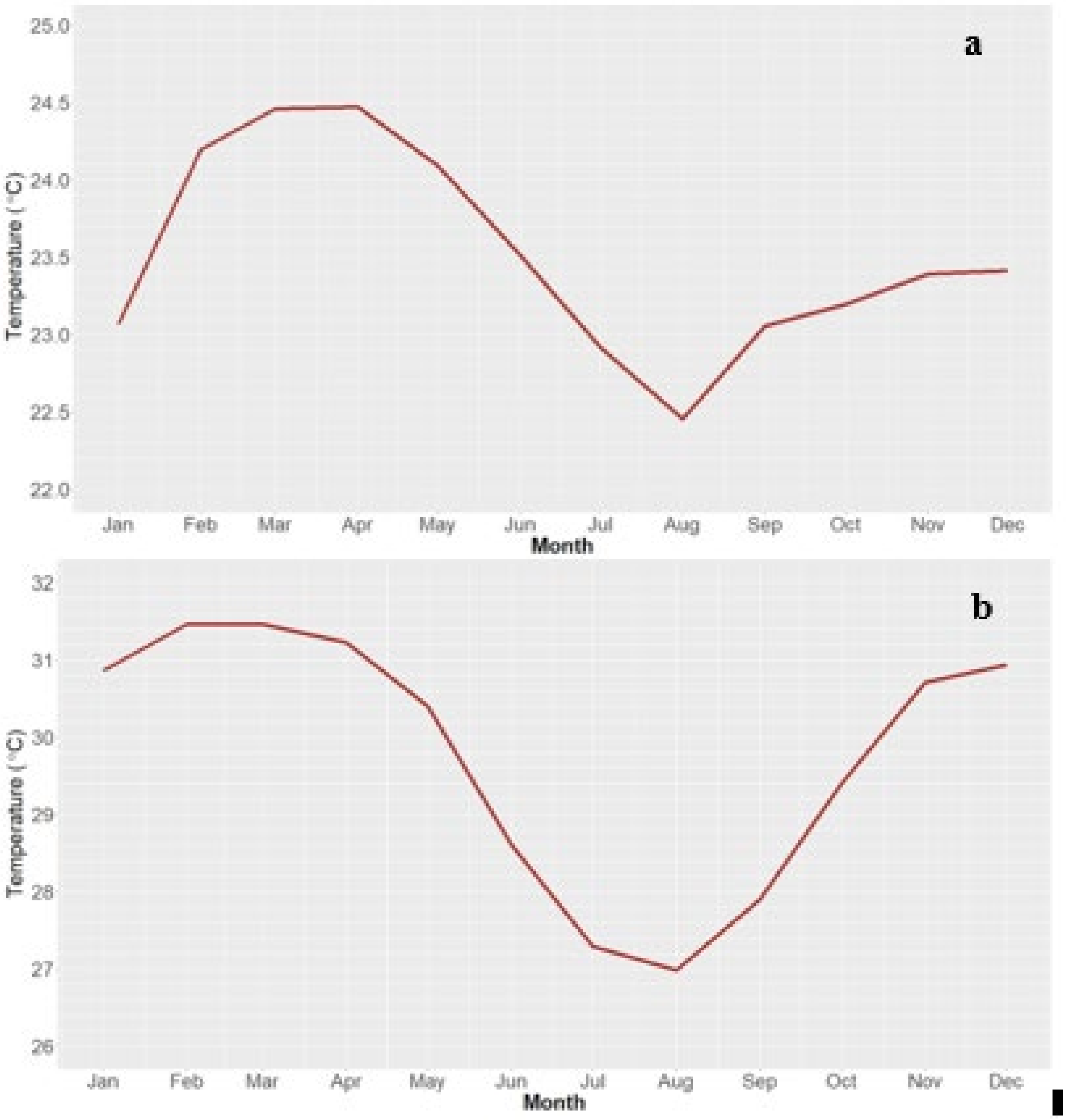


Source: Asare and Klutse, 2023.

3.1.2 Temperature Characteristics

Temperature is an essential climate variable that affects people's livelihood activities. Therefore, understanding the state of temperature during the day and the night is important to the vulnerability of the people and developing the right adaptation strategy.

Figure 12. Monthly (a) mean minimum and (b) mean maximum temperature over Cape Coast



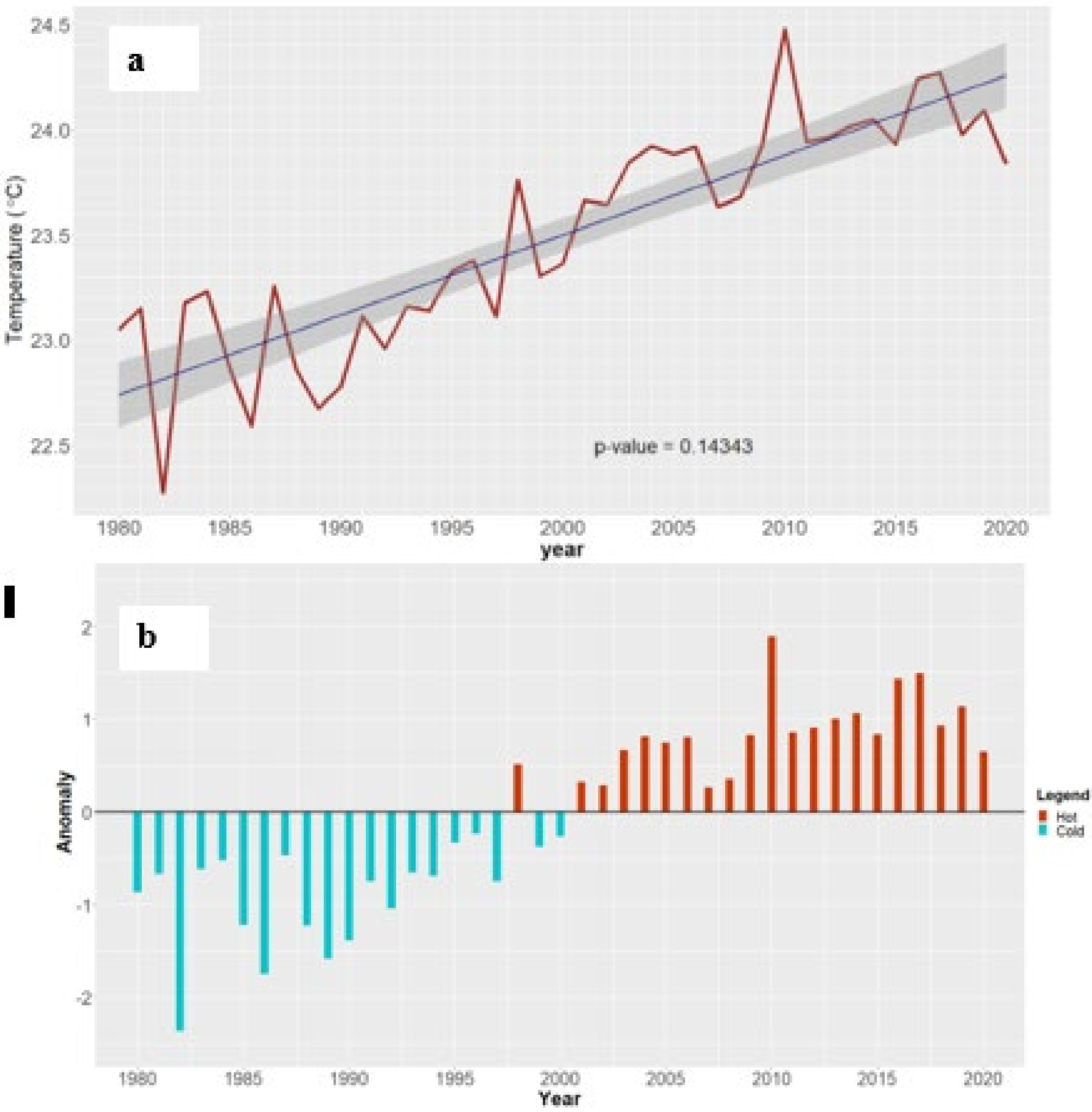
Source: Asare and Klutse, 2023.

The seasonal night temperature cycle over Cape Coast was similar to daytime but differed in peak months. For example, the coldest night and day temperature all occurred in August. The monthly mean minimum and maximum temperature are shown in Figure 12. Minimum temperature variability had the first peak in March-April at 24.5°C and a slightly lower peak in December at 23.4°C. The lowest minimum temperature was recorded in August at 22.5°C. The maximum temperature plot produced two distinct peaks of close magnitudes of 31.5°C in February-March and December with 31°C. Cape Coast recorded the lowest maximum temperature in August, with 27°C.

3.1.2.1 Mean Annual Minimum Temperature and Anomaly

The annual mean trend of minimum temperature over Cape Coast is in Figure 13a and indicates a small inter-annual variability with a significant increasing trend. The anomaly in Figure 13b shows a period of cold years from 1980 to 1997 and a clear period of hot years from 2001 to 2020. The trend is consistent with the global temperature increase.

Figure 13. Annual mean minimum temperature (a) and anomaly (b) over Cape Coast

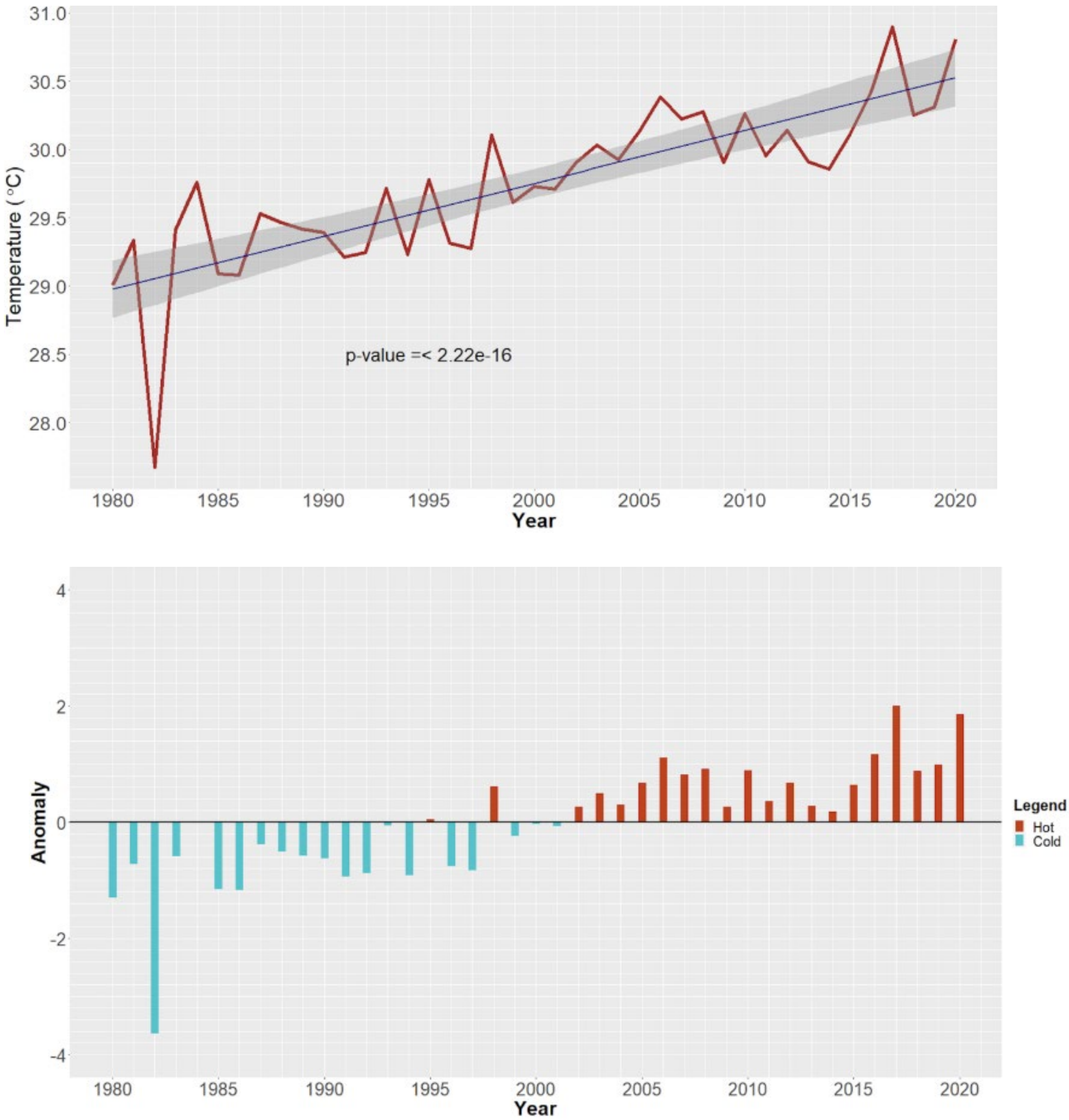


Source: Asare and Klutse, 2023.

3.1.2.2 Mean Annual Maximum Temperature and Anomaly

The annual mean trend of maximum temperature (Figure 14) increased significantly from 1980 to 2020 with small variability. The year 1982 experienced a much lower temperature of about 27.7°C. The anomaly trend of maximum temperature in Figure 14b shows different hot and cold years, with the early years of 1980 to 2000 being relatively colder than the later years of 2000 to 2020, which were observed to be warmer.

Figure 14. Annual (a) mean maximum temperature and (b) anomaly over Cape Coast

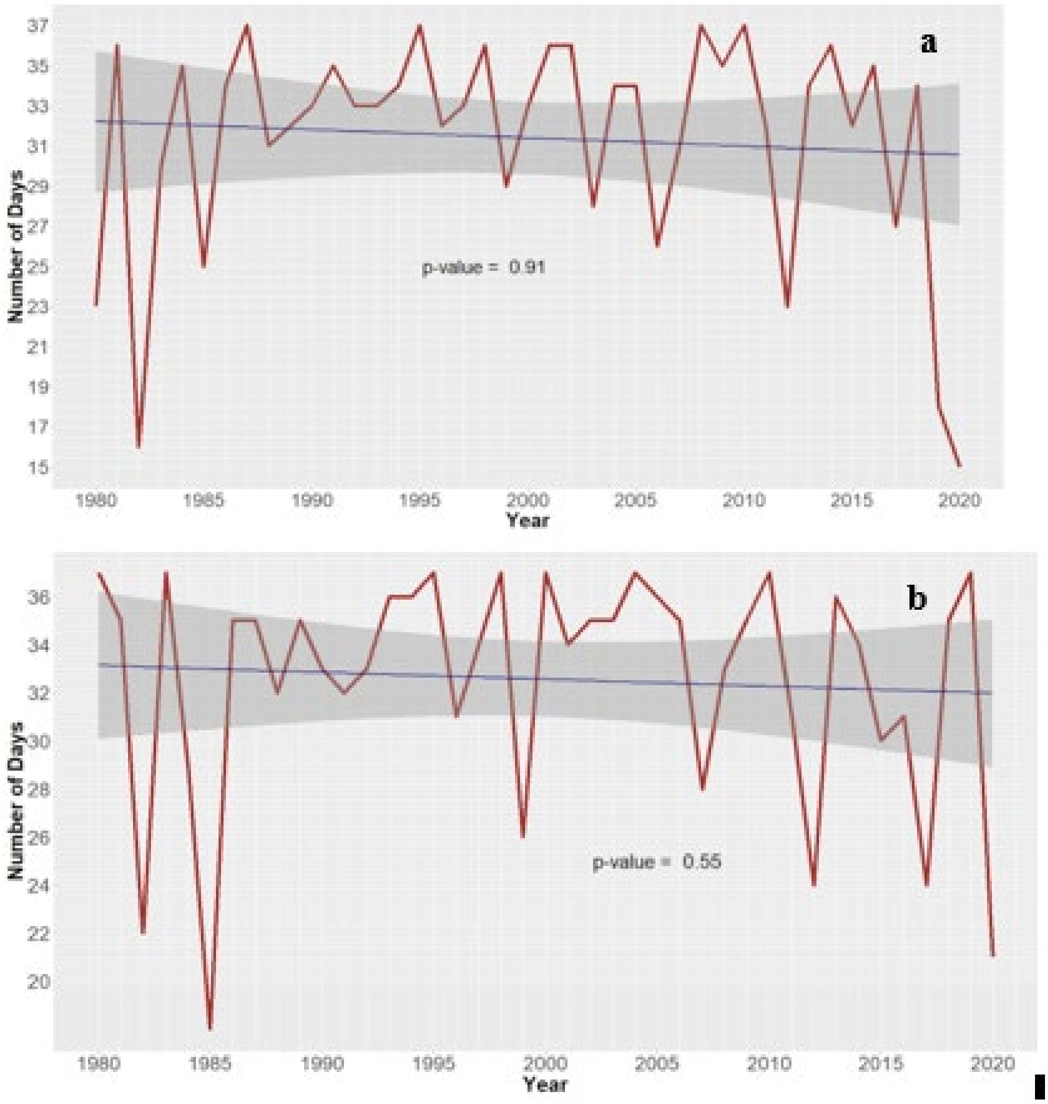


Source: Asare and Klutse, 2023.

3.1.2.3 Frequency of Hot and Cold Days

Hot days of the year are defined as the maximum of the maximum temperature per year, and hot nights of the year are defined as the maximum of the minimum temperature per year. Over Cape Coast, in Figure 15a, the trend of hot days decreased slightly with high inter-annual variability.

Figure 15. Frequency of (a) hot days and (b) hot nights temperature over Cape Coast



Source: Asare and Klutse, 2023.

For example, Cape Coast recorded above 25 hot days and up to 37 hot days from 1985 to about 2011 annually. The least number of hot nights was recorded in 1985, followed by 2020 and then 1982. The other years were above 24 hot nights up to 37 hot nights. The maximum frequency of hot nights in Figure 15b was similar to that observed in the frequency of hot days.

3.1.2.4 Summary of Historical Climate Information

- Rainfall in Cape Coast is variable on monthly and annual scales. This means some years received more rainfall while others received less rainfall. The erratic nature of the rainfall makes planning and decision making difficult.
- The period between 2001 and 2010 was consistently wet, but this changed to more variable annual conditions in the recent past.
- The annual mean trend of maximum temperature increased significantly from 1980 to 2020 with small variability. The period 1980 to 2000 was relatively colder than the later years of 2000 to 2020, which were observed to be warmer.
- Rain days of the year varied highly over the period, consistent with interannual variation in annual rainfall total. This impacted rainfall distribution which may have affected agriculture.
- The number of heavy rainfall events varied each year. Years with more heavy rainfall events may have result in related hazards like floods in the area.
- Wet spells decreased and dry spell increased slightly in Cape Coast. The shortest dry period ever observed was seven days, whereas the longest before 2020 was 26 days.
- Day and night temperatures increased significantly in Cape Coast and were consistent with global temperature increases. This may have impacted human health and stressed the ecosystem.
- Hot days and hot nights varied on Cape Coast and revealed a trend of temperature increase.
- The temperature during the day peaked in February and March, and the night temperature peaked in March and April.
- There was evidence of climate change, but it was best revealed in temperature compared to rainfall-related variables, except for the most extended wet spell.

3.1.3. District seasonal change calendar

The district seasonal calendar is a tool that was used to collect firsthand data from the Phase II participatory workshop on stakeholder experiences of climate change, how they differ from the norm, and how the change is affecting them. The timeframe for the observed changes is since 2010. This information is used to confirm and complement those obtained in literature. The results are presented in Table 1.

Table 1. Cape Coast Metropolis seasonal calendar

Season (Length)	Key events (Annual cycle)	Typical climate	Observed changes	Observed impacts
Dry season (Late Nov-April)	Prepare farmlands for planting during the latter part of the dry season	Higher temperature No rains Dry air (low humidity)	Changing in planting season from March to April.	People struggle to get water. Dust and pollution Bush fires Heatwaves Skin diseases and respiration diseases vegetation withers
Major rainy season (April – July)	Planting of maize and other crops (vegetables)	Intense winds More freq. rains Foggy	Intense rains Low to moderate Temperature	Floods and surface water pollution Roofs removal by wind Outbreak of vector borne diseases Soil erosion Infrastructure deterioration and Collapse of building Landslide Loss of lives and properties Trees are uprooted Vehicular accidents Underground fuel contamination at fuel stations by underground water Construction works and employments slow down PPR disease emerge (Pest of small ruminants) Disruption of social-cultural activities
Minor rainy season (Oct – Nov.)	Planting of maize and other crops (vegetables) Stream fishing The sea turtles come to lay at the beaches	Drizzling Intermittent heavy rains, Thundering and lightening	Experiencing rains and high temperatures at the same time. Out of season rainfall patterns	Forest fires because of lighting Seasonal fish types emerge Flood

3.2 Qualitative Assessment of the Factors of Vulnerability to Identify Vulnerable Locations, Sectors, and Groups

3.2.1 Extreme Event Records in the Cape Coast Metro

The IPCC Sixth Assessment Report (2022) projects that climate extreme events will increase in frequency and intensity in the near to distance future. There is significant evidence of extreme climate events and hazards manifestation already affecting Ghana. This includes high temperatures, heatwaves, heavy rainfall, floods (inland and coastal), dry spells/droughts, and windstorms, which impact natural and human systems. It is imperative to take stock of such occurrences in the metro area, to outline those areas or communities currently exposed to such hazards, and to support adaptation planning. Records show that floods constitute the highest number of extreme climatic events in the municipality (EPA, 2021).

Figure 16. Flood and drought occurrences in the CCMA

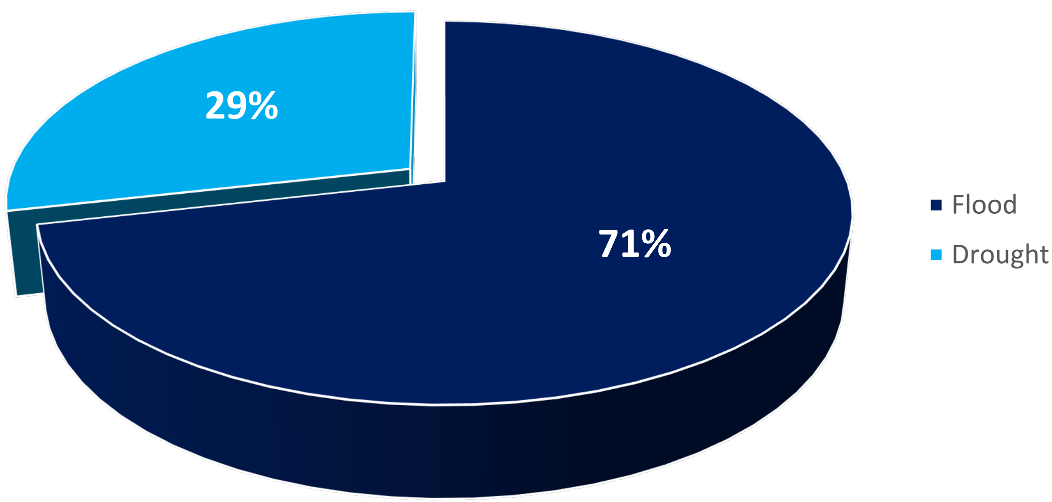


Table 2. Disaster/hazard occurrences in the CCMA

Year	Occurrence	Climatic/ non-climatic	Description of damage	Affected sector(s)	No. of affected people	Estimated cost	Source (e.g., literature, survey, etc.)
15-Jun-22	Flood	Climatic	Major towns in the Cape Coast Metro were flooded following a heavy downpour.	Agriculture, health, education, roads, transportation, and infrastructure. (school submerged)	N/A	N/A	Stakeholders at workshop[1]
01-Oct-21	Flood	Climatic	Many schools, including the University of Cape Coast (UCC), had to suspend activities for the day, while most shops remained closed.	Metro-wide sectors			Stakeholders at workshop[2]
30-Oct-19	Flood	Climatic	Many residents were locked in their homes after about 6 hours of rainfall.	Metro-wide sectors	N/A	N/A	Stakeholders at workshop[3]
June, 2016	Flood	Climatic	Flooding resulting from heavy rain which were accompanied by strong winds, thunderstorms, and lightning.	Infrastructure	Five people died in Cape Coast[4].	N/A	Stakeholders at workshop[5]

[1] Myjoyonline: https://www.myjoyonline.com /cape-coast-moree-abura-flooded-after-downpour/
[2] Graphic Online: https://www.graphic.com.gh/news/general-news/ghana-news-heavy-rains-flood-cape-coast.html
[3] Graphic Online: https://www.graphic.com.gh/news/general-news/ghana-news-heavy-rains-flood-cape-coast.html
[4] Three people died after a house collapsed. Other victims died after being electrocuted by power cables falling into flood water. The fifth victim is thought to have drowned in flood water.
[5] https://floodlist.com/africa/ghana-floods-central-region-june-2016

Year	Occurrence	Climatic/ non-climatic	Description of damage	Affected sector(s)	No. of affected people	Estimated cost	Source (e.g., literature, survey, etc.)
8-Jul-09	Flood	Climatic	Flooding of homes and destruction of properties. Schools in affected areas suspended studies.	Infrastructure	15 people in 15 houses in five communities were rendered homeless	N/A	Stakeholders at workshop[6]
1994	Drought	Climatic	Drought, but shorter than the one in 1992.	Water, agriculture, human health, and sanitation	N/A	N/A	Stakeholders at workshop
1992	Drought	Climatic	Long duration of drought that caused water shortages in the Metro.	Water, agriculture, human health, and sanitation	N/A	N/A	Stakeholders at workshop

[6] Ghana Web: https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Floods-destroy-properties-near-Cape-Coast-Elmina-165108

3.2.2 Analysis of Factors of Vulnerability in the Municipality

3.2.2.1 Dependence on Rainfed Agriculture

Agriculture plays a dominant role in the livelihoods of households of 60% of people in the Cape Coast Metropolis, providing food security and assisting in poverty reduction (MOFA, 2016). Agriculture is dominated by smallholder farmers, who constitute 99.7% of the agricultural population (MOFA, 2016). It is predominantly subsistence in practice and dominated by physical labour and basic hand tools. Irrigation of arable land in the metropolis is underdeveloped (MoFA, 2016). 2018 data indicated that January experienced weather which caused most plants to show signs of moisture stress. As a result, cropping activities were reduced and most rural folks engaged in off-farm alternate livelihood activities, including charcoal production. Few farmers irrigated from traditional dugouts to cultivate vegetables (CCMA, 2020). This demonstrates the high dependency of agriculture in the metropolis on climate, especially rainfed agriculture. Additionally, farms close to the sea can be inundated by storms, erosion, and saltwater.

3.2.2.2 Illegal Mining (Sand, Clay, and Gold)

Illegal coastal sand and stone mining is widely practised along the coast of Cape Coast to meet the demands of the construction industry (commercial and medium scales) and to reduce the cost of construction or renovations by poorer coastal inhabitants. A study by Jonah et al. (2015) quantified the short-term recession rate of the Cape Coast shoreline and found that there was a relationship between sand mining activity and the rate of local coastline erosion. Jonal et al. (2015) concluded that sand mining was the main cause of erosion along the coastline of Cape Coast, more than sea level rise, changes of storm frequency and storm surges resulting from climate change, or other human interference. Arable farmlands are also sometimes destroyed by sand mining activities (CCMA, 2019). With noted rising sea level of the Cape Coast Sea (Mensimah et al., 2011) and fast recessing coastline because of sand mining, the rate of inundation of assets, infrastructure, resorts, and businesses will be increase and become more severe.

3.3.2.3 High Flood-Prone Areas

Over 21% of the CCMA was classified as high flood hazard zones (Danso et al., 2020). This is due to a combination of climatic factors (rainfall) and dominant anthropogenic factors such as poor physical planning, improper waste disposal systems, and lack of or poorly designed drainage systems. Additionally, CCMA has a coastal stretch of about 13 km that is also vulnerable to coastal flooding. As noted in Table 2, floods have become annual occurrences in CCMA in recent years. A projected shift of rainfall intensity towards the southwestern part of Ghana (Logah et al., 2013) where CCMA is situated, compounded by population growth and increases in built areas, is expected to increase flooding enough to have adverse implications for human health, infrastructure, water resources, and socio-economic well-being. Notably, not all of the 13-km coastal zone is walled, raising the question of whether the wall can shield the coast from stronger tides and higher sea levels in the near to distant future.

3.3.2.4 Unreliable Water Supply

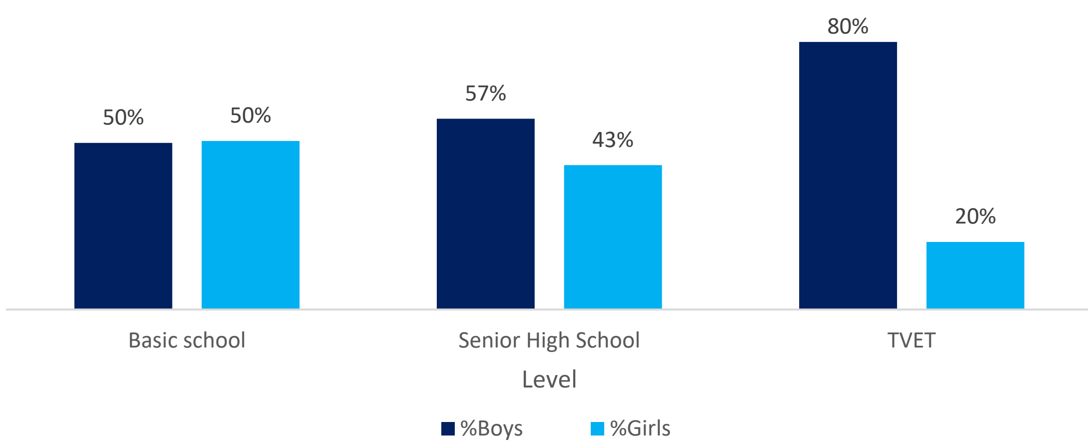
CCMA is drained largely by the Kakum River, which serves as its main source of drinking water. The Kakum River is dammed at Brimso, a location close to Cape Coast where the water is treated and distributed to the Metropolis. The effects of destruction of the surrounding environment within the river basin is negatively impacting the sustainability of this natural resource and causing perennial water shortages in the city, particularly in the dry season. Droughts, higher evapotranspiration rates resulting from higher temperatures, and saltwater infiltration of alternative waters sources via coastal flooding will compound and exacerbate the current water crisis.

3.2.3 Gender-Related Vulnerabilities

Gender is socially ascribed roles, responsibilities, rights, and opportunities associated with being a man or a woman, and the social relations between women and men. These roles and responsibilities shape how social groups, including persons with disabilities (PWD), the elderly, women, and children, may suffer or take advantage of the effects of climate change. Traditionally, women often have different occupations from men and are more involved in family life and are often responsible for taking care of others, which often increases the risks they face from climate change. For example, in case of a disaster, women often try to protect and save their children/relatives, which often hinders their timely escape and access to shelter and health care. In addition, women are often socially restricted from leaving their communities (migrating) as a coping mechanism (used by men) (Resurrección et al., 2019). Like women, PWD emphasized during the participatory stakeholder workshop that they will have a challenge getting help to escape climate-related disasters since their counterparts without disability, on whom they often rely for mobility assistance will themselves be escaping to safety.

Figure 17 shows that girls receive fewer years of education than boys in the CCMA at the senior high and technical and vocational education (TVET) level. Limited education levels and skill development can affect girls' ability to (i) understand and act on information concerning climate risks and adaptation measures; and (ii) generate income. Climate change would also affect the income of low-income families, and this could further affect their access to education (Demetriades & Esplen, 2010).

Figure 17. Percentage of school enrollment of boys and girls in the Cape Coast Metropolis in 2019



Source: Ghana Education Service.

Table 3 provides aggregated data of how men, women and youth in the metropolis have accessed, benefited, or participated in programs/activities/projects that have direct or indirect significance to building their resilience to the impacts of climate change. The data implies limited access to such resources by women relative to men. A total of 67.6% of the beneficiaries of these programs have been men, while women only represented 32.2%. The lack of access is also reflective of low adaptive capacity which would in turn result in low productivity and income of female counterparts. Even in some cases where women may have access to land, they have limited control over it, as they barely own it and therefore cannot make decisions regarding its use.

Table 3. List of men, women, and youth representation in key district interventions

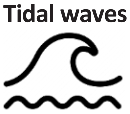
Name of project/program/activity	Beneficiaries by demographic				
	Male	Female	Youth	Aged	PWD
Planting for Food and Job (2017-2019)	1629	872			
PERD coconut distribution and beneficiary farmers	66	7	60		
Input Distribution to farmers (fertilizer, seed maize, vegetables, FAW)	6671	2664			
GAPs training in citrus and vegetable production	434	129			
Access to Improved Agriculture Technology and Extension Services					
Beneficiaries of crop technologies demonstrated	2,156	1,107			
Demonstration on vegetable nursery management training	79	31			
Farmers adopting improved technologies (2018 - 2019)	347	254			
Access to Extension (home and farm visit) (2018 - 2019)	23185	11575			
Climate change awareness/sensitization Training	766	198			
Total Beneficiaries	35333	16837	60		
% of Beneficiaries	67.6%	32.2%	0.1%		

Source: Department of Agriculture, CCMA.

3.2.4. Risk Mapping of Vulnerable Locations

Participatory hazard/risk mapping provides information on the most exposed locations (in terms of people, infrastructure and assets, crops, and livestock) affected by hazards such as floods (coastal and mainland), fires, and storms. Stakeholders in the Phase II workshop undertook a participatory risk mapping exercise to identify and visualize hotspots of climate-related hazards in the Metropolis. This was done using a printed district map on which the participants located the hazard prone areas, associated hazards, and affected people or resources based on their past experiences and historic occurrence of hazards. Flooding is the dominant hazard identified in CCMA, with a higher concentration of flood prone areas in the south. Flooding in the southern part is heavily associated with impacts on infrastructure, while in the north it is associated with destruction of farms. This can be attributed to the fact that settlements are concentrated in the south and farming activities in the north.

Table 4. Hazards identified, potential impacts, and affected people/locations

Hazard	Description	Potential impacts	Vulnerable people, communities, facilities
Flooding of settlements 	The south experiences floods resulting from rainfall coupled with the heavily built environment, inadequate drainage systems, and poor town planning.	• Destruction of infrastructure (homes, schools, roads, bridges) • Negative impacts on human health and can lead to loss of life • Pollution of water bodies and sanitation in the metropolis	**Communities:** Mempeasem, Academy, Abura New Town, Kwaporow, Tseukyir, Interbeten (CCTH), Cape Tech, Interberton Junction **Facilities/Assets:** schools, hospital, farms
Flooding of farms 	The north experiences floods resulting from heavy rains and destruction of vegetation from mining activities.	• Major destruction is associated with farms	**Communities:** Efutu, Ewusikrom, Dehia
Landslide 	Heavy rains are expected to increase landslides.	• Destroys properties, livelihoods, and in extreme situations, takes lives	**Communities:** Nkanfoa, Ekon
Tidal waves 	Communities along the coast without sea walls are expected to experience coastal flooding resulting from sea level rise and storm surges.	• Destruction of infrastructure (homes, schools, beach resorts) along the coast • Can lead to loss of human lives	**Communities:** Abakam, Brofoyedro
Storm 	Storms that occur in the wet season have become stronger in recent years.	• Destruction of infrastructure (homes and schools) • Can lead to suspension of academic activities in the school • Can lead to loss of human lives	**Communities:** University of Cape Coast area, near Saint Monica

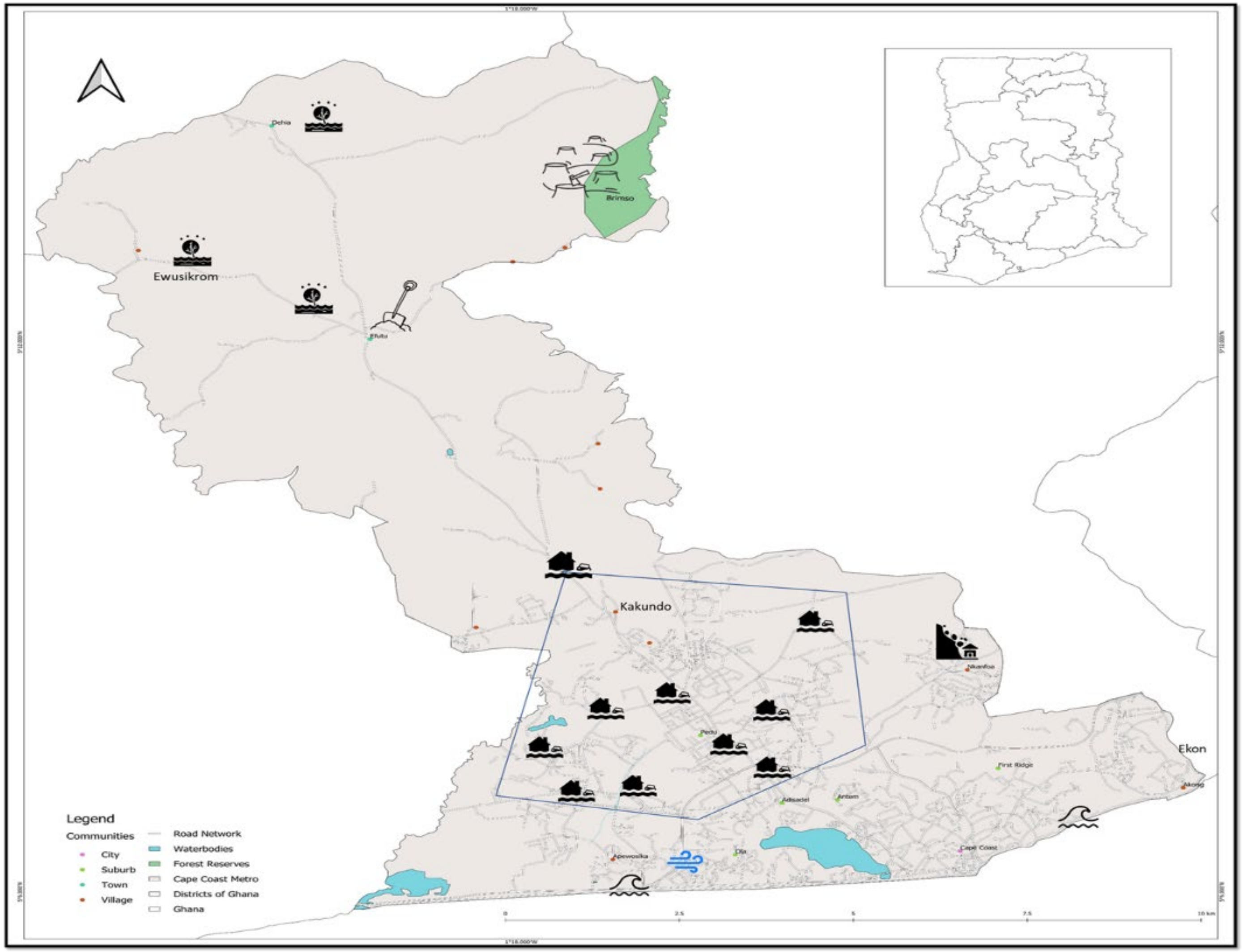
Human-induced activities in the CCMA that could exacerbate the impacts of climate change are prevailing in the northern part. These are mainly sand and mineral mining activities.

Table 5. Unsustainable human activities in Northern Cape Coast

Activity	Description	Potential Impact	Locations
Sand mining 	Sand mining at both commercial and small-scale levels to meet construction needs	Poses hazard to agriculture and food security in the metropolis since arable lands are being destroyed by sand mining	Efutu
Forest encroachment 	Encroachment of the Brimso forest reserve by miners	Destruction of biodiversity and ecosystem. This could limit ecosystem services such as soil retention, freshwater provision, and dust suppression.	Brimso

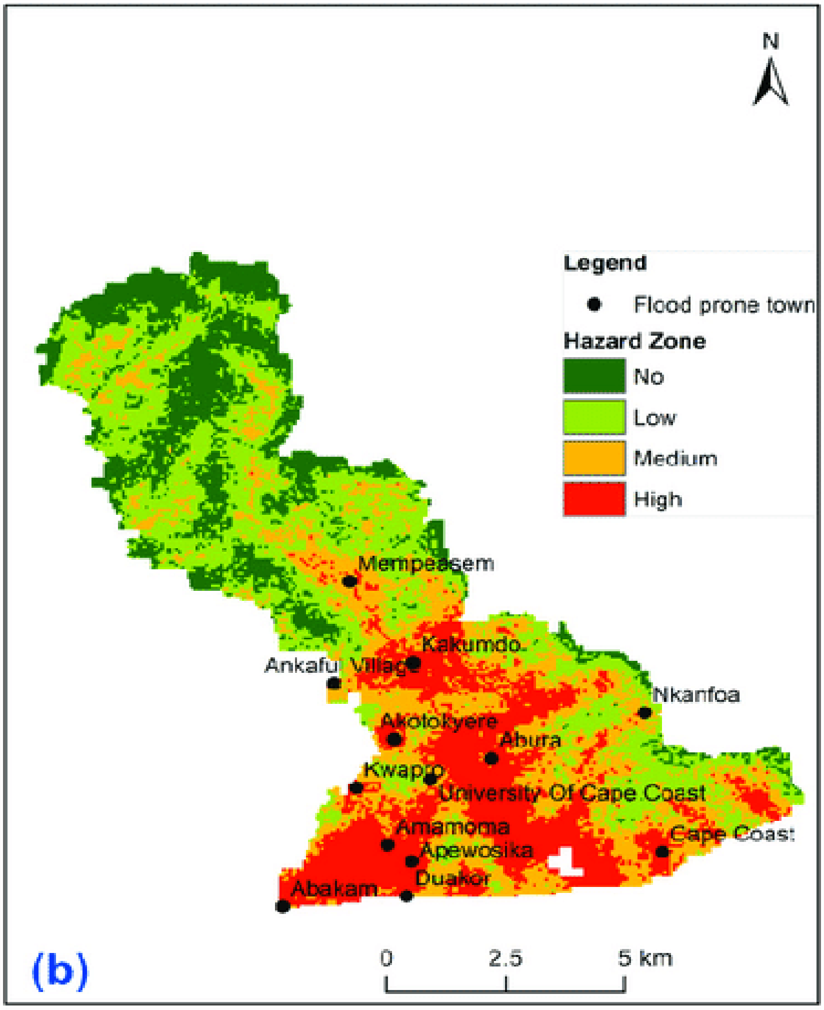
Figure 18. A group mapping climate risk prone areas in the CCMA during the workshop

Figure 19. Participatory hazard mapping of hazards in the Cape Coast metropolis



To verify the outputs of the participatory hazard maps produced from the stakeholder workshop, we compare it to a district flood hazard map produced by Danso et al. (2020) using geospatial techniques (Figure 20). Their analysis revealed that high flood hazard zones within the Cape Coast Metropolis were concentrated around the coastal areas extending inland up to the middle zone. Unlike the outcome in the south of metropolis, many places in the north fall within no (18.18%) or low (33.80%) flood zones. High flood hazard zones cover about 21.94% of the study area. Some of the major characteristics of the hotspots include low slope and elevation values, as well as being situated within a few meters of streams. However, both high (21.94%) and medium (26.07%) flood hazard zones constitute 48% of the entire study area.

Figure 20. Geospatial flood hazard map of Cape Coast Metropolis



Source: Danso et al. (2020).

It is evident from Figure 19 and Figure 20 that the participatory hazard map from the stakeholder workshop is very reflective of the geospatial flood hazard map of Cape Coast Metropolis and is useful in assessing climate vulnerability and adaptation planning.

3.2.5 Assessing Community Functions Using Matrix of Function (MoF)

A Matrix of Functions (MoF) was used to assess community functions in the municipality (Fee et al., 2017). An MoF is a tool widely used in spatial planning that provides a comprehensive way of describing which services and functions are available in each ward and village tract of the township; the hierarchy and importance of these settlements in relation to one another; where functions are missing; and how balanced the township's spatial development is. When applied to climate change, it improves knowledge of how the present spatial structure and functionality of a district support or limit the area's adaptability to climate change.

The MoF was developed by collecting data with a simple questionnaire to determine where services were available. The information collected through the survey enables planners and policy-makers to analyze the district's level of physical and socio−economic development, which characterizes its vulnerability to climate change. Community representatives invited to the stakeholder workshop completed the MoF data collection form. Key functions were listed, processed, and mapped in a spreadsheet application (Figure 22). Click here to access the MoF of CCMA in full details.

Figure 21. Town/community representatives completing the MoF form

An overview of the MoF is described below:

- The columns show the "functions," ordered from left to right according to their frequency.
- The rows show the names of communities/villages in CCMA, ordered from top to bottom as per the highest presence of functions.
- A black cell indicates the presence of the function (not how many times the function is present, just if it is present or not), while a white cell indicates its absence in the community/village concerned.
- Rows with more black cells (functions present) indicate urban areas. A decreasing presence of functions typically, means that a community is more rural.
- Functions to the left are more basic and common to communities while the ones to the right indicate functions that are more likely to be found in urban areas.

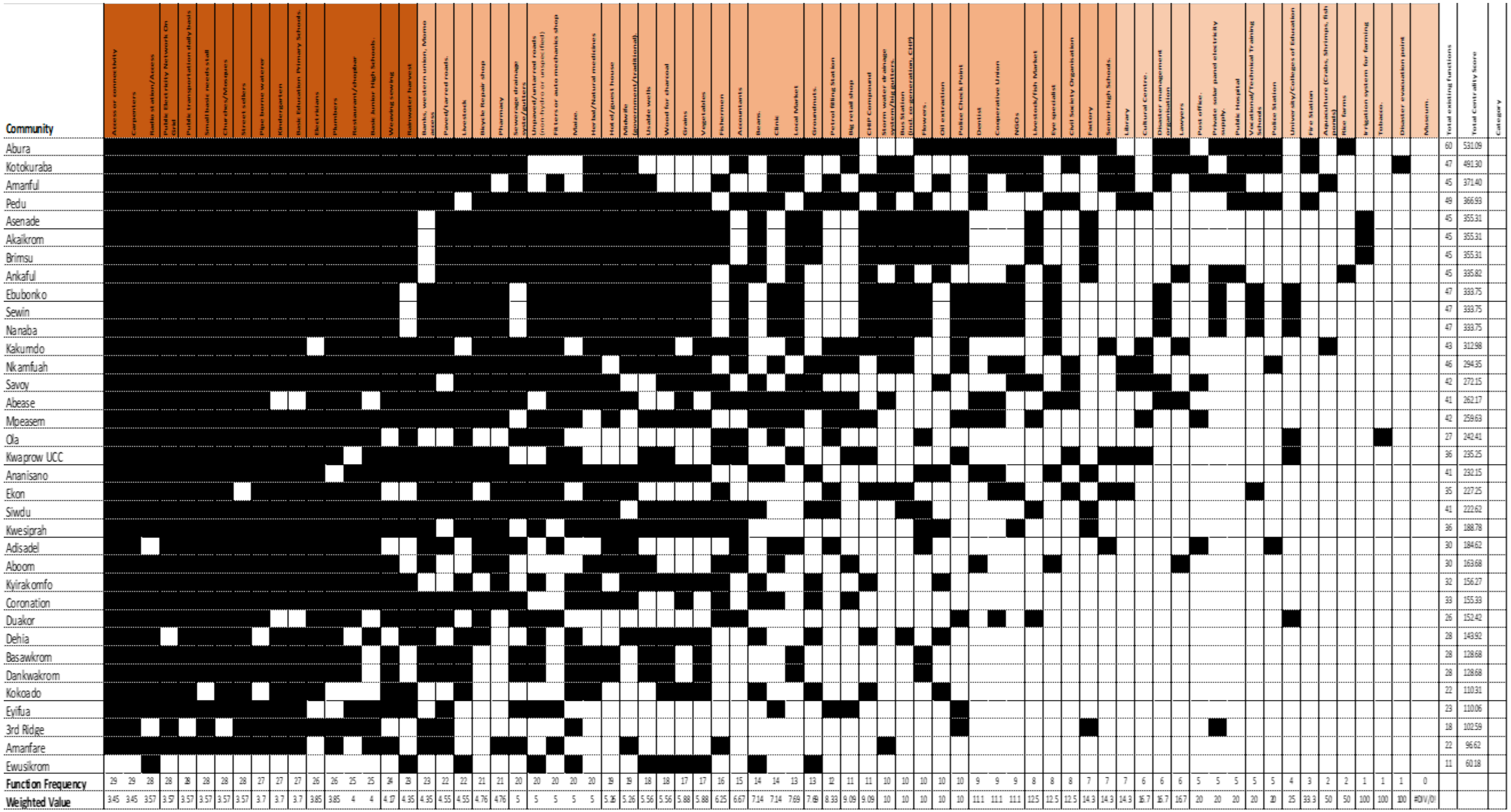
The MoF is interpreted to give an understanding of the level of vulnerability of different towns and villages within the municipality based on the availability of functions. Specific results of the MoF are presented below:

- The results show that the Metropolis is relatively urbanized (more black cells). Urban areas exhibit specific attributes that enhance their resilience to climate change in contrast to rural regions. These attributes encompass well-developed transportation networks, upgraded infrastructure for buildings and housing, availability of clean water and sanitation systems, dependable energy sources, diverse economic activities, accessible healthcare amenities, robust social networks, and established institutions, including local governmental bodies. These traits empower urban areas to endure and rebound from climate-induced occurrences such as floods, storms, and heatwaves with greater efficacy.
- All communities have the following functionalities: Access or connectivity to a mobile network, radio station/access, public electricity network on grid, public transportation on a daily basis, small basic needs stalls, churches/mosques, pipe-borne water, basic schools, and rain harvest systems. These functionalities contribute significantly to enhancing a community's resilience to climate change in various ways:
    - Access or connectivity to a mobile network and radio station/access allows for timely communication, dissemination of weather warnings, and coordination during climate-related emergencies. It enables residents to stay informed and access help if needed.
    - A stable electricity supply supports various critical functions such as powering communication devices, medical equipment, and emergency services. It ensures that essential services remain operational during climate events.
    - Access to public transportation enables residents to evacuate or relocate efficiently during imminent threats, reducing vulnerability to climate-related hazards and promoting safe mobility.
    - Small basic needs stall provide access to essential goods and supplies during emergencies when traditional supply chains might be disrupted. They help ensure that residents have access to necessities like food, water, and basic supplies.
    - Access to clean and reliable water sources is crucial for drinking, sanitation, and hygiene, especially during climate events that can contaminate local water sources. It reduces health risks and ensures basic needs are met.
    - Basic schools can serve as shelters during emergencies and are vital for educating communities about climate resilience, disaster preparedness, and sustainable practices.
    - Rain harvest systems collect and store rainwater, helping communities mitigate water scarcity during droughts or water supply disruptions. They promote self-sufficiency and reduce dependence on external sources.

- Museum is the only functionality missing in the municipality.
- Ewusikrom is the community with the fewest functions, while Abura has the most.
- In terms of health, each town has access to health care (at least a pharmacy, CHPS, public hospital, or clinic) except for Duakor, Basawkrom, Dankwakrom, 3rd Ridge, and Ewusikrom.
- The MoF showed that maize is a staple in most communities as well as vegetables. It has been observed that changes in the onset and cessation of rain have negative impacts on maize production and pose a serious threat to household food security, especially in areas where maize is a staple food (Klutse et al., 2013).

Although the MoF provides some information on communities that might be more vulnerable to climate change, it doesn't cover all communities due to the resource constraints in inviting representatives from all the communities in the municipality to the workshop. The MoF also does not indicate the number or frequency of each function. However, combining the MoF with the participatory hazard map and/or town level VA helped to highlight hotspots of vulnerability – those areas with fewer functionalities – in the metropolis that require more focused and inclusive adaptation planning.

Figure 22. Matric of function for selected towns in the CCMA. Click here to access the MoF of CCMA in full details



3.2.6 Prevailing Climate Change Hazards and Their Associated Impacts on Economic Sectors or Activities

The participatory stakeholder engagement workshop identified floods, storms, tidal waves, and droughts as recurring climate hazards in the metropolis. These hazards have serious implications for economic sectors and activities within CCMA. An understanding of how these hazards impact the economic sectors is imperative for estimating current and future impacts in the face of a changing climate and to prioritize the sectors for adaptation planning. To determine prevailing climate change hazards and their associated impacts on economic sectors or activities, participants were organized into sectoral groups (groups of people working in one sector) to brainstorm climate manifestations in the sector, vulnerabilities, impacts, and adaptation measures.

3.2.6.1 Impact on Agriculture (Crop, Livestock, and Fisheries)

While climate change impacts can be positive in some regions, they can be negative in other regions. Increasingly erratic rainfall, high temperatures, and more heat waves, floods, dry spells, rainstorms, and lightning are observed climate change manifestations relating to CCMA's agriculture sector. In recent times, erratic rainfall has become pronounced, with reduced annual rainfall intensity. The sector is also witnessing an increased delay in the onset of rains as well as reduced relative humidity and an increased rate of evaporation.

Floods have become the most prevailing climate hazard in the metropolis and result from direct heavy downpours (flash floods), rivers overflowing their banks (riverine flood), and/or intrusion of seawater as result of tidal waves (coastal floods), compounded by poor drainage systems, waste management, and urban planning. Floods physically damage farms, crops, livestock, and the physical infrastructure of agriculture and food supply chains to reduce agricultural productivity yields and food availability (Atanga & Tankpa, 2021). Efutu, Essuekyir, Ankanful, Kwaprow, Bakaano, and Siwdu are farming areas in the metropolis noted to be highly impacted by floods. In addition, an increase in pest and disease incidence in on farms has been observed to correlate with climate change manifestations in the metropolis.

In livestock production, the workshop sector group indicated reduction in litter size in livestock and poor feed conversion efficiency. Human activities such as deforestation, sand mining, excessive use of inorganic fertilizer, slash and burn activities, and estate development on arable land are noted to exacerbate the climate change impacts on this agriculture sector.

Climate change impacts have also been identified in inland fishing and lagoons. A combination of pollution and climate change has been documented to affect the Fosu Lagoon in the metropolis which has in turn impacted the livelihoods of fishermen (Kwadzo et al., 2022). Agyapong (2008) earlier noted that a large portion of the lagoon sometimes dries up during the dry season and has led to the dying of fish species. This has devastating impacts on the livelihoods of community members whose lives depend on the lagoons. A study by Akaba and Akuamoah-Boateng (2018) also confirmed workshop observations from agricultural sector representatives that sea fishers are experiencing erratic rainfall, strong wind/storm with high tides, high temperatures, droughts, floods and heavy precipitation. Reduced fish catch has been attributed to increasing sea temperature, which is driving fish away into the deep beyond the safe reach of fishermen.

These effects lead to low productivity, reduced income, food insecurity, and labour emigration. Those impacted have resorted to changing fishing methods, seasonal migrations, and livelihoods diversification as responses to the climate change effects. Women play a major role in the fishery value chain, particularly downstream through processing, preservation, marketing, and sales. They have suffered highly from some of the climate change impacts in this sector.

With a limited budget, the metro department of agriculture is adopting capacity building and creating climate awareness campaigns in the areas listed in Table 8 as an imminent adaptation measure.

3.2.6.2 Impact on Infrastructure and Transportation

Erratic rainfall, increasing rainstorms, lightning, and floods (coastal and inland) have serious implications for buildings, roads, and drainage systems in the metropolis. The metropolis represents a monument of old Ghana and has very old forts, castles, roads, and communities with old buildings. In the face of intense and frequent climate extreme events such as floods, rainstorms, and tidal waves, these structures have been impacted, affecting lives and livelihoods. These impacts are especially evident in the southern part of the metropolis which is a built environment that lies along the coast.

Inadequate, broken, and silted drainage structures, dumping of refuse in drains, building in waterways, mud buildings (e.g., Brofoyedru area), washing away of coconut trees along the coast due to tidal waves (e.g., from Ola Hospital to the Breeze), sand mining at the beach, and poor maintenance of the drainage system are noted conditions that predispose infrastructure in the metropolis to disaster.

Ongoing adaptation measures include:

- Sea defence project to deal with tidal waves.
- Enforcement of the law to check deviant behaviour (sand mining, construction in unauthorized areas).
- Arrest of people building without permits issued by the Building Inspectorate.
- Regular desilting of the earth channel and drains by Department of Urban Roads (DUR).

3.2.6.3 Impacts on Tourism

The coast of the metropolis is dominated by sandy beaches, hotels, and resorts of different sizes, hosting hundreds to thousands of tourists daily. Because of its colonial past and slave history, Cape Coast is the tourism hub of Ghana and receives many tourists from around the world throughout the year. The coastal area has been impacted by sea level rise and storm surges, with some studies calculating that Ghana loses an average of 2 metres of coastline annually to coastal erosion (Appeaning, 2021). A large proportion of the Cape Coast coastal area is walled, which helps to protect coastal historic sites and other infrastructure from coastal erosion and sea surges.

3.2.6.4 Impact on Forestry (Biodiversity and Ecosystems)

CCMA has a native forest close to the Kakum River. Habitat disturbances by human activities such as a rapid pace of deforestation, pollution, logging, poaching by illegal miners, and encroachment into the forest threatens the forest and leads to its fragmentation. Stakeholders reported cases of some rare or potential medicinal plant species having disappeared from the Cape Coast environment. Forests have an impact on the local climate of their surroundings. They moderate higher temperatures and heatwaves by causing rainfall and evapotranspiration, and support soil retention.

3.2.6.5 Impact on Water, Sanitation, and Human Health

The CCMA boasts of 100% pipe-borne water access by dwellers. However, it suffers from perennial water shortages, particularly in the dry season. This is due to drought and the destruction of the surrounding environment of the Kakum River basin, which is dammed at Brimso, a location close to Cape Coast where the water is treated and distributed to the Metropolis. The Kakum River Basin provides the domestic water supply as well as water for industrial and agricultural purposes.

Flooding events have become rampant in recent times and have significant implications for urban sanitation and human health in the metropolis. Both inland and coastal flooding impact ecological and socio-economic development, especially farming and related activities. This is exacerbated by the metropolis's hilly and undulating topography.

Climatic events and extremes have direct impacts such as injuries and death. Flooding events in the Metropolis in 2016 led to loss of life. During the participatory stakeholder workshop, participants indicated additional health impacts, including the prevalence of skin rashes and respiratory diseases during the dry season.

Human activities such as inappropriate farming activities on the banks of the river and at the source, use of agrochemicals in farming, sand mining, dumping of liquid and solid waste material from domestic and industrial sources into the basin, poor planning schemes in the basin area, and indiscriminate harvesting of wood from the source to the midstream in the metropolis will exacerbate the impact of climate change on water, sanitation, and human health.

3.2.5.6 Impact on Finance, Trade, and Industry

Climate elements and associated hazards have little direct links to the financial, trade, and industry sectors. However, these businesses are heavily tied to core climate-dependent sectors. Agriculture, for example, supplies commodities for commerce as well as raw materials for manufacturing. Rural and commercial banks also lend to farmers. The effects of climate change on these sectors may result in debt defaults by borrowers, while traders and industries may face commodity and raw material shortages, respectively. The impacts of climate hazards on these sectors according to the workshop sector group included:

- Increased cost of insurance for both the insurer and insured.
- Rising operational cost of business.
- Growing scarcity of raw materials which affect prices.
- Low productivity when workers are affected.

Table 6. Mapping climate element and associated hazards to economic impacts

Climate element	Hazard	Economic sectors				
		Agriculture (crop, livestock & fishery)	Forestry (biodiversity & ecosystems)	Water, sanitation & human health	Transportation & infrastructure	Finance, trade & industry
Temperature	Increasing temperature	Longer dry spells leading to decreases in crop productivity. Warming of sea water as a result of high temperature causes fish to dive deeper, beyond reach of fishermen. Death of livestock.	Increased forest fires leading to forest destruction.	Evapo-transpiration leading to the drying up of lagoons and recession of the Kakum River Basin. Water scarcity causes poor sanitary conditions and affects human health. Higher temperatures are noted to cause respiratory tract infections and skin diseases.	High temperatures heat roads and destroy asphalt.	Default of loans by farmers. Low productivity of raw materials will affect industry output. Traders will have fewer commodities to trade.
Rainfall	Drought	Low agriculture productivity (food scarcity).	Increased forest fires, degraded forests and reduction in biodiversity.	Water shortages, high cost of water. Poor sanitation conditions due to lack of water for cleaning. Dry air causes respiratory tract infections.	Drought results in dusty roads causing pollution and health-related respiratory diseases.	Default of loans by farmers. Low productivity of raw materials will affect industry output. Traders will have fewer commodities to trade.
	Floods	Erosion and destruction of farms. Destruction of farmlands along the coast.	Flooding can have a negative effect on wildlife, causing drowning, disease proliferation, and habitat destruction. Salination of wetlands as a result of sea water intrusion.	Pollution of water bodies and worsening sanitation in slum areas. Destruction of life and properties. Increased prevalence of communicable diseases such as malaria. Salinity of water bodies close to the sea.	Floods wash away roads and collapse bridges. Destruction of buildings and roofing. Coastal flooding will destroy roads, beach resorts, and properties along the coast.	Default of loans by farmers and fishermen. Low productivity of raw materials will affect industry output. Trades will have ferwer commodities to trade.
	Rainfall variability	Increases unpredictability of farming season. May increase crop loss. Increases risk and uncertainty in fishing.	May affect forest management by authorities.			Default of loans by farmers. Low productivity of raw materials will affect industry output. Traders will have fewer commodities to trade.

3.2.7 Ranking of All Sectors to Consider the Most Critical and Highly Vulnerable Sectors to Focus on in the VA Process

Climate change impacts vary from one sector to the other based on how the sector interfaces with and depends on climate variables. In addressing climate change in the face of limited resources, it is imperative to rank the sectors to be prioritized both in the vulnerability assessment and for adaptation planning. The five sectors identified in the municipality are agriculture; forest; water/health, and sanitation; infrastructure and transportation; and finance, trade, and industry. Stakeholders who represent the various sectors worked in breakout sector groups to rank the sectors based on four criteria: certainty of impact, timing of impact, severity of impact and importance of resource. These were ranked on the scale of 1 to 5. The result is presented in Table 7.

Table 7. Ranking of sectors' vulnerability to impacts of climate change

Sector	Certainty of impact	Timing of impact	Severity of impact	Importance of resource	Weighted average
Agriculture (crop, fishery & livestock)	5	5	5	5	5
Forests (biodiversity and ecosystems)	4	4	5	5	4.5
Water/health and sanitation	5	3.5	5	5	4.6
Infrastructure and transportation (including coastal tourism)	4	4	5	5	5
Finance, trade, and industry	4	2	4	5	4

High = 5, medium-high = 4, medium = 3, medium-low = 2, low = 1

3.3 Quantitative Assessment of Climate Change Vulnerabilities in the Cape Coast Municipality

3.3.1 Description of Climate Change Vulnerability Methodology

The participatory risk mapping and matrix of function activities as well as the literature review have identified locations and economic sectors of the district vulnerable to climate change hazards and impacts. The locations constituted 23 communities in the districts while the sectors are agriculture (crop, fishery & livestock); forests (biodiversity and ecosystems); water, health, and sanitation; infrastructure and transportation; and finance, trade, and industry. These sectors also reflect the sectors of focus of the NAP process in Ghana. Indicators were derived from the qualitative vulnerability assessment results to quantitatively measure the identified vulnerabilities in these communities and sectors of the district. Questionnaires were derived based on the variable for each indicator (see Appendix 1) and administered to a predetermined sample size of households in each community. Indicators were also derived to estimate sector specific vulnerabilities. Enumerators (primarily staff from the municipal assembly) were trained to visit the communities and interview households for the needed information. Overall, 200 households were interviewed. The information was collected by enumerators digitally and saved to a cloud database.

The IPCC (2022) defines vulnerability as the propensity or predisposition to be adversely affected, which encompasses three components: exposure, sensitivity, and adaptive capacity. The quantitative vulnerability assessment determined the magnitude and rate of variation in climate change vulnerability components across the communities and sectors. The district-specific climate change vulnerability was calculated using the following steps.

Setting vulnerability score range

A vulnerability score range was set on a scale of -1 to +1, with -1 indicating low vulnerability (no improvement necessary or possible) and +1 indicating high vulnerability (system no longer functional).

Data normalization

Because different indicators have different scales, units, and magnitudes, working within this score range can be very problematic. It is therefore imperative to apply a tool called normalization. The term “normalization” refers to the transformation of indicator values measured on different scales and in different units into unit-less values on a common scale (GIZ, 2014). Indicators might have different scales of measurement ranging from numeric or metric to nominal to ordinal. Normalization therefore helps to put them on a common scale.

The min-max method was applied in normalization of indicators. This method transforms all values to scores ranging from 0 to 1 by subtracting the minimum score and dividing it by the range of the indicator values. The following formula is used to apply min-max.

$$X_{i,0\ \text{to}\ 1} = \frac{Xi - Xmin}{Xmax - Xmin} \qquad \text{Equation 1}$$

Source: GIZ, 2014.

where

X_i represents the individual data point to be transformed,

X_{Min} the lowest value for that indicator,

X_{Max} the highest value for that indicator, and

$X_{i,0\ \text{to}1}$ the new value you wish to calculate, i.e., the normalized data point within the range of 0 to 1.

Aggregating indicator

Several individual indicators may contribute to the overall value of a component. This means that the individual indicators must be aggregated to the level of component.

$$CI = \frac{(I_1 * w_1 + I_2 * w_2 + \cdots I_n * w_n)}{\sum_1^n w} \qquad \text{Equation 2}$$

Source: GIZ (2014).

where *CI* is the composite indicator, e.g., adaptive capacity; *I* is an individual indicator of a vulnerability component, (such as % of community population with alternative livelihood, % of community population belonging to a social organisation, % of community population with access to early warning systems, etc.); and *W* represents the weight assigned to an indicator. Some of the indicators are thought to have a higher effect on a vulnerability component than others (GIZ, 2014). Weighting was applied to such indicators when applicable and appropriate using stakeholder input or expert opinion.

Determining overall vulnerability

After determining each composite indicator all the components are added together to determine the overall climate vulnerability of the district. The IPCC equation for climate change vulnerability is:

Climate change vulnerability (CCV) = (Exposure x Sensitivity) – Adaptive Capacity   Equation 3

The parameters for each component are further divided into general and sector specific. For community level vulnerabilities, general parameters were used while sector specific parameters were used for sectoral vulnerabilities.

The research team collected information and data on vulnerability parameters listed in Table 8 through the survey of 200 households. The parameters for exposure were derived from the data obtained from GMet and the survey on the frequency of climate extreme events such as floods and droughts/long dry spells.

Table 8. Vulnerability parameters

Vulnerability parameters	Scale	Variables	Spatial data
Exposure	Community	Mean annual rainfall	
		Average number of Consecutive Dry Days (CDD)	
		Average number of Consecutive Wet Days (CWD)	
		Average number of warm days	
		Average number of days of heavy precipitation	
		Annual minimum temperature	
		Annual maximum temperature	
		Frequency of flood events	
		Frequency of long dry spells	

Vulnerability parameters	Scale	Variables	Spatial data
Sensitivity	Community	% of community population with livelihood dependent on rainfed agriculture	
		% of community population living in flood-prone areas	
		% of community population with challenges with water access	
		% of community population with challenges with health care access	
		% of community population with no education	
Adaptive capacity	Community	Social	% of community population belonging to a social organisation
			% of community population on NHIS
		Economic	% of community population with alternative livelihood
			% of community population with access to credit
			% of community population with receives remittances from family and friends
		Infrastructure	% of community population with access to safe sanitation facilities
			% of community population with access to good road network
			% of community with market access
		Individual knowledge	% of community population received awareness training on climate related events.
		Access to information	% of community population with access to early warning systems

Table 9. Example of the method used to calculate district-specific climate change vulnerability

Community	Exposure (A)		Sensitivity (B)		Adaptive capacity (C)		CCV (A x B) – C
	Frequency of occurrence of extreme floods events (mean)	Normalized data	% of community population living in flood prone areas	Normalized data	% of community population on NHIS	Normalized data	
Abenkyim	3.8	0.5	22%	0.66	100%	0	0.33
Aboaso	1.875	0.3	33%	1	100%	0	0.30
Afransie	1.615385	0.3	0%	0	100%	0	0

Source: Author.

3.3.2 Results of Quantitative Climate Change Vulnerability Assessment

The quantitative vulnerability assessment results from the studied communities are displayed in the maps on Figures 23 to 26 A negative index shows that the combined effects of exposure and sensitivity to climate change are less than the affected population's ability to adapt to the changes. A positive index, on the other hand, shows that the afflicted population's adaptive ability is lower than the combined impacts of exposure and sensitivity. The larger the bubble, the greater the vulnerability to climate change.

3.3.2.1 Overall Vulnerabilities

From the analyses, it is evident that all communities in the Municipality are vulnerable to the impacts of climate change to varying degrees. In terms of exposure to climate change, most of the most exposed communities are located on the coastal areas of the municipality. The most exposed communities in the coastal zone include Bakaano, Anaafo, Aboom, Siwdu, Ekon, and Kwesiprah. The least exposed communities include Nkafoa, Pedu and Amamoma. Similarly, most of the most sensitive communities from the survey are found on the coastline. They include Bakaano, Anaafo, Kwesiprah, and Ekon. Other sensitive communities (Dehia, Ewusikrom, Efutu, Kyirakomfo) are located in the northern sections of the Metropolis. With regards to adaptive capacity rating, Anaafo, Bakaano, Siwdu, Duakor, and Efutu all have relatively low capacity to adapt to the climate change impacts due to low level of alternative income generation, limited access to climate information, and low awareness of issues of climate change (Figure 23).

From the survey, it was established that the five least vulnerable communities in the Cape Coast municipality are Aboom, Efutu, Nkafoa, Abura and Pedu. It is important to note that these communities are part of the well planned and newly developed areas of the metropolis. The five communities with the highest vulnerability status are Bakaano, Kotokuraba, Ekon, Dehia, Ewusikrom, and Swidu. These communities are highly exposed and sensitive to flooding and other hazards. Communities like Bakaano, Ekon, and Amoakofoa, by virtue of being located along the coastal lagoons, tend to be sensitive to coastal flooding and erosion events.

During the household surveys, several households reported some of their fears. A 55-year-old woman stated:

"I have lived in this community since I was 10 years old. The sea and the lagoon were healthy and provided us with fish and other resources. In recent years, however, the Bakaano is polluted with waste from all over the city. People intentionally dump refuse into it. The sea level has risen and taken over many homes. The rains are also irregular because of climate change, so all the pollutants in the Baka have stayed in and destroyed the water quality. I think erosion and flooding are two of the biggest concerns we face here We are afraid that the sea will wash our homes away in the next 10 years."

Figure 23. Exposure (a), sensitivity (b) and adaptive capacity (c) distribution across selected communities

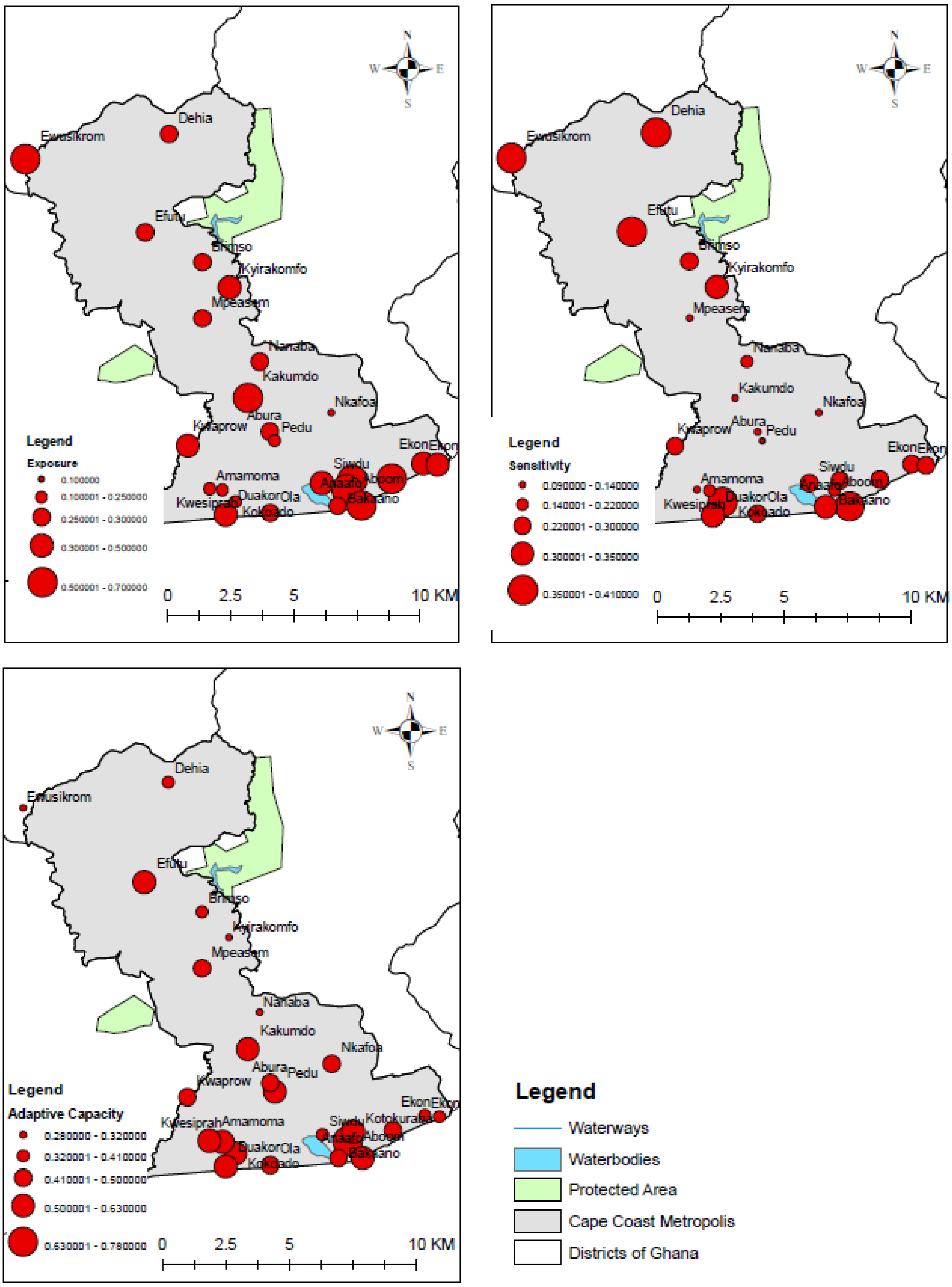
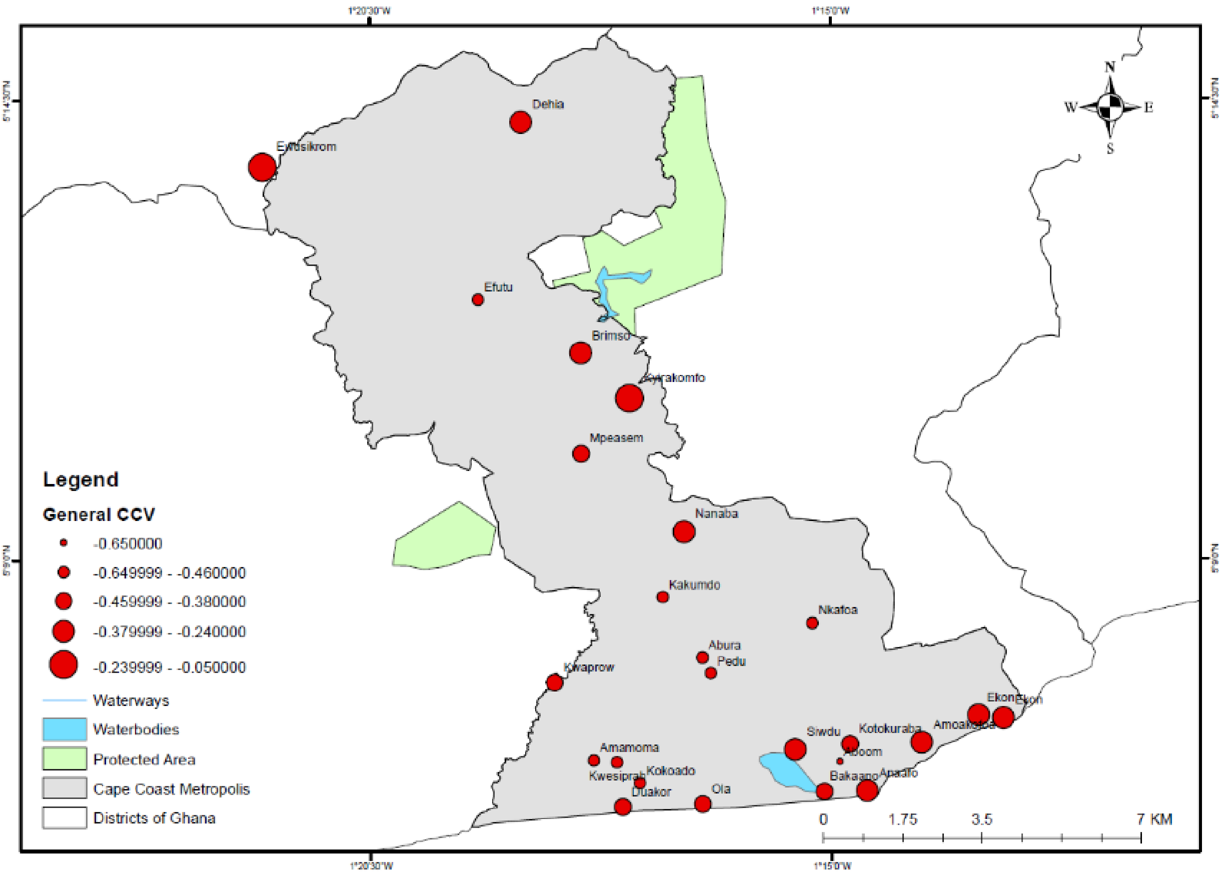


Figure 24. Vulnerability of selected communities



A respondent during the household survey in the Municipality indicated that climate change represents a major threat to residents' livelihood as farmers:

"You know that the rains have been inconsistent in the last 10 years, right? Well, if you don't know I am telling you. This has made farming in this community difficult. The soil is infertile, dry and with no rain, crops like maize, pepper and even pineapple are not yielding much. I have stopped farming and started trading in second-hand clothes. As a woman, I feel like giving up on life, but my children are the reason why I continue to do this. I am a widow."

[48-year-old female resident of Ewusi]

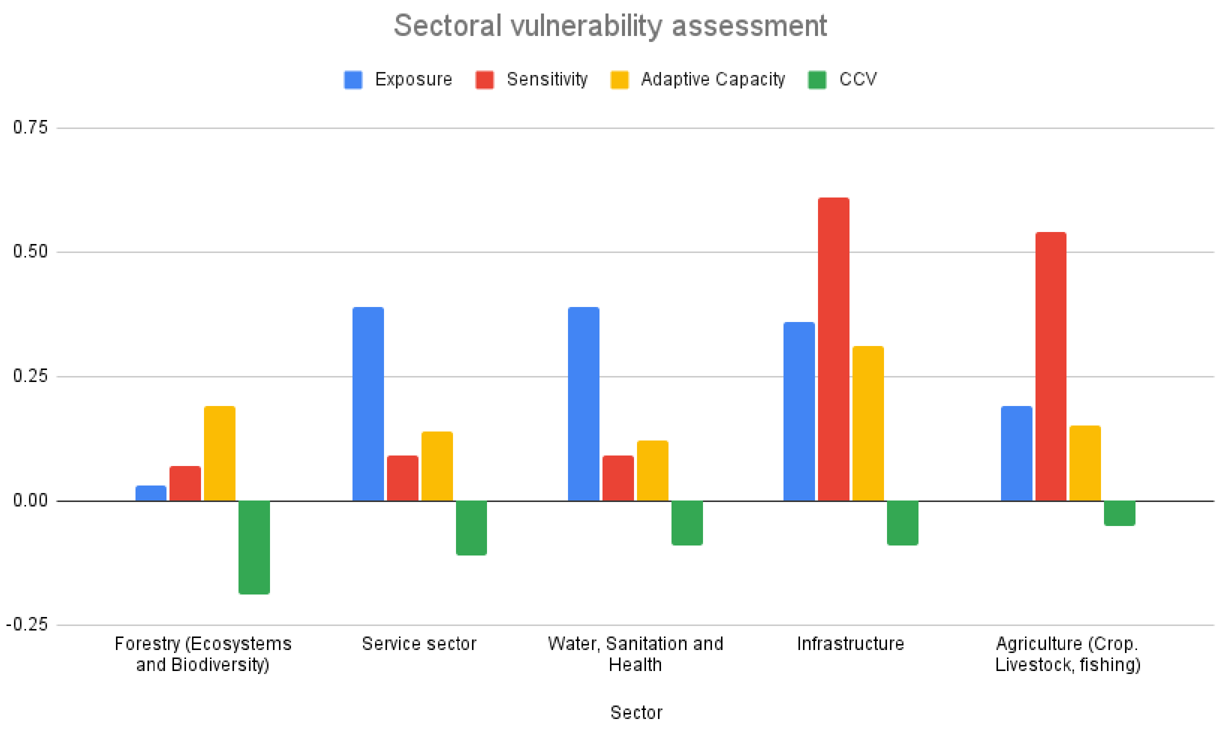
3.3.2.2 Sectoral Vulnerability

Climate change impacts can differ significantly across different socio-economic sectors. Well-established climate impacts such as increased frequency and intensity of natural disasters, loss of livelihoods, and food and water insecurity affect established sectors such as agriculture, services, water, sanitation and health, infrastructure, and forestry differently. Understanding this is important in the design and implementation of adaptation actions and responses. For instance, climate change can cause soil degradation, crop failures, and decreased food production, which directly affects the agriculture sector by increasing food insecurity. Within the agriculture sector, small-scale farmers are often the most vulnerable to these hazards.

In terms of sector-specific vulnerabilities, the exposure component resulting from the climate/ weather data provided by GMet is constant because it is at the municipal level. However, variations exist in exposure due to the different frequency of extreme events such as floods and droughts in the different communities. Sensitivity and adaptive capacity were calculated by aggregating the various parameters related to each respective sector. For example, issues related to agriculture were collated into water sector sensitivity and adaptive capacity.

Overall, agriculture is the most vulnerable sector to climate change (Figure 25). The results show the service, water, sanitation and health, and infrastructure sectors also are heavily exposed. This can be explained by respondents' reports of torrential rainfall contributing to flooding which in turn affects these sectors in diverse ways. For instance, many mentioned that flash floods in the Municipality have been the main cause of infrastructure damages, impacting roads, homes, and residential and industrial facilities. Some respondents also reported an increase in diarrhea and malaria as health hazards due to climate change. The high sensitivity of the infrastructure sector is due to high exposure and sensitivity to floods. Flooding affects the service sector's ability to function properly because it can prevent workers from traveling to work or shut down their workplaces for multiple days. The agriculture sector is the second most sensitive sector to climate change impacts after infrastructure.

Figure 25. Sector-related breakdown of climate change vulnerability parameters



3.3.2.3 Agriculture Sector Vulnerability

Even though the Cape Coast metropolis is largely urban, agriculture remains one of the most important sectors of the local economy. As the qualitative analyses revealed, the agriculture sector is highly exposed to the vagaries of the weather. From the questionnaire survey, the indicators exposure, sensitivity, and adaptive capacity for the Cape Coast were evaluated (Table 10) and mapped (Figure 26).

Table 10. Indicators for exposure, sensitivity, and adaptive capacity for the Cape Coast Municipality

Exposure	Sensitivity	Adaptive Capacity
Frequency of occurrence of drought/dry spell events Frequency of occurrence of extreme floods events Mean annual rainfall Average number of Consecutive Dry Days (CDD) Average number of Consecutive Wet Days (CWD) Average number of heavy precipitations Annual minimum temperature Annual maximum temperature	% of farming HH with no education) % of HH with livelihood dependence on rainfed agriculture % of HH with NO access to good road network? % of HH with farms in flood prone area % of total farm output loss to postharvest losses.	of farming HH that receive information on weather forecasts Total size farm (average since 5 years ago) % of HH who grow other crops % of HH that have irrigation system % of HH that have access to water for dry season farming % of HH that are members of a Farmer Based Association (FBO)? % of HH that have access to/contact with Agricultural Extension Agents (AEA) % of HH that get information on improved production methods and systems % of HH that have subscribed to any insurance product

The results of the agriculture sector vulnerability assessment (Figure 24) indicate that vulnerability of each sector in the Municipality differs from community to community. The communities that have higher vulnerability are Dehia, Efutu, Brimso, and Ewusikrom. These are communities with a fair balance of urban and rural populations. Agriculture is the main livelihood agriculture of the majority of households interviewed. As one household head stated:

"My crops have failed consistently in the past 5 years. The rains are not falling like it used to. When it rains, it is very severe and it destroys many of our crops and farmers lose their entire livelihood. Climate change is a constrain to the development of poor communities like u.s."

[40-year-old male farmer, Brimso]

Figure 26. Agriculture sector-related exposure (i), sensitivity (ii) and adaptive capacity (iii) in the selected communities in the Cape Coast municipality

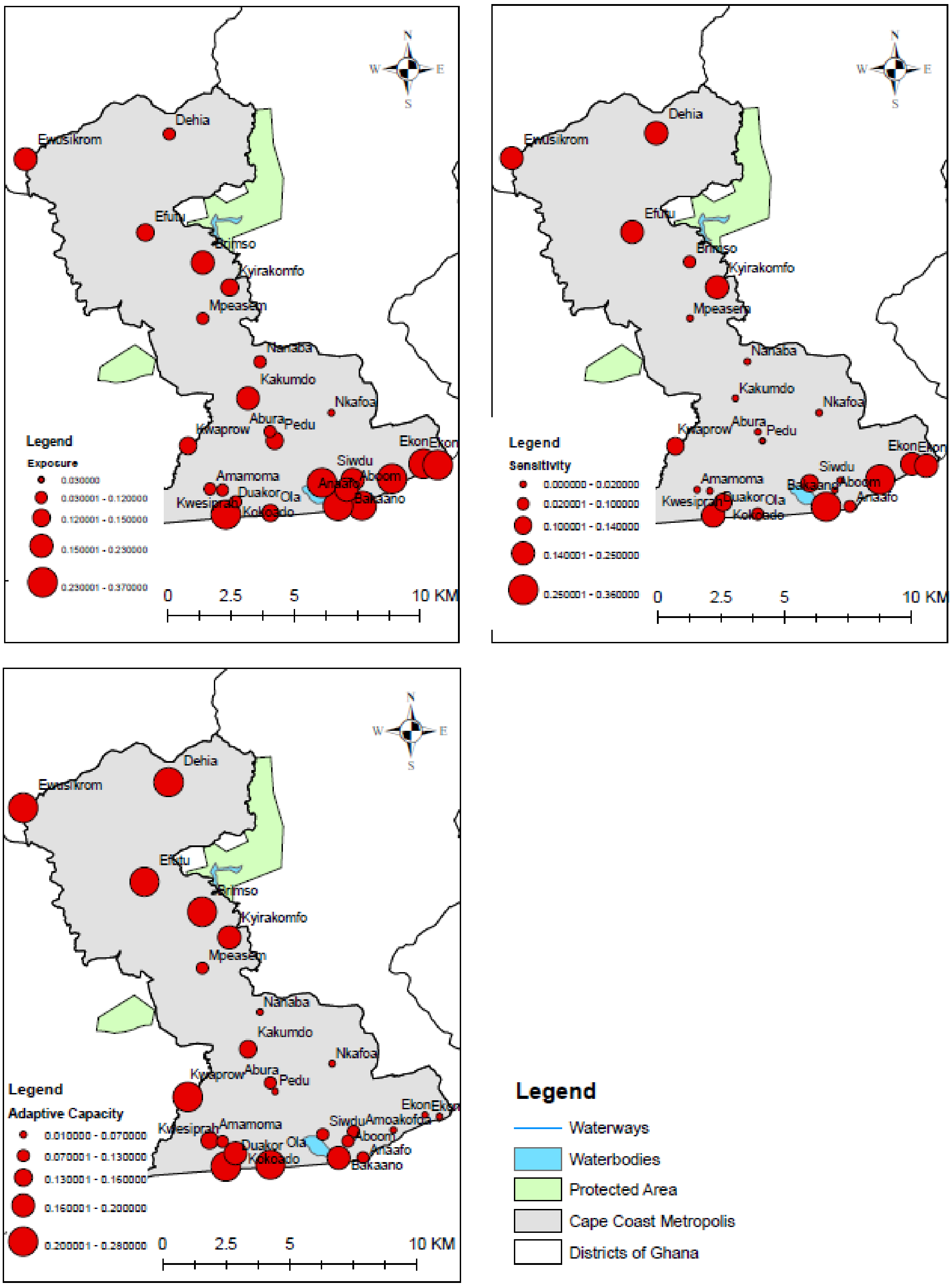


Figure 27. Agriculture sector-related vulnerability map of the selected communities

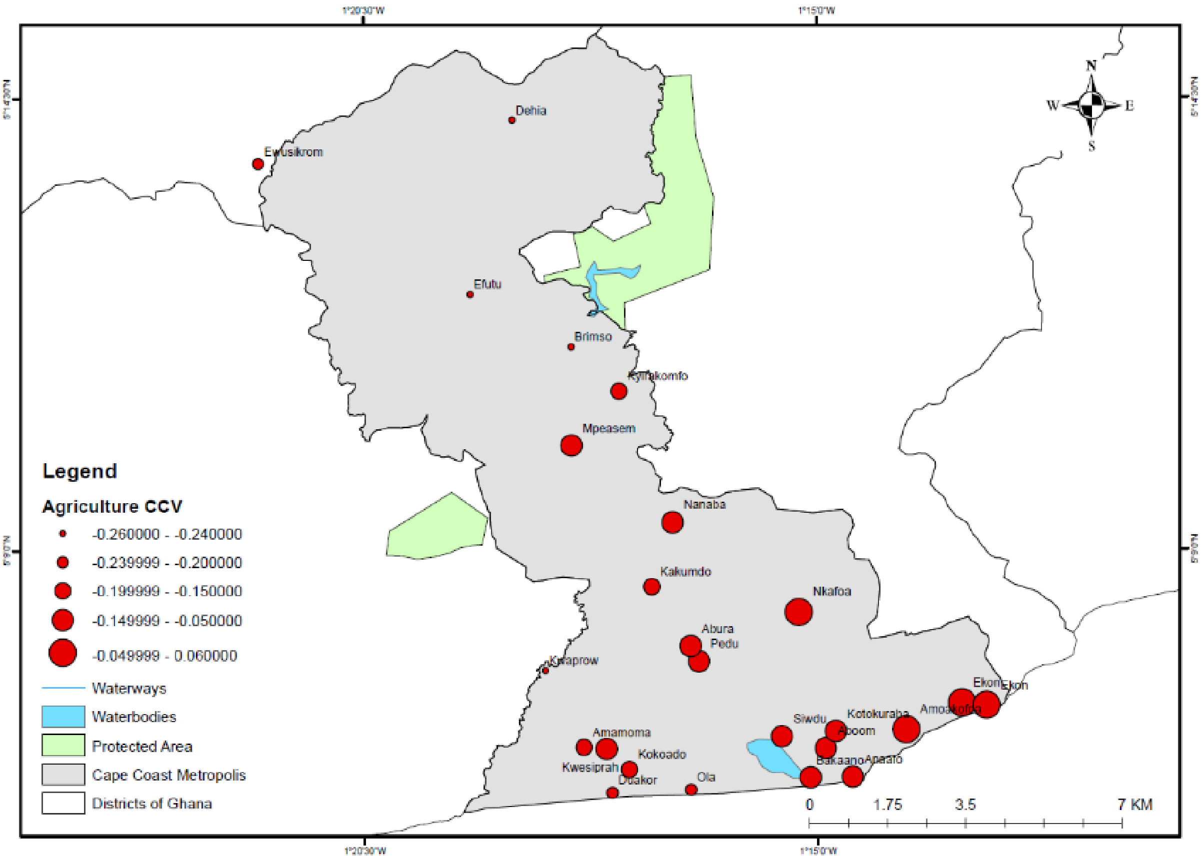


Figure 28. Flood and coastal erosion prone areas of the Municipality

Source: Y.A. Boafo, 2022.

4. Assessing Future Climate Change Risk

4.1 Climate Projections

Climate change projections, which were made with baseline climate information, provide foreknowledge of what policy-makers can expect going forward and are a critical input to planning. These projections help policy-makers identify necessary interventions and exploit future opportunities. Projections from 2020 to the end of the century for rainfall, and minimum and maximum temperature are presented in this section.

4.1.1 Description of the Climate Projection Method

The analysis projected future climate for RCP4.5 and RCP8.5 emission scenarios. The baseline was the period 1980-2020, whereas the future projections are up to the year 2100. The climate projection took the following steps.

4.1.2 Data Collection for Climate Projection

Observational climatological data from the 1980 to 2020 was derived from information provided by the Ghana Meteorological Agency and model data from satellite observations. The source of model data used for the rainfall-related indicators was the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), while ERA5 data was used for the temperature-related indicators. The data was cleaned by eliminating outliers and inaccuracies resulting from administrative or transposition errors. After the cleaning, the data was used in further analysis during the simulation and downscaling stage.

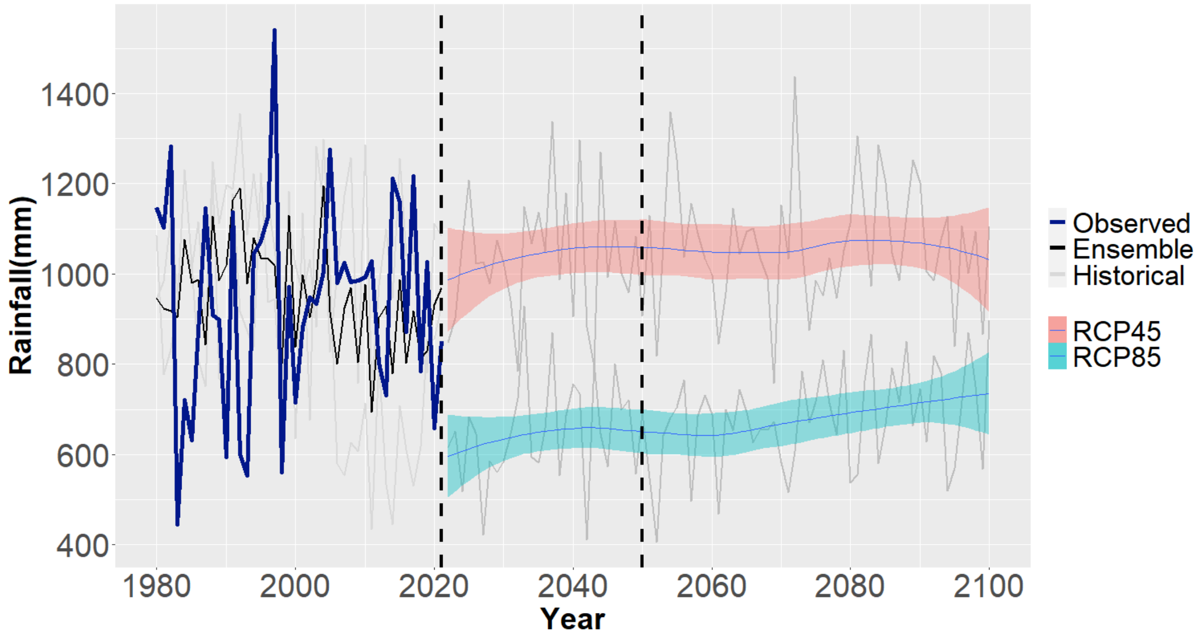
4.1.3 Simulation and Downscaling

The VA team downscaled daily rainfall and maximum and minimum temperature data using the quantile-quantile transformation method. The projections (corresponding to 10 different combinations of General Circulation Models and Regional Climate Models) were produced for the RCP4.5 and RCP8.5 emission scenarios. The downscaled data was transformed into annual averages of rainfall and temperatures and plotted.

4.1.4 Analysis of Downscaled Results

The results of the analysis of observed and projected data are summarized below. Projected rainfall over Cape Coast (Figure 29) will continue to experience a slight but not significant increase up to the mid-century, beyond which there could be a decline that lasts until the late 2070s. After that, annual rainfall over the area will most likely increase and then assume a new decreasing trend towards the end of the century. The rainfall pattern over Cape Coast and its environs will generally remain variable to the end of the century for both pathways. The consistent inter-annual and decadal variations will present themselves in terms of rainfall distribution, heavy events, onset, cessation, and dry spells. Years with low annual rainfall are likely to include long dry periods within the rainfall season. Wet years are likely to experience extreme events like floods and dry years are likely to experience drought. Mean annual rainfall will vary between 600 mm to 1,200 mm.

Figure 29. Projected rainfall over Cape Coast



The temperature during the day and night assumes an increasing trend and will continue to rise until the end of the century. As a result, the nighttime temperature will likely increase by 1°C by the middle of the century. The trend will continue, and it is projected to be about a 1.5°C increase from 2050 to the end of the century, as shown in Figures 30 and 31. The temperature during the day is expected to increase by 1°C by the middle of the century.

Figure 30. Projected annual minimum temperature over Cape Coast

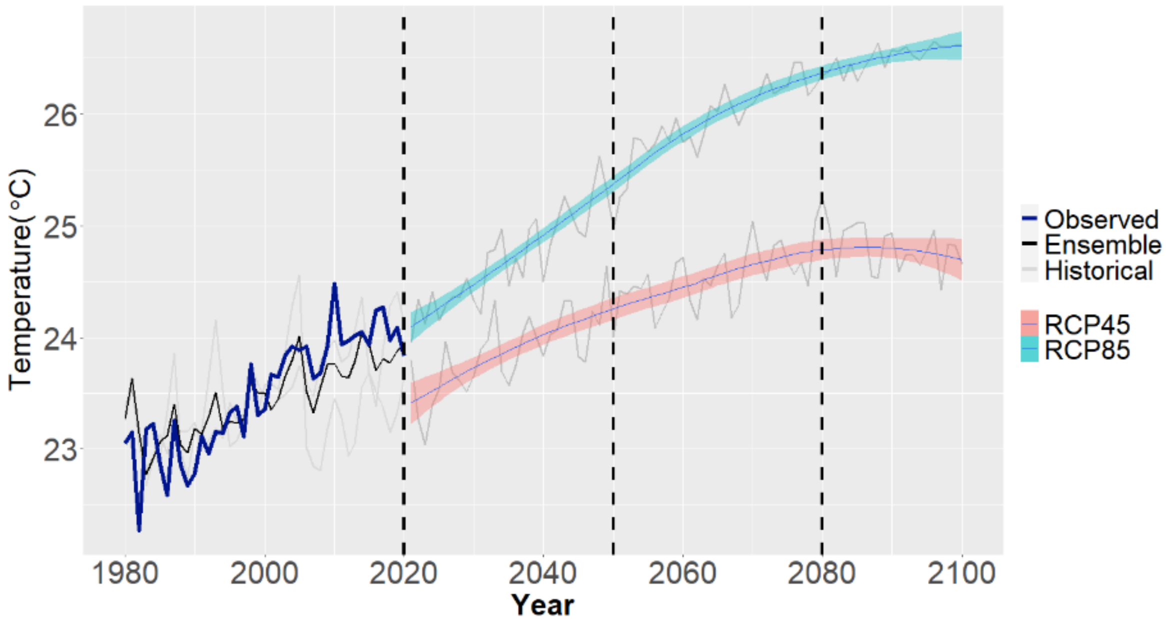
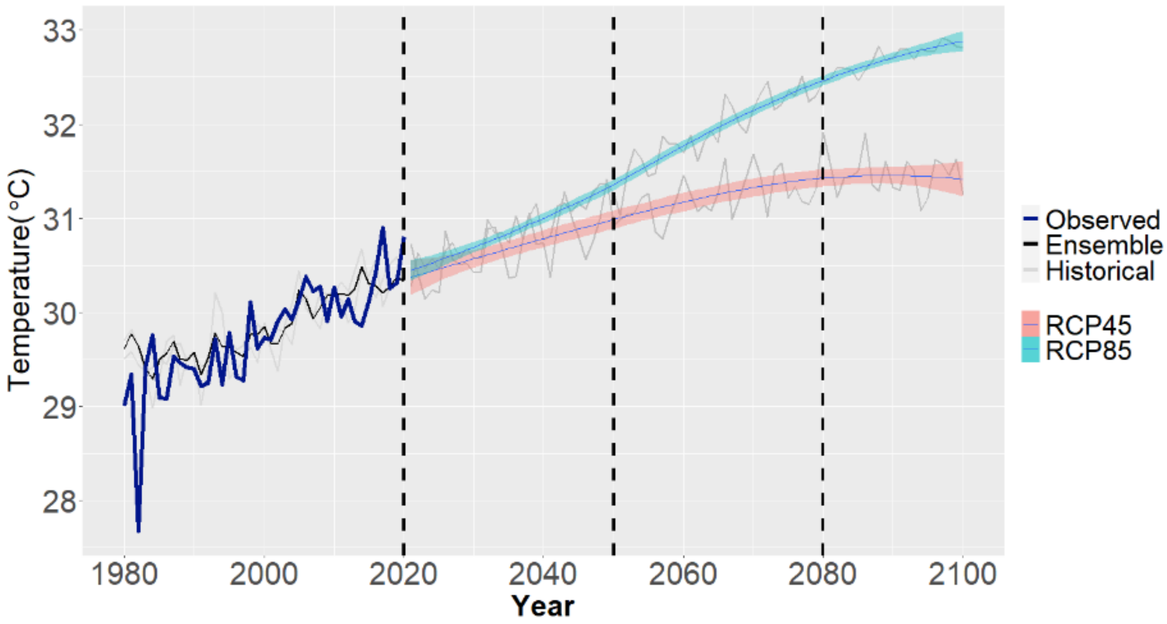


Figure 31. Projected annual maximum temperature over Cape Coast



The temperature during the day will further increase towards the end of the century. It is projected that the temperature will increase by 1°C from 2050 to 2100. As a result, the mean annual daytime temperature is projected to reach 32°C by the end of the century.

The increase in night temperature seems to be at a higher rate than daytime temperature, as shown in Figures 30 and 31. This means that the temperature at night will likely continue to be warm while cold nights will continue to reduce. Likewise, cold days will continue to decrease while warm days will rise.

4.1.5 Summary of Climate Change Projections

Rainfall over Cape Coast will remain variable at decadal and annual time step through 2050. The slight increase experienced in the 2020s may continue to mid-century, although it is not significant. There will be intermittent dry and wet years over Cape Coast because of rainfall variability. Some years may have an early onset of the rainy season, while others may experience delays. Some years are likely to have prolonged dry spells, particularly during years with low rainfall. Average daytime and nighttime temperatures are likely to rise steadily. Cold days and nights will likely decline, while warm nights and days will continue to rise over Cape Coast.

4.1.6 Expected Climate Change Impacts and Risks

The projected climate changes are expected to have various impacts on the Cape Coast Metropolis. These impacts and risks were identified through a literature review, stakeholder workshop, and expert opinion and are summarized below:

- There is the potential of flooding in some places for wet years. Landslide-prone areas in the metropolis are projected to experience some of the devastating impacts from climate hazards such as floods and rainstorms.
- Floods may become recurring events, particularly in low-lying areas along the coast. The risk of urban flooding is classified as high for the metropolis. This means that potentially damaging and life-threatening urban floods are expected to occur at least once in the next 10 years.
- Sea level rise is projected to exacerbate shoreline recession, particularly on sandy shores, inundating low-lying coastal areas and threatening some of the CCMA's castles and other coastal landmarks (GFDRR, 2022). Although a large proportion of the coastal area is walled, not all of it is, raising the question of whether the wall can shield stronger tides and higher sea levels in the near to distant future. This has serious implications for infrastructure, including beach resorts, homes, and roads along the coast. Impacts may result in damage to properties, loss of investments, and loss of livelihoods and employment for many women and youth. Impacts in CCMA will also have broader negative impacts for the tourism sector in Ghana, given the district's broad appeal to visitors to Ghana.
- In terms of transportation, some of the major roads connecting the Greater Accra region to the Western regions lie along the shores of the Cape Coast Metropolitan Assembly. Expected long-term implications of sea level rise and coastal inundation for this infrastructure includes but are not limited to direct impacts on transport infrastructure and operations, network and mobility effects, increased accident frequency and severity, negative changes in passenger travel patterns (i.e., travel behaviour), and other indirect socio-economic impacts.
- Water scarcity is a potential threat because of high evapotranspiration emanating from increasing temperatures, particularly during the dry season. Droughts, higher evapotranspiration rates resulting from higher temperatures, and saltwater infiltration of alternative waters sources via coastal flooding and sea level rise will compound and exacerbate the current water crisis. Combined with an increased demand for domestic and industrial water use with a growing population, the metropolis is expected to face more frequent and more intense water crises.
- Any shortage of water will affect domestic water uses. People with no money or means to afford quality water may have to rely on poor-quality and unsafe water sources. Water availability and quality have significant implications for sanitation and health, and contamination could bring different health challenges.
- Increasing temperatures compounded by high levels of humidity along the coast will negatively impact the health of the people. Diseases that thrive at high temperatures may increase or emerge in the municipality.

- Various ecosystems (forests, wetlands, mangroves, lagoons, etc.) will be stressed because of rising temperatures. Widespread deforestation in the municipality will worsen future temperature and rainfall in the municipality in a negative way, such as increasing daily temperatures and heatwaves, which may cause human health problems.
- Higher temperatures, prolonged dry spells, and erratic rainfall patterns can affect agricultural yields and productivity, and will impact the livelihoods of the people, particularly those engaged in agriculture. Farms close to the sea stand the chance of being inundated by storms, erosion, and saltwater.

The risk and uncertainty of fishing will increase, with fluctuations in fish and wild stock distributions and reductions in the duration of fishing seasons. There is an associated risk of high fish spoilage and mortality.

5. Policy Implications of the Vulnerability Assessment Results and Recommendations

5.1 Climate Response Scenarios

The results of the analysis of prevailing and projected climate change (Sections 3.1 and 4.1) highlight the need to implement measures to build resilience to the identified vulnerabilities to limit current and future climate change impacts. Based on the VA results and the draft Cape Coast Medium-Term Development Plan (MTDP) (2022-2025) the following scenarios were created as well as recommendations for adaptation options to consider in building resilience.

Table 11. Climate response scenarios for Cape Coast Municipal Assembly

Scenario	Required response and impact
A: Business as usual	**Response:** Authorities and communities do not recognize the urgent need to address current and future climate change impacts and vulnerabilities; or do recognize the need but take no action. **Impact:** Climate change will increasingly affect people's life, livelihoods, health, and safety until 2050 and beyond; current socio–economic and environmental vulnerabilities will increase; development will be impeded.
B: Climate change resilience is built to maintain current living standards by 2050	**Response:** The Cape Coast Municipality recognizes the urgent need to address climate change and implement some district-level projects as part of fulfilling its responsibilities to improve the well-being of its citizenry, ranging from agricultural-related supports to the provision of health and infrastructure projects. **Impact:** This scenario will enhance current adaptive capacity and reduce the impacts of current climate change. However, resilience might not be built enough to withstand future impacts.
C: Climate change resilience is built that enables economic and social development, despite changes in climate by 2050	**Response:** The Cape Coast Municipality prioritizes climate change action and considers it as a development issue by mainstreaming adaptation and low-carbon economy issues into district development policies, programs, and projects in a manner that promotes gender inclusivity. **Impact:** The Cape Coast Municipality will attain climate-compatible development by harnessing the triple synergies of socioeconomic development, climate resilient development, and low-carbon development. This will reduce socioeconomic loss and damage resulting from the impacts of climate change beyond 2050.

5.2 Recommended Adaptation Options

In line with the key findings from this vulnerability assessment, we propose the following broad set of adaptation options for communities and households in the Cape Coast Metropolitan Assembly. These proposed adaptation options were arrived at through experts' input and a review of pertinent literature. We focus these proposals on the prioritized key areas of vulnerability and the most appropriate adaptation options to address these vulnerabilities.

- **Protection of properties and infrastructure:** Destruction of and damage to properties and infrastructure is expected to result from rainfall-driven floods and coastal erosion from sea level rise and storm surges. This is due to their high exposure and sensitivity. New infrastructure (private and public) should be planned, designed, and implemented to account for current and future climatic changes. The current hard seawall defense extends along some of the communities; however, respondents indicated it does not offer complete protection against sea water intrusion and flooding. The Cape Coast Metropolitan Assembly will need to be mindful of the potential maladaptation effects of seawalls, and as recommended by the IPCC (2022), ensure they are integrated into a long-term adaptive plan. In metropolitan areas that are vulnerable to flood and erosion, traditional and grey engineering infrastructure such as seawalls and groynes could be constructed or retrofitted to address sea level rise as a short- and medium-term adaptation option.
- **Planting mangroves and incorporating nature-based solutions:** Nature-based solutions can be a greener and cheaper way to block storm surges and coastal erosion. Nature-based adaptation solutions, which have low uptake in Cape Coast, can help to address the needs of communities along the coast that are relatively more vulnerable to the impacts of climate change than those inland. The Cape Coast Metropolitan Assembly has been involved in tree planting and greening the metropolis as part of the implementation of its MTDP. The planting of mangroves along vulnerable coastal areas is a priority medium-term adaptation option.
- **Enforcing laws on coastal mining:** The vulnerability of the coastal area is largely due to coastal erosion which is exacerbated by human activities such as sand mining along the coast. Enforcement of laws prohibiting sand mining is critical in ensuring that such human activities do not worsen the erosion impacts of sea level rise and tidal waves.
- **Improving early warning systems and access to climate services:** Considering the higher flooding records and dependency of the agriculture sector on rainfall, early warning systems and access to climate services is imperative. This will help farmers and fisherfolk to cope with current and projected rainfall variabilities. The CARE Adaptation Learning Programme in East Mamprusi and Garu-Tempane Districts (C4Eco, 2017) yielded good results that can be replicated.
- **Enforcing building permits and building code:** Flooding levels have been very high in the metropolis, especially in the southern part, and have risen in recent years. Vulnerability to flooding is increased by building in waterways and flood-prone areas. The CCMA must therefore ensure that building permits are not awarded to people building in flood-prone areas. Also, buildings and infrastructure must incorporate and use materials that make them resilient to climate extreme events like floods.

- **Constructing drainage systems and regular distillation:** The lack of drainage systems or existing systems being clogged was identified as a major contributor to flooding in the metropolis. Choked drainage systems also have health implications such as breeding of mosquitoes and contamination of water, contributing to outbreaks of diseases such as cholera and malaria. Good drainage systems, proper disposal of waste, and efficient waste collection and management systems must be enforced in the metropolis.
- **Raising awareness through climate education and outreach programs:** Awareness of climate change and its associated impacts is low. The CCMA can integrate climate change awareness and education in ongoing and planned programs, such as public health campaigns, training of agricultural extension workers, and disaster risk reduction programmes.
- **Installing irrigation systems:** No farmers in CCMA use irrigation agriculture; the VA showed that the penetration of irrigation technology in the metropolis was 0%. The total reliance on rainfed agriculture is a recipe for disaster in the face of changing climate with rising temperature and high rainfall variability. The development of both traditional and modern irrigation infrastructure is required.

References

Acquah, H. D. (2011). Public awareness and quality of knowledge regarding climate change in Ghana: a logistic regression approach. *Journal of Sustainable Development in Africa, 13*(3), 146-157.

Agyapong, J. F. (2008). *Public perception on the degradation of freshwater bodies-A case study of the Fosu Lagoon in Cape Coast, Ghana*. Unpublished report submitted to the Department of Geography and Tourism, University of Cape Coast, Ghana

Akaba, S., & Akuamoah-Boateng, S. (2018). An evaluation of climate change effects on fishermen and adaption strategies in central region, Ghana. In *Climate Change Impacts and Adaptation Strategies for Coastal Communities* (pp. 133-147). Springer, Cham.

Antwi-Agyei, P., Dougill, A. J., Agyekum, T. P., & Stringer, L. C. (2018). Alignment between nationally determined contributions and the sustainable development goals for West Africa. *Climate Policy*, *18*(10), 1296-1312.

Appeaning, K.A. (2021). Ghana's Coastline, swallowed by the sea. *UNESCO Courier* 2021-1. https://en.unesco.org/courier/2021-1/ghanas-coastline-swallowed-sea

Asante, F. A., & Amuakwa-Mensah, F. (2014). Climate change and variability in Ghana: Stocktaking. *Climate, 3*(1), 78-101

Asare, K. and Klutse, N.A.B. (2023). *Present and future rainfall and temperature patterns of selected stations in Ghana*. Ghana Meteorological Agency.

Asare-Nuamah, P., & Botchway, E. (2019). Understanding climate variability and change: analysis of temperature and rainfall across agroecological zones in Ghana. *Heliyon, 5*(10), e02654.

Atanga, R. A., & Tankpa, V. (2021). Climate change, flood disaster risk and food security nexus in Northern Ghana. *Frontiers in Sustainable Food Systems, 5*, 706721.

CARE International. (2019). *Climate Vulnerability and Capacity Analysis Handbook Version 2.0.* [Daze, A., Ceinos, A, & Deering, K. (authors)]. CARE Climate Change and Resilience Platform. https://careclimatechange.org/cvca/

C4 Ecosolutions. (2017). *Impact assessment on climate information services for community-case adaptation to climate change: Ghana Country Report.* Nairobi: Adaptation Learning Programme, CARE International. https://careclimatechange.org/wp-content/uploads/2019/06/Ghana-Climate-Services-Country-Report.pdf

CCMA (Cape Coast Metropolitan Assembly). (2020). *MTDP 2018–2020 for Cape Coast Metropolitan Assembly (CCMA)*. Prepared by Metropolitan Planning Unit with support from other Decentralized Departments.

CCMA (Cape Coast Metropolitan Assembly). (2017). *2018-2021 Medium Term Development Plan (MTDP). An Agenda For Jobs: Creating Prosperity And Equal Opportunity For All 2018-2021*. https://ndpc.gov.gh/media/Cape_Coast.pdf

Dadson, I. Y., Owusu, A. B., & Adams, O. (2016). Analysis of shoreline change along Cape Coast-Sekondi coast, Ghana. *Geography Journal,* 2016.

Danso, S. Y., Ma, Y., Adjakloe, Y. D. A., & Addo, I. Y. (2020). Application of an Index-Based Approach in Geospatial Techniques for the Mapping of Flood Hazard Areas: A Case of Cape Coast Metropolis in Ghana. *Water, 12*(12), 3483.

Demetriades, J., & Esplen, E. (2010). The gender dimensions of poverty and climate change adaptation. *Social dimensions of climate change: Equity and vulnerability in a warming world*. 133-143

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). (2014). Framework for climate change vulnerability assessment. Retrieved from https://www.weadapt.org/sites/weadapt.org/files/legacy-new/knowledge-base/files/1522/5476022698f9agiz2014-1733en-framework-climate-change.pdf

Environmental Protection Agency. (2018). *Ghana's National Adaptation Plan Framework.* EPA in partnership with NDPC and Ministry of Finance. NAP Global Network. https://napglobalnetwork.org/wp-content/uploads/2020/06/napgn-en-2020-Ghana's-Adaptation-Strategy-and-Action-Plan-for-the-Infrastructure-Sector.pdf

Environmental Protection Agency. (2020). *Integrating Gender Consideration into Ghana's National Adaptation Plan Process*. NAP Global Network. https://napglobalnetwork.org/wp-content/uploads/2020/12/napgn-en-2020-integrating-gender-considerations-into-ghanas-nap-process.pdf

Environmental Protection Agency (EPA) (2021). *Ghana's Adaptation Communication to the United Nations Framework Convention on Climate Change*. https://unfccc.int/sites/default/files/resource/Ghana_AdCom%20to%20the%20UNFCCC_November%202021_Final%20with%20foreword.pdf

The Global Facility for Disaster Reduction and Recovery (GFDRR). (2022). *ThinkHazard!* https://www.thinkhazard.org/en/

Ghana Statistical Services. (2014). *2010 Population and Housing Census. District Analytical Report. Cape Coast Municipality*. Ghana Statistical Service, Accra.

Ghana Statistical Service. (2022). *Ghana 2021 Housing and Population Census. Population of Regions and Districts. General Report Volume 3A*. Ghana Statistical Service, Accra.

Hashmiu, I., Agbenyega, O., & Dawoe, E. (2022). Cash crops and food security: evidence from small holder cocoa and cashew farmers in Ghana. *Agriculture & Food Security 11:12*, page 7 of 21.

IPCC. (2022). Annex II: Glossary [Möller, V., R. van Diemen, J.B.R. Matthews, C. Méndez, S. Semenov, J.S. Fuglestvedt, A. Reisinger (eds.)]. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge and New York: Cambridge University Press, pp. 2897–2930, https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Annex-II.pdf

IPCC. (2022). Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge and New York: Cambridge University Press, pp. 3–33, doi:10.1017/9781009325844.001.

Jonah, F. E., Adjei-Boateng, D., Agbo, N. W., Mensah, E. A., & Edziyie, R. E. (2015). Assessment of sand and stone mining along the coastline of Cape Coast, Ghana. *Annals of GIS*, 21(3), 223-231.

Krause, D., Schwab, M., & Birkmann, J. (2015). An Actor-Oriented and Context-Specific Framework for Evaluating Climate Change Adaptation. *New Directions for Evaluation*, *2015*(147), 37-48.

Klutse, N. A. B., Owusu, K., Adukpo, D. C., Nkrumah, F., & Quagraine, K. (2013). *Farmer's observation on climate change impacts on maize (Zea mays) production in a selected agro ecological zone in Ghana*.

Kwadzo, M., Miyittah, M. K., Dovie, D. B., Kosivi, R. K., & Owusu, R. (2022). Pollution and climate change impacts on livelihood outcomes of lagoon fishermen in Central Region, Ghana. *Current Research in Environmental Sustainability, 4,* 100137. https://doi.org/10.1016/j.crsust.2022.100137

LDC Expert Group. (2012). *National Adaptation Plans: Technical guidelines for the national adaptation plan process.* United Nations Framework Convention on Climate Change (UNFCCC). https://unfccc.int/files/adaptation/cancun_adaptation_framework/national_adaptation_plans/application/pdf/naptechguidelines_eng_low_res.pdf

Logah, F. Y., Obuobie, E., Ofori, D., & Kankam-Yeboah, K. (2013). *Analysis of rainfall variability in Ghana*.

Mensimah, E., Abrefah, R. G., Ampomah-Amoako, E., & Agbemava, S. E. (2011). *Determination of sea-level rise in cape coast, Ghana using extreme value theory.*

Ministry of Environment, Science, Technology and Innovation. (2013). *Ghana National Climate Change Policy*. Accra: Government of Ghana. https://archive.un-page.org/files/public/ghanaclimatechangepolicy.pdf

Moe, C. L., & Rheingans, R. D. (2006). Global challenges in water, sanitation and health. *Journal of water and health, 4(*S1), 41-57.

Ministry of Food and Agriculture. (2016). *Agriculture in Ghana facts and figures (2015).* Accra: Government of Ghana.

Owusu-Sekyere, J. D., Alhassan, M., & Nyarko, B. K. (2011). *Assessment of climate shift and crop yields in the Cape Coast area in the Central Region of Ghana*.

Resurrección, B. P., Bee, B. A., Dankelman, I., Park, C. M. Y., Haldar, M., & McMullen, C. P. (2019). *Gender-transformative climate change adaptation: advancing social equity.* Paper commissioned by the Global Commission on Adaptation (GCA).

Stanturf, J. A., Warren, M. L., Charnley, S., Polasky, S. C., Goodrick, S. L., Armah, F., & Nyako, Y. A. (2011). *Ghana climate change vulnerability and adaptation assessment*. Washington: United States Agency for International Development.

Vermeer, M., & Rahmstorf, S. (2009). Global sea level linked to global temperature. *Proceedings of the National Academy of Sciences, 106*(51), 21527-21532.

Xu, H., Xu, K., Lian, J., & Ma, C. (2019). Compound effects of rainfall and storm tides on coastal flooding risk. *Stochastic Environmental Research and Risk Assessment, 33*(7), 1249-1261.

Appendix 1. Research Questionnaire for Vulnerability Assessment at the Cape Coast Municipality

Date: ______________________	Operational area: ______________________	Community/Town/Village: ______________________
Latitude: ______________________	Longitude: ______________________	
Questionnaire ID: ______________________	Enumerator: ______________________	

A. Respondents Profile

A1. Name of household head: _________________________ (Is the respondent same as household head? [YES] [NO]) Contact phone No: ___________________

A2. Gender of household head: 1=Female 2=Male

B. Household Composition

B1. How many people in the household are Male [_________]

B2. How many people in the household are Female [_________]

B3. How many people in the household are above 60 years [_________]

B4. How many people in the household are below 18 years [_________]

B5. How many people in the household have any form disability [_________]

B6. Highest level of formal education of members of the household (enter number in bracket)

- Basic (Primary/Middle/JHS) = [____________]
- Secondary (Secondary/vocational) = [____________]
- Tertiary (Training college/Polytechnic/University) = [______________]

C. Livelihood strategies

C1. Primary occupation of the household (select a sector most applicable to your household)
Agriculture (Crop = [__] Livestock & Poultry = [__] Fishing = [__])
Forestry (Ecosystems and Biodiversity) = [__] Water = [__]
Human Health and Sanitation = [__] Infrastructure (Roads and Buildings, Transport) = [__]
Service Sector (Finance, Trade and Industry, Tourism) = [__]

C2. Are you engaged in other income generating activities? [__] 1 = Yes 2 = No

C3. If yes, which other income generating activities are you engaged in? Agriculture (Crop = [__] Livestock & Poultry = [__] Fishing = [__]) Forestry (Ecosystems and Biodiversity) = [__] Water = [__] Human Health and Sanitation = [__] Infrastructure (Roads and Buildings, Transport) = [__] Service Sector (Finance, Trade and Industry, Tourism) = [__]

C4. Does any member of your household work outside this community? [__] 1 = Yes 2 = No

C5. How many people of the household are unemployed? [__]

D. Assessment General Climate Exposure

D1. How many extreme drought/dry spells have occurred in this community since 2012 (10 years ago) [__]

D2. How many extreme flood(s) have occurred in this community since 2012 (10 years ago). [__]

E. Assessment of General Sensitivity

E1. Do you receive information on weather forecasts for your livelihood activities or in the community? [__] 1 = Yes 2 = No

E2. If yes, what are your main sources of information? [__]/ [__]/ [__]/ [__]/ [__]/ [__]/ [__]
1 = GMet 2 = Newspaper/ Television/ Radio/Phone alert 3 = Friends/family
4 = Agricultural Extension Agent (AEA) 5 = Personal Observation/Indigenous knowledge
6 = Community radio 7 = Other (*Specify*)____

E3. How often do you access this information for your activities [__]
1 = Very often 2 = often 3 = Sometimes 4 = Less often 5 = Not at all

E4. Do you have access to good road network? [__] 1 = Yes 2 = No

E5. What material is your house made of? [__]
1 = Cement 2 = Bricks 3 = Mud 4 = Cement/Brick/Mud 5 = Other (specify)

E6. Is your house in a flood prone area? [__] 1 = Yes 2 = No

E7. What is the level of proximity of your house and the Odo River? [__]
Very close = 5 close = 4 somewhat low = 3 far = 2 very far = 1

E7. Do you have access to internet connectivity? [__] 1 = Yes 2 = No

E8. Do you have a health facility in this community? [__] 1 = Yes 2 = No

E9. How long (minutes) does it take to get to a health facility? ____________minutes

E10. Are you on the National Health Insurance Scheme? [__] 1 = Yes 2 = No

E11. Do you have access to ready market in this community? [__] 1 = Yes 2 = No

E12. If yes, how long (minutes) do you have to travel to the market? ________minutes

E13. Has water availability been a problem? [__] 1 = Yes 2 = No

E14. How long (minutes) does it take to get to the water source? _________Minutes

Assessment of General Adaptive Capacity

F. Social network

F1. Are you a member of any social organisation? [__] 1 = Yes 2 = No

F2. Are you aware of any active gender related organisations and associations in the community? [__] 1 = Yes 2 = No

F3. Does your household benefit from any government social interventions (e.g., LEAP, subsidy, land tenure arrangement) in the [__] 1 = Yes 2 = No

F4. Did you received support from any organisations/institutions (Research and Development Institution, governmental organisation, non-governmental organization) to coping with climate-related issues? [__] 1 = Yes 2 = No

G. Availability and access to credit

G1. Do you have access to credit for your economic activities? [__] 1 = Yes 2 = No

G2. Has your household received remittances/assistance from family or friends within the past 12 months? [__] 1 = Yes 2 = No

G3. Do you have access to any subsidies ? [__] 1 = Yes 2 = No

Sector Specific Indicators

H. Agriculture Sector

H1. What is the total size of your farm? (Average since 5 years ago): ______________ acres

H3. What is the major crop you cultivate? _______________

H4. Do you grow other crops? [__] 1 = Yes 2 = No

H5. Do you have livestock/poultry? [__] 1 = Yes 2 = No

H6. Do you have irrigation system on your farm? [__] 1 = Yes 2 = No

H7. If yes, what percentage of your farm land is under irrigation? ________________

H8. Do you have access to water for dry season farming? [__] 1 = Yes 2 = No

H9. Are you a member of a Farmer Based Association (FBO)? [__] 1 = Yes 2 = No

H10. Do you have access to/contact with Agricultural Extension Agents (AEA) [__] 1 = Yes 2 = No

H11. If yes how often? [ ] 1) Weekly 2) Monthly 3) Quarterly 4) Every six months 5) Annually

H12. Do you get information on improved production methods and systems?
[__] 1 = Yes 2 = No

H13. Is your farm in a flood prone area? [__] 1 = Yes 2 = No

H14. What is the level of proximity between your farm (fish, poultry, livestock) and the Odo River?
[__] Very close = 5 close = 4 somewhat low = 3 far = 2 very far = 1

H15. What percentage of your total output do you lose as a result of post-harvest losses?
____

H16. Do you know about agricultural insurance? [__] 1 = Yes 2 = No

H17. If yes, have you subscribed to any insurance product? [__] 1 = Yes 2 = No

I. Health Sector

I1. What is the level of prevalence of climate-sensitive diseases in the community [__]
Very low = 1 low = 2 somewhat low = 3 high = 4 very high = 5
(*e.g. Cholera; Typhoid, Bacillary dysentery, Infectious, hepatitis, Giardiasis, Scabies, Lice, Trachoma, Dysenteries, Ascariasis, schistosomiasis, Bilharziasis, Threadworm, Yellow fever, Dengue fever, and Malaria*)

I2. Do you have access to safe sanitation facilities? [__] 1 = Yes 2 = No

I3. Do you have access to health care? [__] 1 = Yes 2 = No

I4. How many health facilities do you have in this community/town? ______________

I5. How many public toilet facilities do you have in this community/town _________

I6. Have you had any training/sensitization on climate related diseases like malnutrition and diarrhea, respiratory diseases, waterborne diseases etc. [__] 1 = Yes 2 = No

J. Water Sector

J1. What is the Average cost of water per month? _______________ (GHS)

J2. What is the level of NGOs and CSOs activity (Collective action - e.g., NGOs and CSOs investing in water) in the community [__]
Very low = 5 low = 4 somewhat low = 3 high = 2 very high = 1

J3. Do you have access to potable water? [__] 1 = Yes 2 = No

J6. Are you aware of any water management regulations (conservation, watershed management) protects our water resources [__] 1 = Yes 2 = No

J7. If yes, what is the level of enforcement of water management policy or regulations [__]
(Scale of 1 - 5) 1 = strict 2 = rather strict 3 = rather weak 4 = weak 5 = no enforcement

K. Forestry Sector

K1. What is the frequency of forest pest and disease in this community since 2012 (10 years ago)
[__] Very low = 1 low = 2 somewhat low = 3 high = 4 very high = 5

K2. What is the frequency of forest fire in this community since 2012 (10 years ago) [__]
Very low = 1 low = 2 somewhat low = 3 high = 4 very high = 5

K3. What is the level of forest cover in this area [__]
Very low = 1 low = 2 somewhat low = 3 high = 4 very high = 5

K5. What is your level accessibility to biodiversity [__]
Very low = 1 low = 2 somewhat low = 3 high = 4 very high = 5

K6. Do you obtain income from engagement with the forestry? [__] 1 = Yes 2 = No

K7. What average distance (km) do you have to travel from the community to the forest?
_______km

K8. Are you aware of any government policies, regulations and laws on land management and regulations (e.g. insect control policy, wildfire control policy) [__] 1 = Yes 2 = No

K9. If yes, what is the level of enforcement [__] (Scale of 1 - 5)
1 = strict 2 = rather strict 3 = rather weak 4 = weak 5 = no enforcement

L. Service Sector

L1. Is your business in a flood prone area? [__] 1 = Yes 2 = No

L2. Do you depend on agriculture for raw materials in your business activities? [__]
1 = Yes 2 = No

L3. Have you insured your business? [__] 1 = Yes 2 = No

L4. Are you a member of any business cooperative? [__] 1 = Yes 2 = No

L5. Are you aware of any government intervention, strict enforcement of regulations and laws (e.g., education policy, credit for businesses) [__] 1 = Yes 2 = No

L6. If yes, what is the level of enforcement [__] (Scale of 1 - 5)
1 = strict 2 = rather strict 3 = rather weak 4 = weak 5 = no enforcement

M. Infrastructure Sector

L1. Have you insured any of your properties (buildings, cars, etc.)? [__] 1 = Yes 2 = No

L3. Are you aware of any climate driven risk based on past threats? [__] 1 = Yes 2 = No

L4. Are you aware of any government policies, regulations and laws regarding building permit [__] 1 = Yes 2 = No

L5. If yes, what is the level of enforcement [__] (Scale of 1 - 5)
1 = strict 2 = rather strict 3 = rather weak 4 = weak 5 = no enforcement

The end: Thank you for your cooperation.

Appendix 2. Stakeholder Mapping

Table 12. Relevant stakeholders, their key roles, responsibilities, and expected outcomes from the vulnerability assessment

W = Workshop; I = Interview; S = Survey; ** = has been contacted and engaged in the first workshop.

Name of institution	Representative	Role/responsibility	Mode of engagement*	Expected outcome from the VA process
PUBLIC/GOVENMENT SECTOR				
National Disaster Management Organisation (NADMO)**	NADMO Director	• Coordinates adaptation planning and mainstreaming at the district level. • Promotes disaster risk reduction and climate change risk management. • Contributes to effective social mobilization for disaster prevention and poverty reduction. • Provides disaster relief and assistance in moments of disasters to the district.	W; I	• Reduction in vulnerability related to climate change and disasters. • Adaptation planning and mainstreaming at the district level will be well coordinated.
National Development Planning Commission (NDPC)	NDPC Regional Officer	• Formulates national development policy frameworks and ensure that the strategies, including consequential policies and programmes, are effectively carried out. • Ensures effective coordination of the preparation, implementation, monitoring and evaluation of national policies, projects, and plans in the district.	W; I	• Programmes/projects of the district disaster plans will be incorporated into their adaptation plans. • Full integration of climate change into economic, environmental, and social decision making of the district.
Ghana Meteorological Agency (GMET)**	GMET Officer	• Provides efficient and reliable meteorological information by collecting, processing, archiving, analyzing and dissemination of findings/meteorological information.	W; I	• Access to district-level climate and weather data.

Name of institution	Representative	Role/responsibility	Mode of engagement*	Expected outcome from the VA process
Environmental Protection Agency (EPA)**	EPA Regional Director	• Acts as an environmental check on pollution and sanitation, environmental protection, and climate action. Also serves as the lead on the NAP process.	W; I	• Support strategic and holistic vulnerability report that will be developed for key sectors in the municipality. • Sectoral priorities and local adaptation priorities will be identified to support the NAP process.
Municipal Planning Unit**	Municipal Planning Officer	• Facilitates and coordinates the preparation of development plans of the District. • Leads monitoring and evaluation activities of the District. • Coordinates implementation of development programmes, projects and activities in the District.	W; I	• Facilitates the effective and coordinated mainstreaming of climate change adaptation. • They will be empowered to integrate climate change adaptation into their development plans. • Their capacities will be improved to undertake monitoring and evaluation (M&E) of climate change adaptation. • Development partners, the private sector and civil society organizations will be well engaged through the Assembly for adaptation financing and outreach.
Forestry Commission**	Forestry Commission Officer	• Regulates the utilisation of forest and wildlife resources, the conservation and management of those resources and the co-ordination of policies related to them.	W; I	• Technical support.
Ministry of Food and Agriculture (MoFA)**	MoFA Municipal Director	• Facilitates technology transfer.	W; I	• Capacity of extension staff will be built at regional and district levels to be able to appropriately mainstream climate change in their extension messaging.
	Agricultural Extension Agent	• Educates residents on concept of climate change, measures to adopt to mitigate and adapt to its effect and other civic matters.	W; I; S	

Name of institution	Representative	Role/responsibility	Mode of engagement*	Expected outcome from the VA process
National Commission on Civic Education	Officer	• Educates residents on concept of climate change, measures to adopt to mitigate and adapt to its effect and other civic matters.	W; I	• Increased awareness raising and climate change education.
Regional Coordinating Council	Director	• Conducts monitoring and evaluating District Climate Change Adaptation Strategy. • Coordinates from a regional level by formulating and carrying out M&E of all plans and programmes of Ministries, Departments and Agencies.	W; I	• Strongly liaise with monitoring staff of National Climate Change Committee to remove bottlenecks in the implementation of Municipal programmes.
Gender Department**	Gender Officer	• Promotes the implementation of activities that address the rights of women, children, and youth.	W; I	• A strategic focus will be given to them for priority gender vulnerabilities to be addressed.
Ghana Health Service**	Municipal Environmental Health Officer	• Supports the integration of climate change into the management of priority health risks in the municipality in harmony with national health development priorities.	W; I	• A strategic focus will be given to them for priority health vulnerabilities to be addressed.
UNFCCC Focal Point	UNFCCC Focal Person	• Coordinates UNFCCC-led policies and programs • Supports the global response to the threat of climate change	W; I	
Ministry of Finance	Representative	• Supports identification and categorization of multi-scalar assessment of vulnerability and adaptation options. • Oversees, coordinates, and manages financing and support in natural resources and climate change activities.	W; I	• Budget support for vulnerability assessment and implementation of adaptation strategies.

Name of institution	Representative	Role/responsibility	Mode of engagement*	Expected outcome from the VA process
RESEARCH/ACADEMIA				
Department of Geography and Regional Planning	Representative	• Climate change for education, research, and capacity building. In relation to climate change, the academia and research institutions are expected to engage in studies and projects where they explore solutions to improve climate vulnerability of the municipality.	W; I	• To provide technical support and contribute research findings in development of the VA and adaptation planning for the Cape Coast Municipal Assembly. • Increased climate change education and capacity building.
DEVELOPMENT PARTNERS				
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	Representative	• Resource mobilization, capacity development and technology development and transfer for current and future adaptation action.	W; I	• Financial and technical support for successful adaptation actions.
International Institute for Sustainable Development			W; I	
United Nations Development Programme			W; I	
CIDA	Representative		W; I	
Urban Development Grant (Urban Development Grant)	Representative		W; I	
UNICEF	Representative		W; I	

Name of institution	Representative	Role/responsibility	Mode of engagement*	Expected outcome from the VA process
NGOs/CSOs				
Green Africa Youth Organization	Representative	• Planning, advocacy, education, and awareness raising, evidence-based research as well as monitoring and evaluation of adaptation efforts. • Initiate and fund projects related to climate change to improve mitigation and adaptation of their targets.	W; I	• Effective monitoring, communicating information, and capacity building.
VULNERABLE GROUPS				
Women**	Representative	• Participate in the design and implementation of activities under the NAP.	W; I; S	• Increased awareness of the public and policy makers on the impacts of climate change on the vulnerable groups, especially women, youth, and people with disabilities, and the roles that each can play in the development and implementation of climate change mitigation and adaptation strategies. • Stronger advocacy, public engagements, awareness creation and other technical support • Identification of the greatest risks to these groups from climate change impacts. • Cooperation for effective implementation of climate adaptation practices. • The voice of these groups will be heard and included in climate change negotiations.
People with disability**	Representative		W; I; S	

Name of institution	Representative	Role/responsibility	Mode of engagement*	Expected outcome from the VA process
PRIVATE SECTOR				
Farm input dealers	Representative	• Promote adoption of improved and resilient technological farm inputs.	W; I; S	• Improve access to information through their communication networks.
Financial institutions	Commercial banks	• Provide access to credit facilities.		• Access to financial and technical support.
	Savings and loans			
TRADITIONAL AUTHORITIES				
Traditional councils**	Representative	• Community mobilization and granting of permission to enter a community and to engage the community members.	W; I	• Identification of the greatest risks to them from climate change impacts. • Cooperation for effective implementation of climate adaptation practices.
OTHER RELEVANT GROUPS				
Farmer-based organizations**	Representatives	• Provide opportunities for farmers to benefit from economies of scale, better bargaining power, and a stronger voice in policy development.	W; I; S	• Identification of the greatest risks to them from climate change impacts. • Effective implementation of climate adaptation practices. • Champion community awareness creation of climate change. • Advocacy, public engagements.
Faith-based organizations	Representatives	• Community mobilization and advocacy	W; I; S	
Opinion leaders	Representatives		W; I; S	
Assembly Members**	Representatives		W; I	
Town/Area councils and unit committees**			W; I; S	• To be able to prepare their own climate change adaptation plans and submit to the District Assemblies.

Name of institution	Representative	Role/responsibility	Mode of engagement*	Expected outcome from the VA process
MEDIA				
Kingdom FM	Representative	• Advocacy and communication of findings. • Engage the community by sensitizing and educating on measures to adopt to mitigate and adapt to the issues of climate change.	W; I	• Increased community awareness creation of climate change. • Advocacy, public engagement.

Appendix 3. Organizations Represented at the Stakeholder Workshops

1. Ghana National Fire Service
2. Ghana Education Service
3. National Youth Authority
4. Environmental Protection Agency
5. University of Cape Coast
6. Cape Coast Technical University
7. National Museums and Monument Board
8. Cape Coast Municipal Assembly
9. Departments of Births and Deaths
10. Forestry Commission
11. National Disaster Management Organization
12. Ghana Meteorological Agency
13. Ministry of Food and Agriculture
14. Ghana Water Company Limited
15. Department of Parks and Gardens
16. Statistical Services Department
17. University of Ghana
18. Cape Coast Technical University
19. Ghana Federation of Disabilities
20. Cape Coast FM
21. ATL FM

CAPE COAST METROPOLITAN ASSEMBLY
UNITY AND DEVELOPMENT

FREEDOM AND JUSTICE