Climate Change Vulnerability Assessments for Bekwai Municipal Assembly

March 2024 | Final Report

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Photo credit: BMA

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Foreword

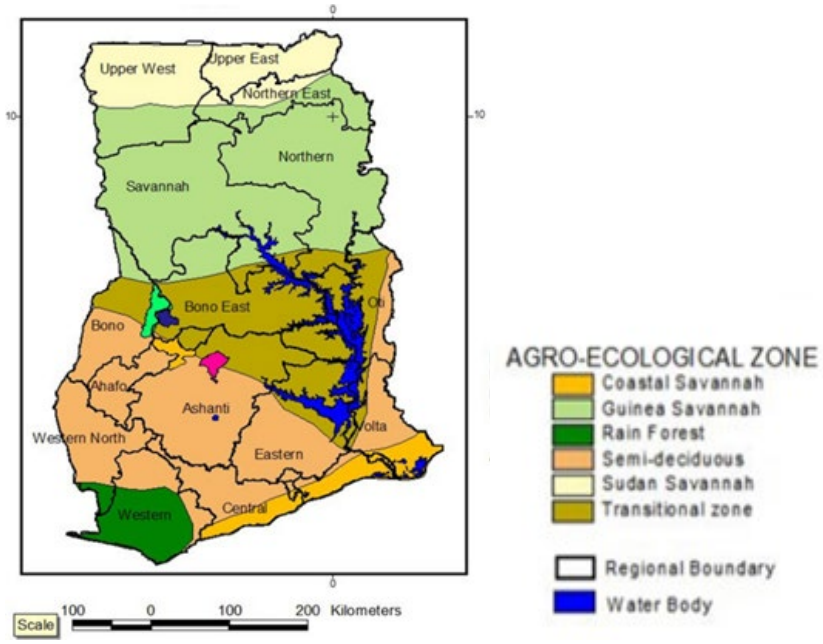
The Government of Ghana prepared six district-level climate vulnerability assessments, each for a municipal assembly located in one of the country's agroecological zones as part of the National Adaptation Planning (NAP) process. These vulnerability assessments aimed to improve the national and subnational 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 Bekwai Municipality in the Ashanti Region of Ghana and is representative of the Semi-Deciduous Forest agro-ecological zone (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.

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Abbreviations

AEA	Agricultural Extension Agent
BMA	Bekwai Municipal Assembly
CARE	Cooperative for Assistance and Relief Everywhere
CCRA	Climate Change Risk Assessment
CHPS	Community Health-Based Planning Services
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station
CMIP3	Coupled Model Intercomparison Project Phase 3
CMIP5	Coupled Model Intercomparison Project Phase 5
CORDEX	Coordinated Regional Downscaling Experiment
CSO	Civil Society Organization
CVCA	Climate Vulnerability and Capacity Analysis
DEM	Digital Elevation Model
EPA	Environmental Protection Agency
FAW	Fall Army Worm
GAYO	Green Africa Youth Organization
GCF	Green Climate Fund
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (German Development Cooperation)
GMet	Ghana Meteorological Agency
GSS	Ghana Statistical Services
IPCC	Intergovernmental Panel on Climate Change
LDC	Least Developed Country
MMDAs	Metropolitan, Municipal, and District Assemblies
MoFA	Ministry of Food and Agriculture
MPCU	Municipal Planning Coordinating Unit
MTDP	Mid-Term Development Plan
NADMO	National Disaster Management Organization
NAP	National Adaptation Planning
NCCE	National Commission on Civic Education
NDPC	National Development Planning Commission
NGO	Non-Governmental Organization
PWD	Person With Disability
R/C	Roman Catholic

RCC	Regional Coordinating Council
RTI	Respiratory Tract Infections
SAR	Synthetic Aperture Radar
SDA	Seventh Day Adventist
SHS	Senior High School
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VA	Vulnerability Assessment
WCRP	World Climate Research Programme
WRF	Weather Research and Forecasting

1. About the Climate Change Vulnerability Assessment Process

1.1 Introduction

The impacts of climate change have become increasingly evident in recent years across key climate-sensitive sectors in Ghana. These sectors include agriculture, fisheries, forestry, water resources, mining, health, and many others. Impacts such as drought, floods (both coastal and inland), and heatwaves have become common in many communities, with significant ramifications for Ghana's sustainable development goals. The government of Ghana, working with development partners, has initiated various efforts, including the ongoing 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 their manifestations, 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 also critical to use this knowledge to address uncertainties and 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 critically important that adaptation planning is driven by an appreciation of the geographical distribution of current and anticipated climate impacts. 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.

1.2 Purpose and Objectives of the Vulnerability Assessment

The overarching objective of this Vulnerability Assessment (VA) process is to assess the vulnerabilities and identify human and natural systems as well as economic sectors in the Bekwai district that are particularly vulnerable to climate variability and change and need special attention in terms of adaptation. This will help the government to make an informed policy decision when channeling funds for adaptation activities. Specific objectives are to:

- Identify district-specific vulnerabilities and prioritize them in the Bekwai municipality to inform adaptation planning and action under the NAP.
- Inform the design of projects/programmes to be implemented in communities and the Bekwai municipality at large.
- Provide knowledge products that can be used to create awareness and for advocacy campaigns on climate vulnerabilities, risks, and adaptation.

1.3 Scope of the Vulnerability Assessment

- **Sectors:** As stipulated in the Ghana NAP framework, this VA addresses the key sectors at risk from climate change impacts in the Bekwai municipality: agriculture (crops and livestock), forestry (ecosystems and biodiversity), infrastructure, water, sanitation and health, and commerce (finance, trade, and industry). Impacts and vulnerabilities were assessed in individual sectors and complemented with cross-sectoral analysis that considered the cascading nature of climate change impacts.
- **Geographic scope:** The six district-specific VA processes seek to ensure agroecological zone representation, with the BMA being selected to represent the Moist Semi-Deciduous Forest Zone. A district or municipality is a higher level of local government that has been granted municipal status by the central government. A district usually comprises larger urban areas, suburbs, towns, and villages and has some autonomy. A township is a smaller administrative unit within a district or municipality. The VA covered the Bekwai municipality and considers townships as the minimum unit of analysis. The township data was obtained through the aggregation of household information.
- **Timeframe for analysis:** Given the long-term nature of climate change and its impacts, the VA examined current vulnerabilities as well as projected future expected impacts up until 2100. This approach provided important information for planning into the future.

1.4 Outputs of the Vulnerability Assessment

This VAs produced seven main outputs elaborated in the following sections of this report:

- Output 1: Development of Climate Projections and Scenarios for the Bekwai Municipal Assembly (4.1)
- Output 2: Description and creation of representative district level vulnerability narratives (3.3)
- Output 3: Projections and description of potential future vulnerabilities (4.2)
- Output 4: Analysis of pathways that link current vulnerabilities to the future (4.2)
- Output 5: Description of prioritized vulnerabilities in key climate-sensitive sectors (3.2)
- Output 6: Creation of a map of vulnerability hotspots in each district (3.3.2.1)
- 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 in the Bekwai Municipality was guided by the principles of the Ghana NAP process and technical guidelines prepared by the Least Developed Country (LDC) Expert Group (2012). 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. This was achieved through the consideration of specific vulnerabilities in various communities and aggregating that to represent the district.
- **Inclusivity**: The VA process made conscious efforts to identify, engage, and include all or most places, institutions, sectors, communities, and groups (including women, youth, and marginalized stakeholder groups) who are currently impacted or projected to be impacted by climate change. Sixty-five stakeholders, including 21 women and 44 men, were engaged both in the design and preparation of the assessment through participation in stakeholder workshops (see participating stakeholder list in the appendix).
- **Relevant to the NAP and national priorities**: The VA process was aligned with and advanced Ghana's NAP process, as well as other national development priorities and those of the Bekwai Municipal Assembly. The VA incorporated sectors and areas of developmental priority in Bekwai Municipality's Medium Term Development Plan (MTDP) and considered how the results of the VA could inform adaptation 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, established stakeholder relationships, and built collaboration fora. The VA process utilized existing structures, including engaging local departments of stakeholders identified in the NAP Framework (e.g., National Development Planning Commission [NDPC], EPA, Forest Commission, fire services, etc.). This approach saved time and costs, strengthened existing structures, and helped to ensure 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 and other marginalized groups such as People with Disabilities; (ii) creation of subsections for gender vulnerabilities; 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 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 to moderate harm or take advantage of beneficial opportunities."

- 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 refers to “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 systems, institutions, humans and other organisms to adjust to potential damages, to take advantage of opportunities, or to cope with the consequences” of climate change – including climate variability and extremes.

1.7 Methodological Framework for the Vulnerability Assessment Process

Bekwai district’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 guidelines (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 makes these groups and their context vulnerable to climate change. Comprehensively assessing vulnerability to climate change requires 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:

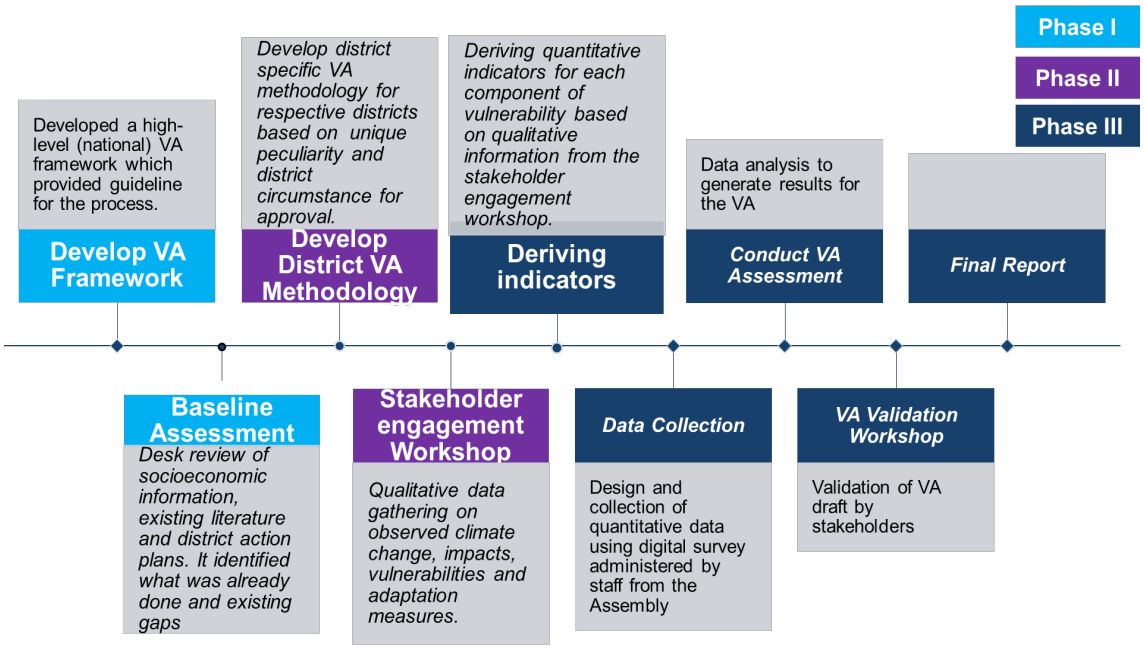
- Who or what is vulnerable to climate and non-climate stressors?
- Where is someone or something vulnerable within the municipality?
- When is someone or something vulnerable?
- Why and how is someone or something vulnerable?
- How important are climate stressors relative to non-climate stressors?

This VA used stakeholder engagement and literature review to complement modelling.

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 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, and to carry 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.

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, as well as participate fully and effectively in subsequent adaptation planning processes in the Bekwai Municipality. The stakeholder engagement plan developed for this VA 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, and in particular the Municipal Planning and Coordination Unit (MPCU), various entities and interest groups within the district were identified and engaged in different ways (Annex 1). Participatory workshops and consultations were used to engage stakeholders. This approach facilitated collaboration, ownership, learning, and knowledge refinement through dialogues. Stakeholders identified and those yet to be identified in this context are the ones that will be affected (positively or negatively) by climate risk and impacts in the community.

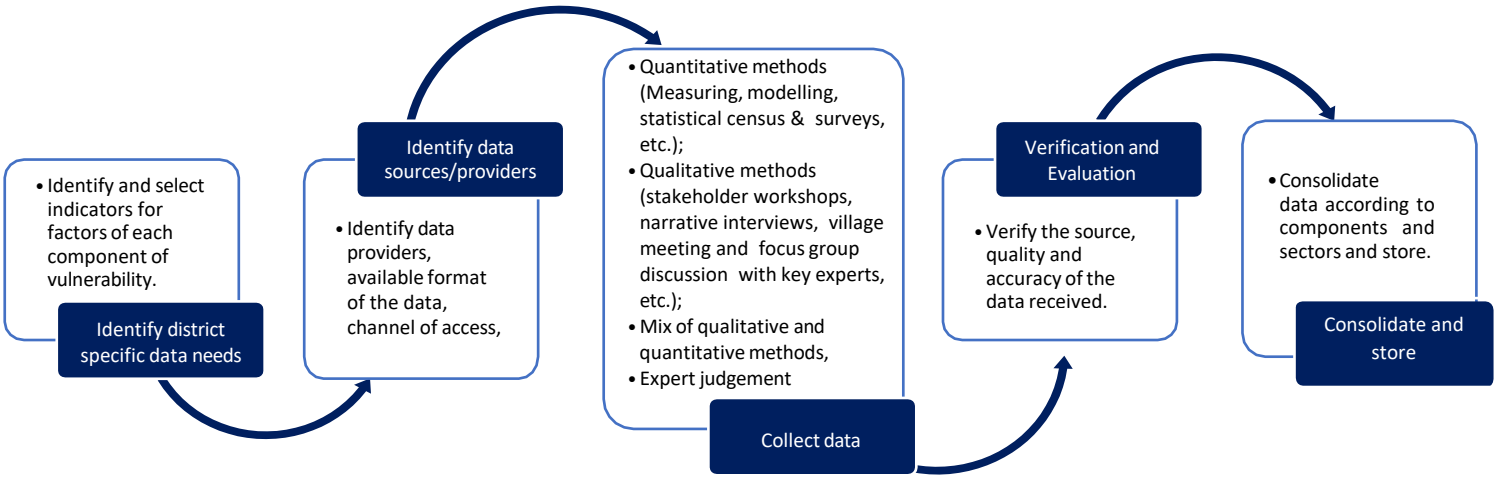
1.7.2 Ensuring Gender Responsiveness

The assessment process ensured that gender-sensitive vulnerabilities were captured and highlighted through (i) inclusion of women and 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 Data Gathering and Management

Data collection and management is key for the development of the VA. Figure 3 summarizes the approach to data collection.

Figure 3. Data collection framework

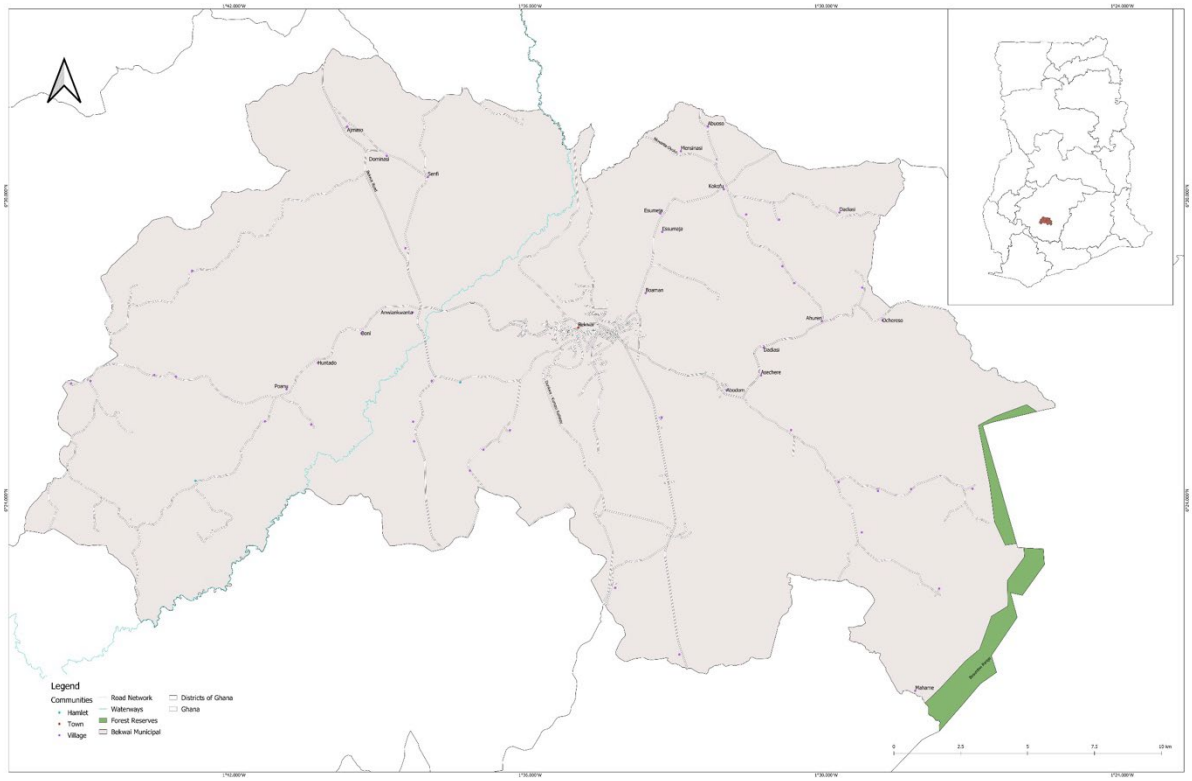


The methodology for data collection entailed:

- **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 stocktake of climate and vulnerability data in the Bekwai Municipality.
- **Stakeholders and experts' consultation:** When relevant, experts at the national, regional, district, and local levels were consulted to collect data and input, and to verify information (See Appendix 2 for a list of stakeholder organizations consulted).
- **Stakeholder engagement workshop:** The stakeholder workshop was used to collect data on prevailing climate change impacts and vulnerabilities while the validation workshop was used to validate the final vulnerability assessment report.
- **Analysis:** The participatory risk mapping and matrix of function activities as well as the literature review contributed to the identification of locations and economic sectors of the district that were particularly vulnerable to climate change hazards and impacts. The locations constituted 23 communities in the districts; while the sectors were agriculture (crop, fishery and livestock), forests (biodiversity and ecosystems), water, health and sanitation, infrastructure and transportation, services, and trade and finance.
- **Community-based survey:** Digital questionnaires were derived based on the variable for each indicator and administered to a predetermined sample size number of households in each of the 23 vulnerable communities. In total, 220 households were interviewed. Enumerators (primarily staff from the Municipal Assembly) were trained to visit the communities and interview households for the needed information.

2. District Profile: About the Bekwai Municipal Assembly

Figure 4. A district map of the Bekwai Municipal Assembly



2.1 Geographical Location and Size

The Bekwai Municipality is in the southern part of the Ashanti Region within latitudes 6.00' and 6.30' north and longitudes 1.00' and 1.35' west. The boundaries of the Municipality are shared to the north with Bosomtwe District, to the south with Adansi North District, to the east with Bosome-Freho District, and to the west with Amansie Central District and Amansie West District. The Municipality covers a total land area of 535.2 km^2 representing 2.2% of the total land area of the Ashanti region (Bekwai Municipal Assembly, 2019).

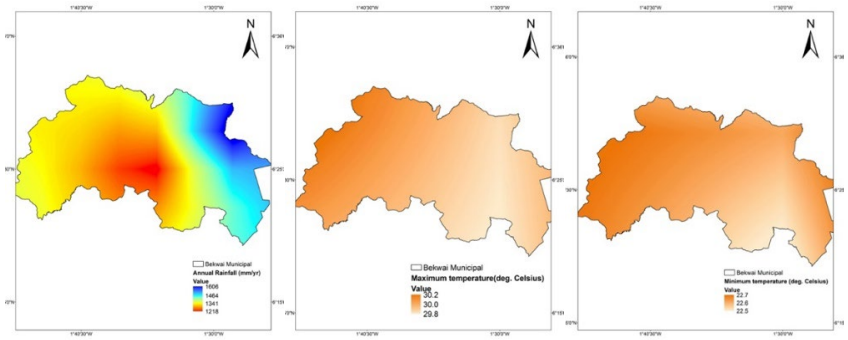
2.2 Topography and Drainage

The Municipality lies within the forest region with an average elevation between 150 metres and 300 metres above sea level. The topography is relatively flat with occasional undulating uplands, which rise to around 240 metres to 300 metres. The major river draining the area is the Odo River and its tributaries include the Dankran River which forms a dendritic pattern. The construction of small irrigation dams on the Odo and Dankran Rivers offers great potential for year-round agricultural development (Bekwai Municipal Assembly, 2019).

2.3 Climate

The climate in the Bekwai Municipality is characterized by an all-year bimodal rainy season with peaks that occur in June and September/October. This is influenced by the north-south movement of the Inter-Tropical Convergence Zone. December and January are the driest months with a relatively low relative humidity. Asante Bekwai begins to have substantial rain in March/April associated with a high relative humidity of about 85% through to November (Bekwai Municipal Assembly, 2019). The mean temperature typically has been about 32°C, but in 2020 and 2021 the average temperature increased to 32.50°C. Understanding the climatology of the Asante Bekwai is essential to developing any adaptation strategy since it is directly linked to people's livelihood activities.

Figure 5. Climate of Asante Bekwai Municipality



Source: Bekwai Municipal Assembly Vulnerability Assessment – Analysis of Climate Modelling Results, 2023.

The climate of Bekwai municipality is not uniform and exhibits spatial variation. The eastern part of the municipality receives relatively more rainfall whereas the south-central part of the municipality receives the least rainfall amount. There is not much variation of temperature between day and night in the municipality. The western part of the municipality is relatively warm compared to the eastern part where rainfall is high.

2.4 Vegetation

The Bekwai Municipality lies within the moist semi-deciduous forest zone. Some of the tree species are odum, wawa, edinam, and mahogany. *Chromolaena odorata,* popularly called akyeampong shrub, seems to be the predominant vegetative cover in many parts of the Municipality. Parts of the forest have been demarcated as a Forest Reserve (e.g., the Prampram forest reserve). Agricultural and industry activities, particularly farming and timber extraction, have reduced a considerable portion of the primary forests to secondary forests (Bekwai Municipal Profile, 2019).

2.5 Soil Types

The soil types in the Municipality are the Bekwai-Oda compound, Asikuma-Atewu-Ansum/Oda compound, Mim-Oda compound, Kobeda-Amuni-Bekwai simple association, Kumasi-Asuansi-Ntaoffin compounds, and Juaso-Manso-Asuboa pomasua compound association. The predominantly loamy soils in the area support the cultivation of tree crops such as cocoa, citrus, coffee, pear, and oil palm as well as food crops such as maize, cassava, cocoyam, and plantain. Some vegetables (e.g., garden eggs and pepper) and cereals (e.g., rice) also do well in the area. Poultry, livestock, and ruminants (including cattle, sheep, and goats) are reared in the municipality, which also has an emerging aquaculture industry (Bekwai Municipal Profile, 2019).

2.6 Demographic Profile

The demographic information of the municipality according to the 2021 Population and Housing Census (Ghana Statistical Service, 2021) is summarized in Table 1.

Table 1. Summary of Bekwai Municipality's demographics

	Number	Percentage
Gender		
Male	66,616	48.3%
Female	71,351	51.7%
Age Groups		
0 -14 years	48,084	34.9%
15 - 64	82,101	59.5%
65+	7,782	5.6%
Urbanization		
Rural	89,233	64.7%
Urban	48,734	35.3%
Literacy		
Literates	83,089	81.9%
Illiterates	18,336	18.1%

Source: City Population (2023), using data derived from Ghana Statistical Service, (2021), *Ghana 2021 Population and Housing Census*.

2.7 Economic Profile

Agriculture forms the largest primary production sector of the Bekwai Municipal Assembly and employs about half of the population. Agriculture comprises four sub-sectors: cropping, poultry, livestock, and aquaculture. Major food crop items in the Municipality include maize, cassava, plantain, and cocoyam. The Municipality is noted for cocoa production and oil palm cultivation. Additionally, nontraditional cash crops such as citrus, rice, pineapple, and cabbage are popular in the district. The sector faces challenges, including inadequate land for large-scale production, over-dependence on rain-fed agriculture, inadequate extension services, inadequate logistics for Extension Staff at post, a high illiteracy rate among farmers leading to misuse of poisonous agricultural chemicals on vegetables, inadequate access to microcredit schemes for farmers, and farmers' unwillingness to pay back revolving-fund loans granted to them, which deprives others of access such funds (Bekwai Municipal Assembly, 2019).

The service and commerce sector constitutes the second-largest contributor to the Assembly's Internally Generated Fund and contributes about 25-35% of the Municipality's GDP. Economic activities in this sector include wholesaling, retailing, petty trading, watch repairs, radio and television repairs, hairdressing, vulcanizing, bread baking, kenkey production, food and phone credit vendors, and the transportation sector, among others. The telecommunication services sub-sector, such as sales of telephone credit and mobile money, is creating jobs for a greater number of people.

The industry sector is dominated by small scale private investment in agro-processing, metal and wood-based work, textiles and garments, leather works, and food processing.

Table 2. Primary production sectors in the Bekwai Municipality

Occupation	Male (%)	Female (%)	Total (%)
Agriculture	29.2	21.0	50.2
Services	10.3	19.8	30.1
Commerce	9.1	13.1	12.0
Industry	4.2	3.7	7.9

Source: Municipal Planning Co-ordinating Unit (MPCU), Sample Survey, March 2017.

2.8 Administrative Arrangement

The Municipal Assembly is made up of 51 members: the Municipal Chief Executive who is the political head and 49 Assembly members, of which 34 are elected and 15 appointed by the President in consultation with chiefs and interest groups in the Municipality. The Member of Parliament for the Bekwai constituency is an ex-officio member of the Assembly. The Presiding Member is elected from the Assembly members to chair the Assembly's proceedings. The Assembly performs its functions through the Executive Committee and several sub-committees. The Executive Committee exercises executive and coordinating functions of the Assembly whilst the Sub-Committees deliberate on relevant issues in their functional areas. For administrative efficiency and effectiveness, the Municipal Chief Executive is supported by a secretariat or the Central Administration which is headed by the Municipal Co-ordinating Director who reports to the Municipal Chief Executive. The Assembly also has the Municipal Planning Co-ordinating Unit (MPCU), which serves as the technical wing. The Central Administration of the office of the Municipal Assembly is made up of the i) General Administration and Finance, and ii) MPCU, as well as other decentralized and non-decentralized supporting departments. The Internal Audit Unit audits the financial transactions of the Assembly and reports to the Municipal Co-ordinating Director and the Presiding Member.

3. Vulnerability Assessment to Current Climate Change

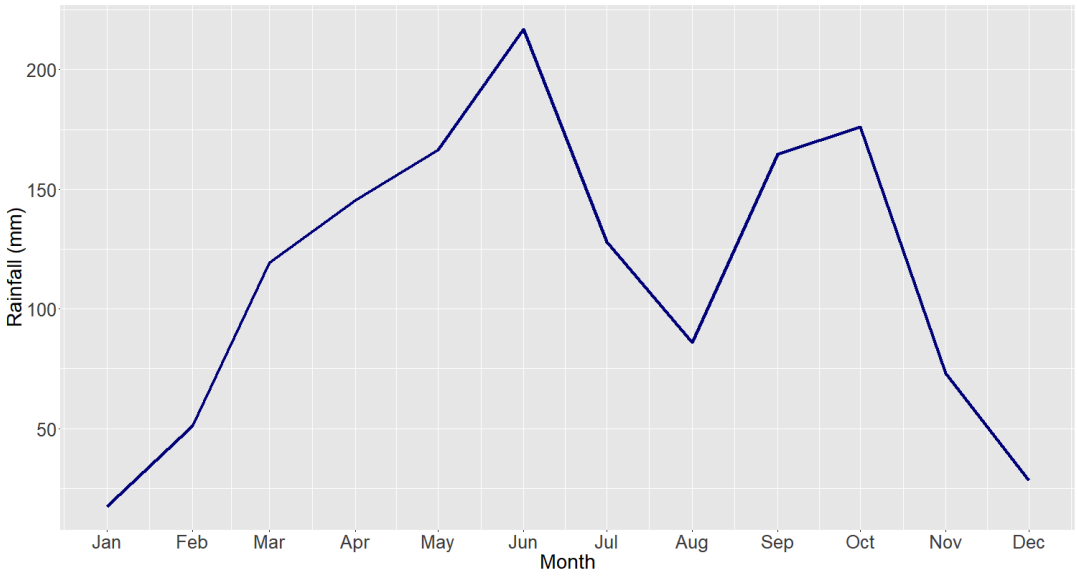
3.1 Analysis of the Observed Climate Changes

The climate change information presented in this section was derived from the analysis of observational climatological data from the 1980s to 2020 as provided by the Ghana Meteorological Agency (GMet). The VA team undertook the analysis and generated the various charts and figures in this section.

3.1.1 Rainfall Characteristics

The Bekwai district, also known in local context as Asante Bekwai, experiences a bimodal wet regime characterized by two peaks occurring in June and October. The wet season spans through the year beginning in January with the lowest precipitation value and increases steadily to a primary peak in June, declines in August, and increases again to a secondary peak in October with a closely substantive amount of rain in September (Figure 6). November sees a steady decline. The primary peak is observed in the major rainfall season and the secondary peak occurred in the minor rainfall season.

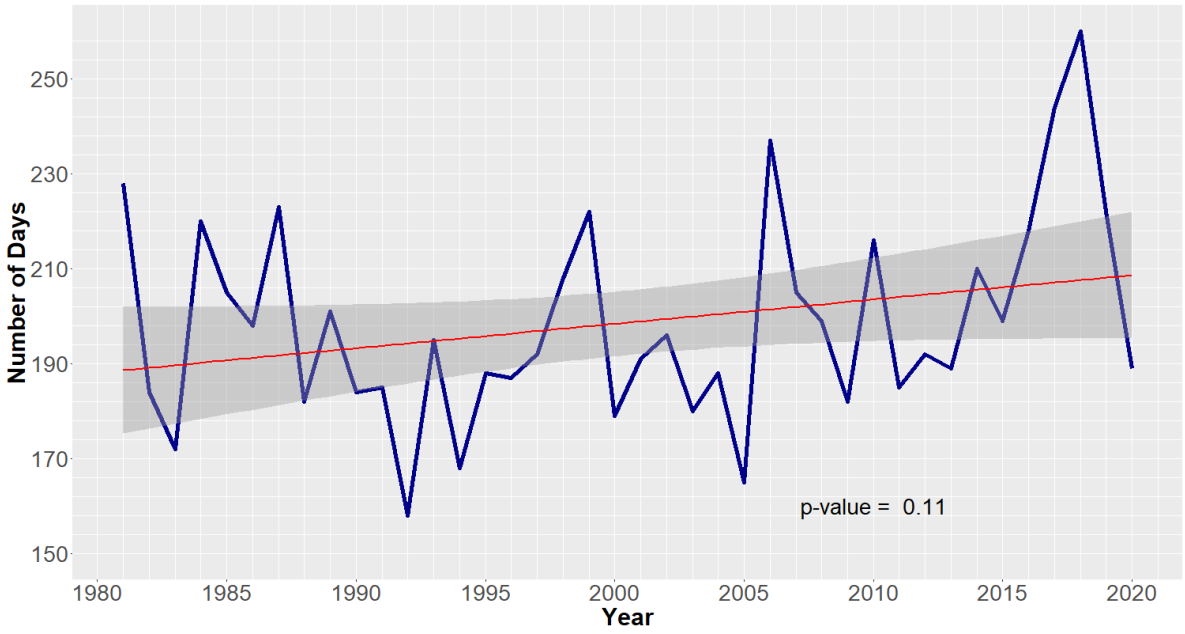
Figure 6. Monthly rainfall over Asante Bekwai



3.1.1.1 Annual Rain Days

Figure 7 presents the number of days in the year with rainfall events defined as days with rainfall amount above 0.85 mm over Asante Bekwai. The number of rainy days has varied significantly over the period 1980-2020. The increasing trend observed in Figure 7 is not significant enough to have notable effects on the long-term mean. The least rainfall event is 163 days of rainfall events that occurred in 1992 and the most is 260 days that occurred in 2019. Rainfall events have varied over the period and the mean trend has increased. The rain days trend is described as variable because of the lack of consistency in the number of rain days constituting the annual rainfall total in the area, despite the observed overall increasing trend.

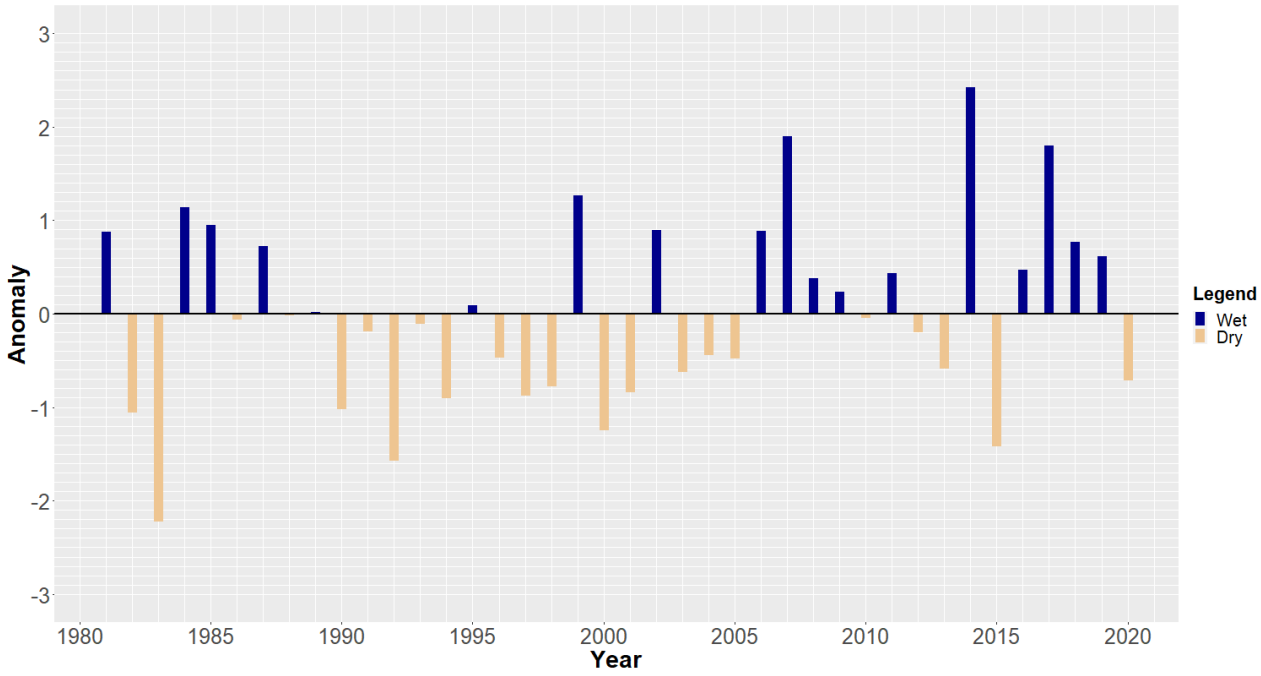
Figure 7. Rainfall event over Asante Bekwai



The blue bars (pointing upwards in Figure 8) indicate wet years, while the brown bars (pointing downwards) indicate dry years. The anomaly trend of the total rainfall in Asante Bekwai shows that the early years (1988 to 2005) were mostly dry, while the most current years (2006 to 2020) were mostly wet; although there was no consistent increase or decrease in annual rainfall totals.

3.1.1.2 Annual Rainfall/Rainfall Anomaly

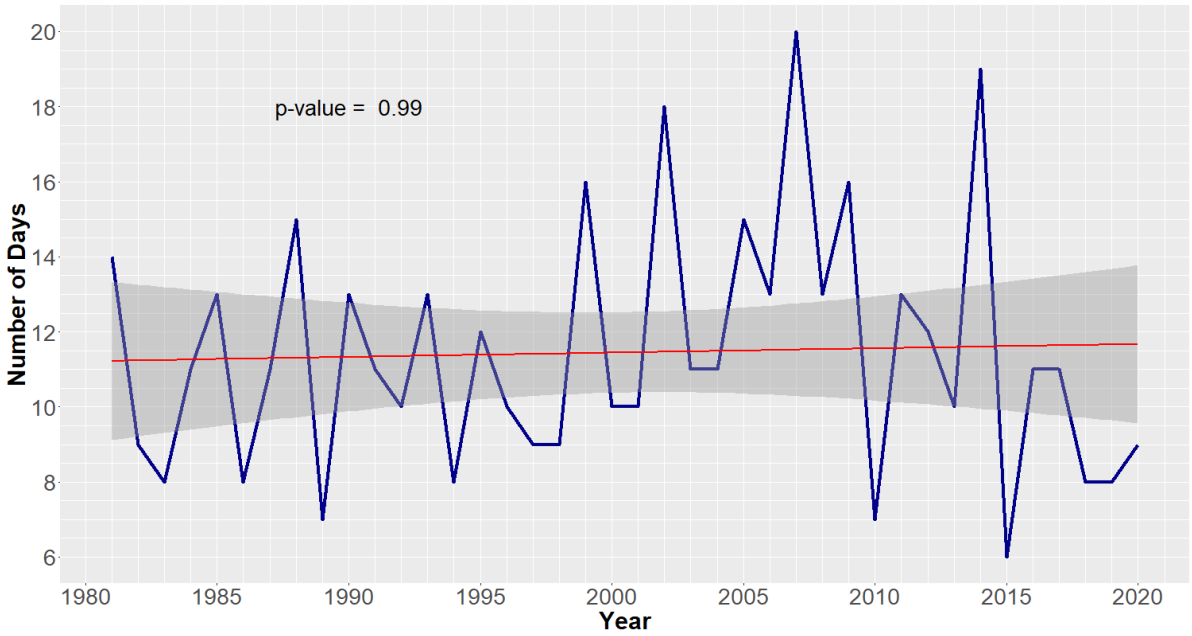
Figure 8. Rainfall anomaly over Asante Bekwai



3.1.1.3 Heavy Rainfall Events

The number of days with heavy rainfall events is defined as the count of days when rainfall is more than 20 mm in a day. Figure 9 presents the heavy rainfall events over Asante Bekwai from 1980 to 2020. Significant inter-annual variability is characteristic of the heavy rainfall events, which may translate to a varying degree of flooding; however, this is subject to other factors, such as environmental factors and day-to-day meteorological factors. The inter-annual variability of rainfall events over Asante Bekwai has not assumed any visible trend over the period 1980-2020.

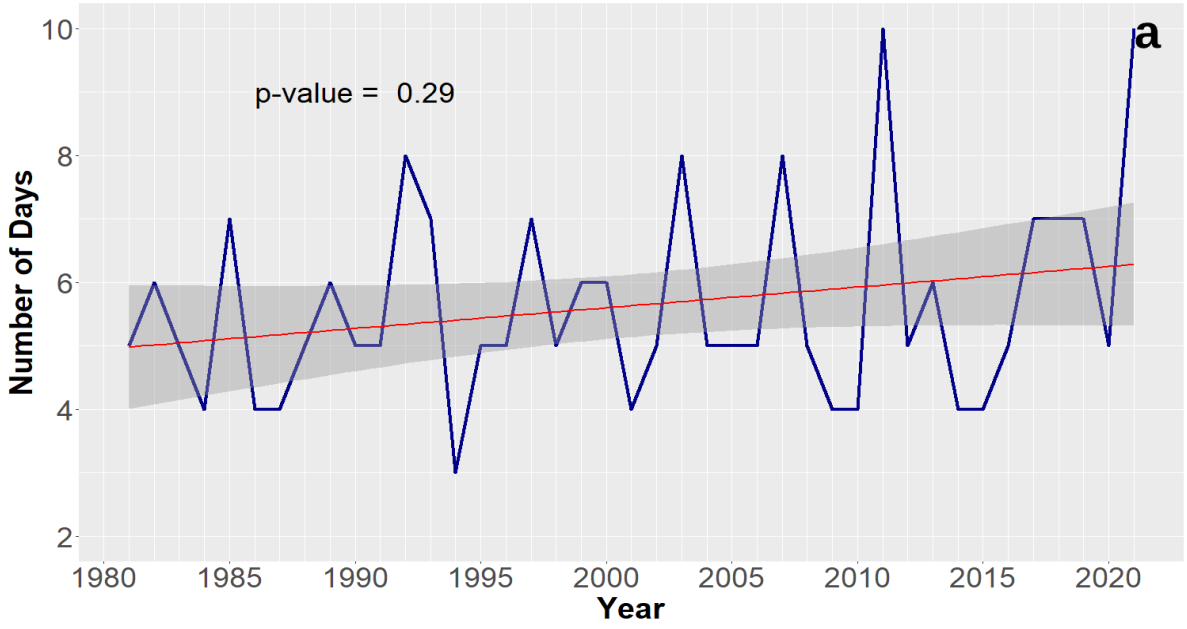
Figure 9. Frequency of heavy rainfall events over Asante Bekwai



3.1.1.4 Consecutive Wet Days

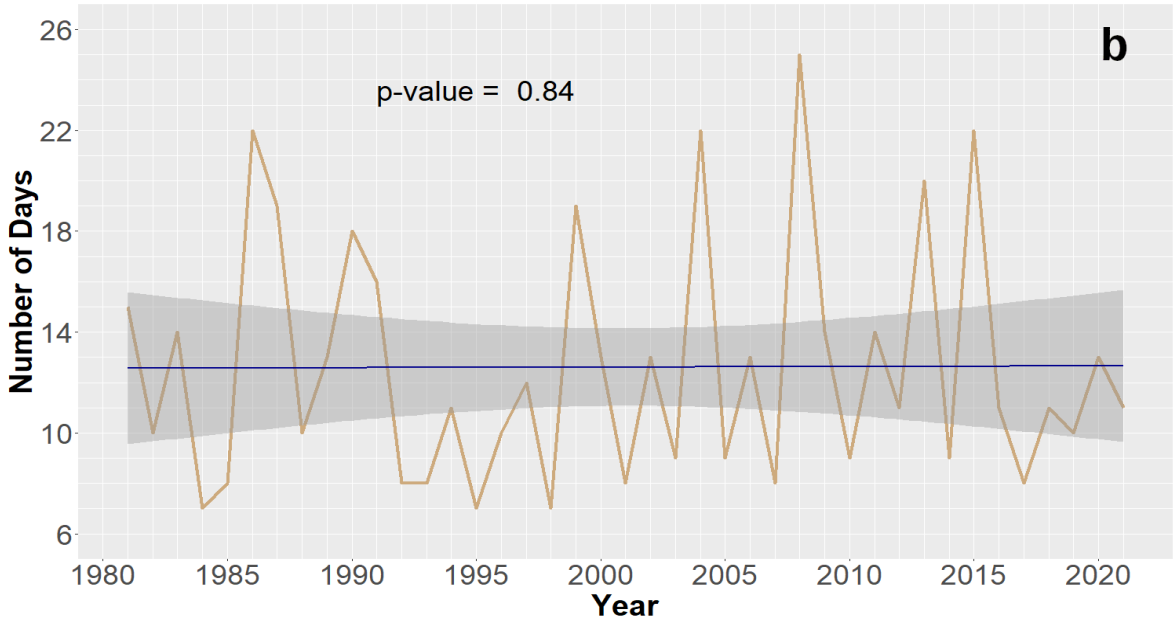
Successive days of rainfall can saturate the soil and increase the tendency of flooding with the low rainfall events. The evaluation of days of continuous rainfall over Asante Bekwai can guide strategic planning to that addresses potential flooding events that may result because the area has a bimodal wet regime that spans the entire year. Figure 10 presents the number of days of wet spells in each year over the study area. Wet spell duration has varied in Asante Bekwai, ranging from 3 to 10 days over the period 1980 to 2020. The mean wet spell duration shows a non-significant increasing trend over the period.

Figure 10. Wet spell duration (number of days) in Asante Bekwai



Dry spell duration (Figure 11) in Asante Bekwai has also varied highly with no clear mean increase or a decrease in the trend.

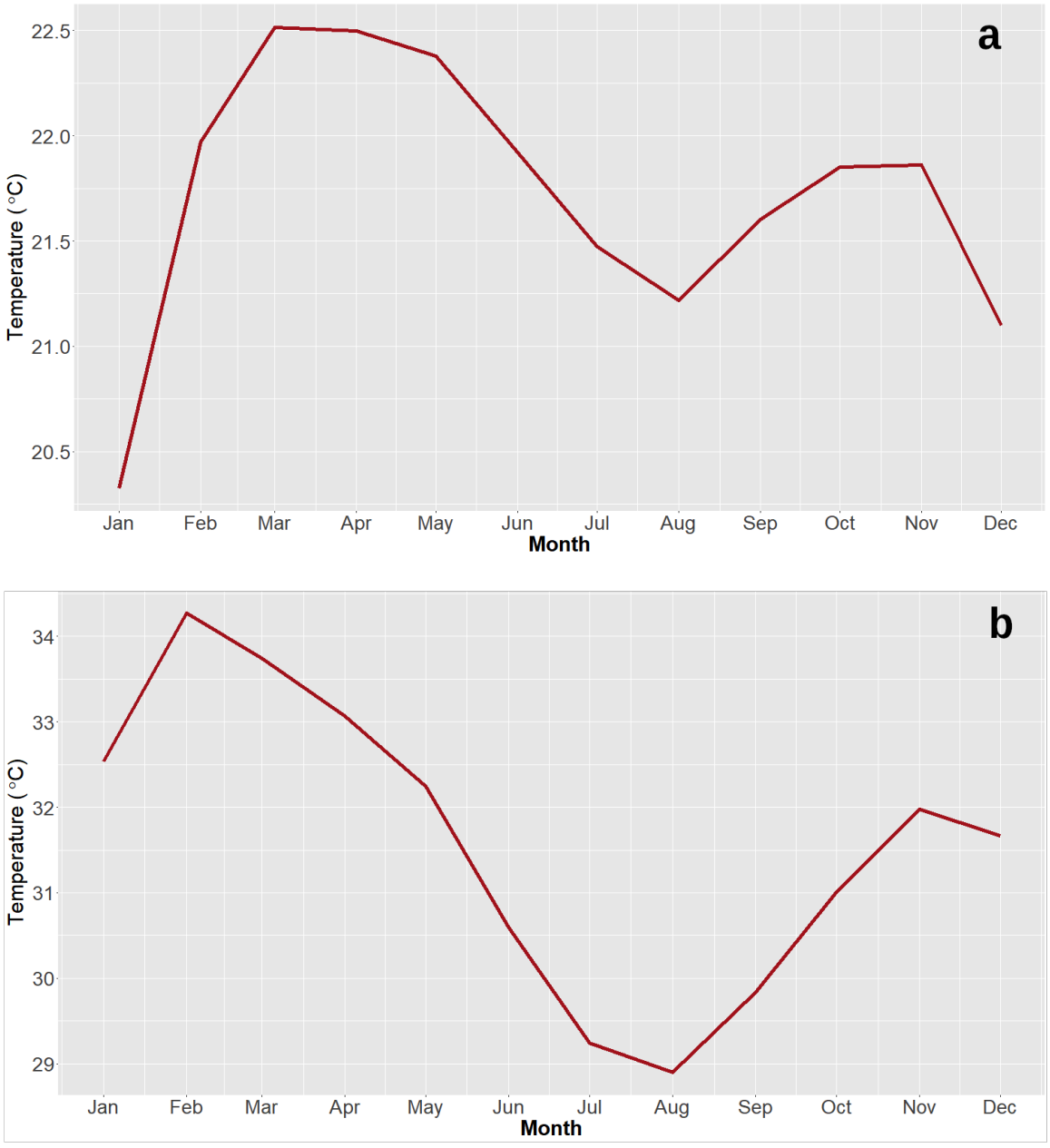
Figure 11. Dry spell duration (number of days) in Asante Bekwai



3.1.2 Temperature Characteristics

The mean minimum temperature over Asante Bekwai has two peaks as shown in Figure 12a. The primary peak of 22.5°C occurs in March to April and the secondary peak occurs in October to November with a minimum temperature value of 21.88°C. Mean maximum temperature (see Figure 12b) peaks in February at a value of 34.2°C and declines steadily to a minimum of 28.8°C in August. A secondary peak of 32°C is observed in November. Both minimum and maximum temperatures have similar profiles but differ only in magnitudes, i.e., both minimum and maximum temperature profiles reached an inter-peak minimum in August which coincided with the peak of the wet season and a secondary maximum in November.

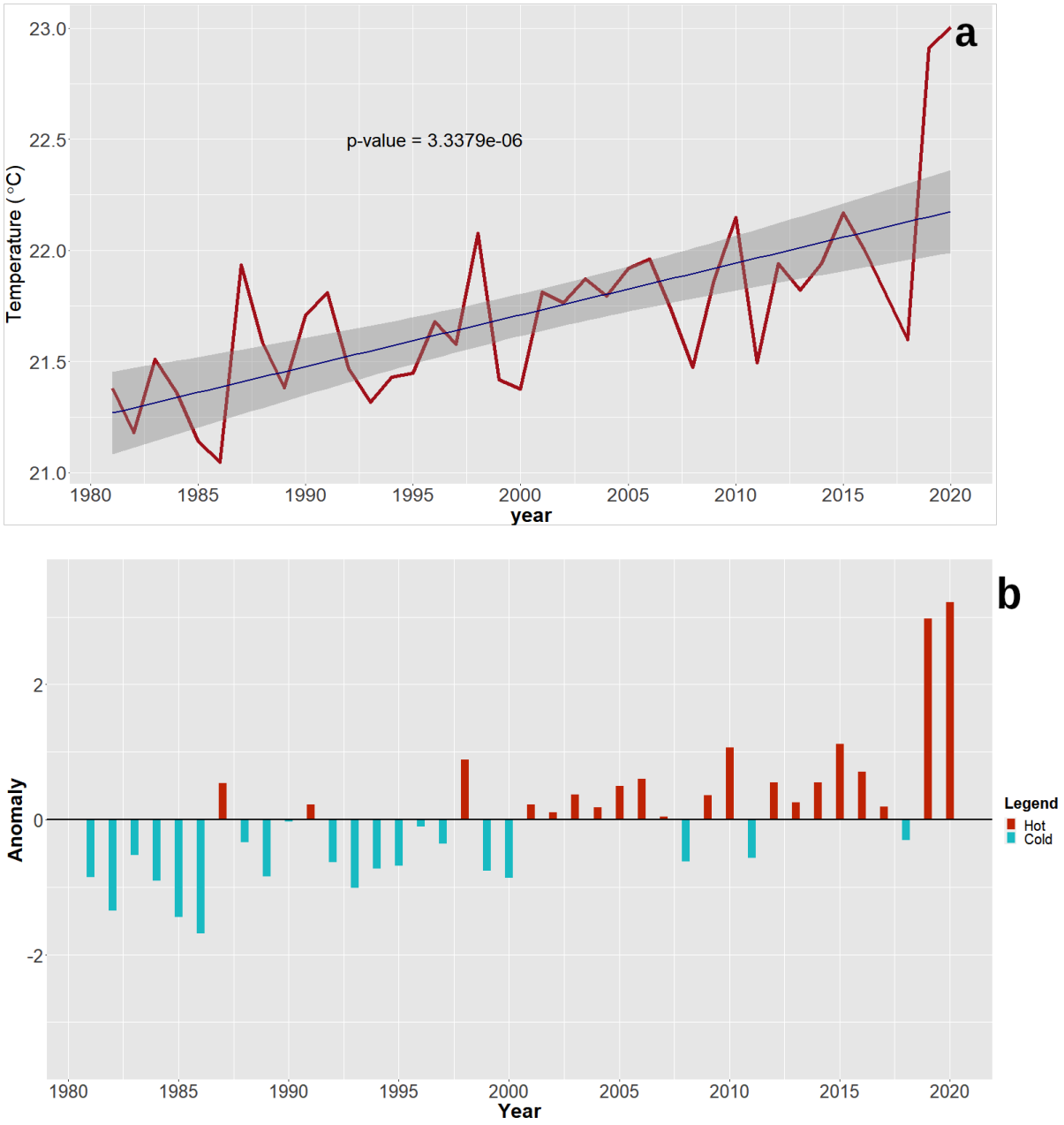
Figure 12. Monthly mean minimum temperature (a) and maximum temperature (b) over Asante Bekwai



3.1.2.1 Mean Annual Minimum Temperature and Anomaly

A mild inter-annual variability of minimum temperature over the study area is presented in Figure 13a. There was an increase in trend of the annual mean minimum temperature over the study period with a low variability which was evident in the annual mean and anomaly plots. This increasing trend signified that recent years were significantly warmer than the past. The anomaly trend shows that the period from 1980 to 2000 was colder and the period from 2001 to 2020 was warmer based on minimum temperatures, which means that night temperatures have become warmer in recent years (see Figure 13a and 13b). Figure 13b shows relatively cold early years (1980 to 2000) and then growing warm years (2001 to 2020), with significant increases in temperature noted in 2019 and 2020.

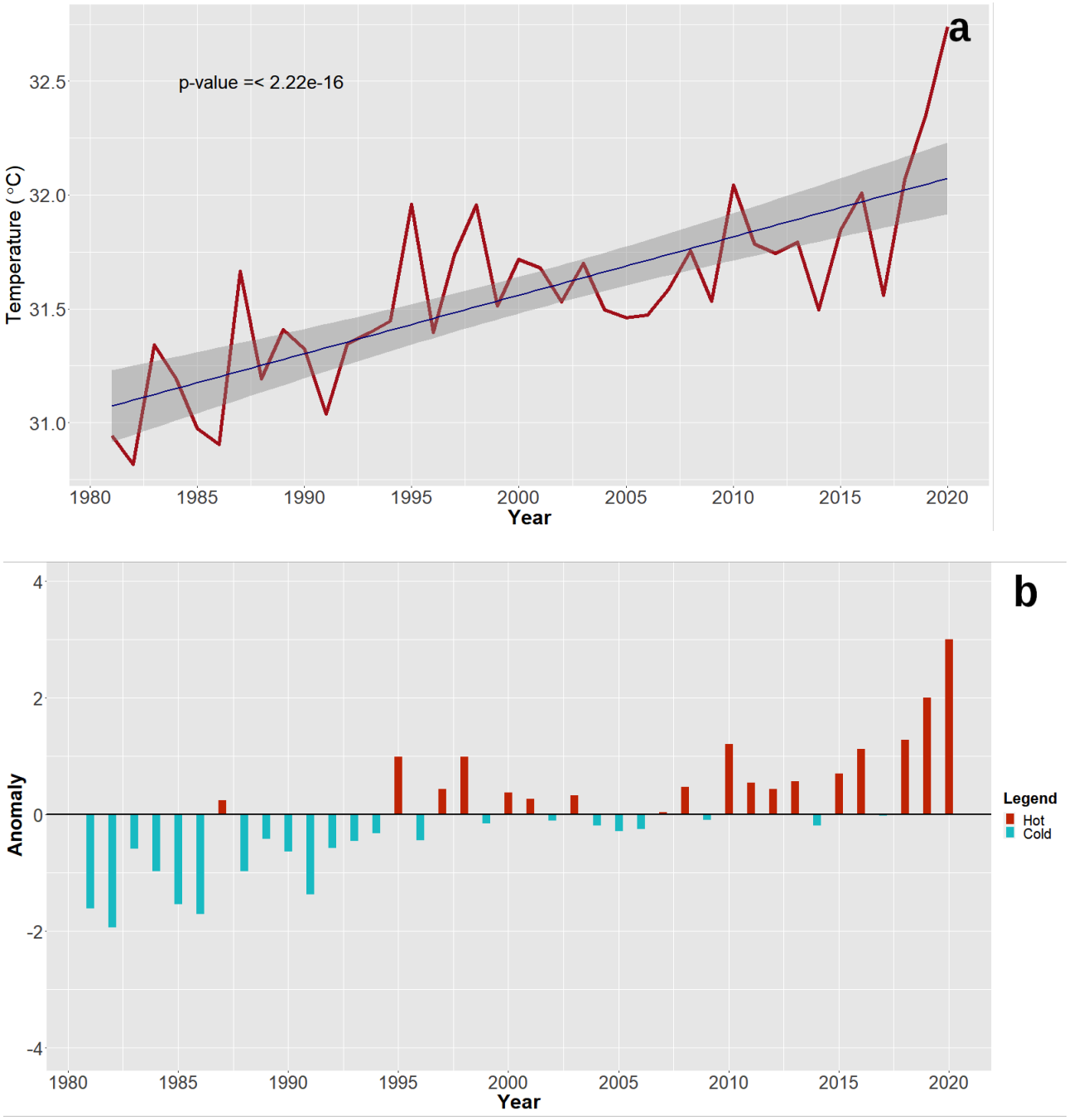
Figure 13. Annual mean minimum temperature (a) and anomaly (b) over Asante Bekwai



3.1.2.2 Mean Annual Maximum Temperature and Anomaly

Asante Bekwai recorded the lowest mean maximum temperature of 30.6°C in 1982. Like the mean minimum temperature, the maximum temperature has varied with a significant increasing trend (Figure 14a). The anomaly trend (Figure 14b) shows that 9 of the 10 years between 2010 and 2020 were warmer than the mean, while only 2 of the 15 years from 1980 to 1995 were warmer than the mean. Thirteen years before 1995 had a maximum temperature lower than the mean.

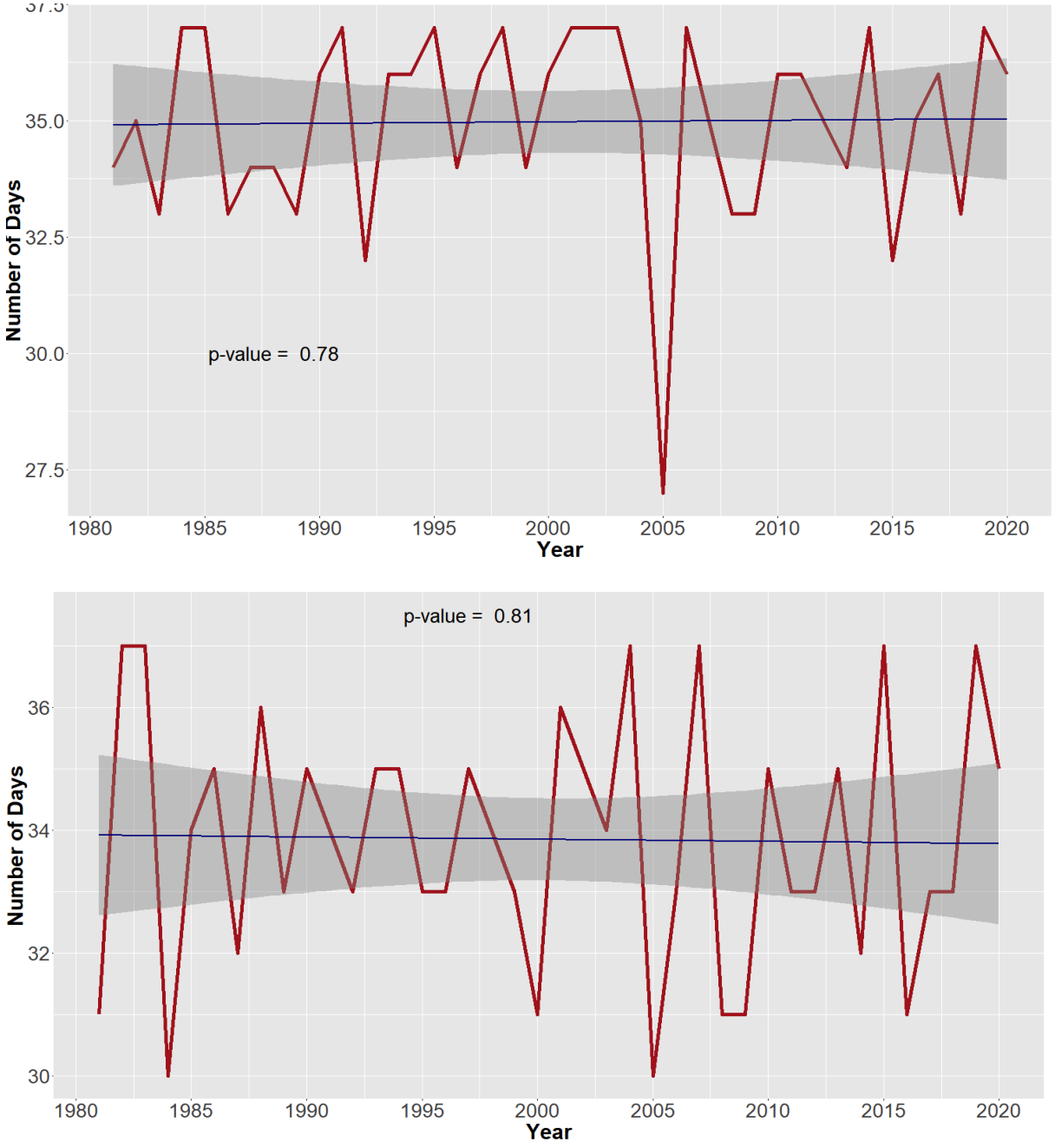
Figure 14. Annual mean maximum temperature (a) and anomaly (b) over Asante Bekwai



3.1.2.3 Frequency of Hot Days and Nights

The frequency of hot days and frequency of hot nights in Asante Bekwai are presented in Figure 15. The number of hot days has varied slightly between 32 days and 37 days in the period except for 2005 which recorded about 27 days. The frequency of hot nights in Asante Bekwai has varied from 30 days to 37 days over the period. There are no obvious trends shown in Figure 15.

Figure 15. Frequency of hot days and hot nights over Asante Bekwai



3.1.2.4 Summary of Historical Climate Information for the Period 1980-2020

The analysis of historical climate in Asante Bekwai shows that the district has become wetter, the duration of wet spells has lengthened, and that recent years have been warmer with higher minimum temperatures. A summary of the historical climate information for 1980-2020 is below:

- The number of rainy days has varied significantly over the period 1980-2020 with some years having a relatively higher number of rain days than others. While there is an increasing trend, it is not significant enough to have notable effects on the long-term mean.
- Heavy rainfall events are variable and differ from year to year. Years with many days of heavy rainfall may result in floods in the Asante Bekwai area.
- The mean wet spell duration, while varied, shows an increasing trend over the period 1980-2020.
- The dry spell duration in Asante Bekwai has varied with no clear mean increase or decrease.
- Hot days and nights in Asante Bekwai have varied over the period. Both minimum and maximum temperatures have increased and are varied in Asante Bekwai.
- The period from 1980 to 2000 was colder and the period from 2001 to 2020 was warmer for minimum temperatures, which means that night temperatures were warmer in recent years.
- The annual mean minimum temperature trend from 1980 to 2020 demonstrated an upward trend with a low variability, signifying that the recent years have become significantly warmer than the past. The most recent 11 years analyzed (2009 to 2020) were warmer than the previous years (1980 to 2008), reflective of the global warming trend.

3.1.3 District Seasonal Change Calendar

To complement the analysis of observed climate change in the municipality, a district seasonal change calendar was constructed during the participatory workshop. The results, which are presented in Figure 16 below, indicate the main seasons, the main activities undertaken in the agriculture sector in each season, the typical climate, the observed changes to the climate, and the observed impacts that have resulted from changes in the climate over the past 10 years.

Figure 16. District seasonal change calendar of Bekwai Municipality

Season (Length)	Key events (Annual cycle)	Typical climate	Observed changes	Observed impacts
Dry season (Jan - Mar)	▪ Training to farmers on fire prevention; ▪ Bushfires and domestic fires; ▪ Mobilise community for health education on respiratory diseases; ▪ Prepare forestland for plantation; ▪ Local irrigation tech thrives around that time.	• No rains • Cool during day time • hot and dry temperatures during day • Very windy	It used to occur in Oct to March	▪ Inadequate rains affect crop production and yield ▪ Increase in forest fires ▪ Property and live loss ▪ Increase in respiratory diseases ▪ Decrease in water availability for distilling local drinks ▪ Affects labour (construction work, farming) ▪ Difficulty in harvesting cassava and leads to high prices ▪ Difficult to get water for domestic use.
Major rainy season (April – July)	▪ Planting by farmers, Education and awareness campaigns,	• Frequent and heavy rains (sometimes daily) • Storms		▪ Malaria, worm infestation prevalence and Anemia; ▪ Farmers not having time to feed wards; ▪ High incidence of snake bites and farm accidents; ▪ Timber operation becomes difficult because of the roads; ▪ Disruption of bridges, disasters in schools, roof removal by winds; ▪ Rains induces sleep and sexual desire; ▪ High intensity rains affects roads (washes away surface gravel of roads); ▪ Livestock diseases increases; ▪ Destruction of crops by rivers overflowing their banks; ▪ Abundance of leafy vegetables in markets; ▪ General disruption of recreational activities, affects markets,
Minor rainy season (Aug – October ending)	• Cereals and grains production • Postharvest (storage, marketing, processing) issues from major season. • Harvesting	• Less frequent, less intense rains	Changed to August - December	▪ Less fire, more vehicular accidents ▪ Changes in pest behaviour, attacking new hosts (FAW). ▪ Prevalence of chorela and vectors

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

3.2.1 Extreme Event Records in the Bekwai Municipality

Climate change impacts include high temperatures, heavy rainfall events and floods, dry spells and droughts, and windstorms, which impact both natural and human systems. Taking stock of the different incidences and timing of extreme events and the timing of it in different communities within the broader municipality helps to clarify the main climate hazards and the extent to which people and communities are exposed. This data can inform and be aligned against climate projections to help create scenarios of future events, which are also used as the basis for effective adaptation planning.

Records in the Bekwai district indicate that flooding is the most common climatic extreme event in local communities, and this is consistent with national records (EPA, 2021).

Table 3. Climate change events/occurrences in the Bekwai Municipality

Year	Occurrence	Climatic or non-climatic	Description of damage	Affected sector(s)	Number of affected people	Estimated cost	Source (e.g., literature, article, survey, etc.)
2008	Fall Army Worm (FAW) outbreak	Partly climatic as warm weather supports growth of the FAW	Destruction of all staple crops.	Agriculture	District-wide (majority in Bekwai)	N/A	Stakeholder participatory workshop
2017	Flood	Climatic	Persistent rainfall at the source of Oda River resulted in the flooding of Anwia Nkwanta near Bekwai.	Transport: Kumasi-Obuasi highway was submerged Agriculture: Death of livestock and destruction of crops	20 houses 1 fishpond Male adults=8 Female adults=14 Boys = 7 Girls = 11	10,404.00 GHS	National Disaster Management Organization (NADMO) – Bekwai Municipal.
2022	Rainstorm	Climatic	The Bekwai SDA Secondary School and Bekwai R/C Primary School were severely affected. Students were dislodged from homes to allow for repairs. Other communities such as Fawoman, Nampasa, Koniyaw, and Gyasikrom were also affected.	Infrastructure, education, human health	1 pupil injured with many others left homeless.	N/A	Ghana News Agency* (18.03.2022)/ also confirmed at the stakeholder workshop.

Note: * https://gna.org.gh/2022/03/one-injured-others-displaced-after-rainstorm-rips-up-buildings-at-bekwai/

Photo of a flooded facility as result of the collapse of the River Odo bridge in 2017.

Credit: Ultimatefmonline.com

3.2.2 Analysis of Drivers of Vulnerability in the District

Not all systems exposed to climate change will be affected or impacted negatively. Although the municipality is exposed to climate change, its physical as well as socio-economic conditions determine the nature of impacts and the extent of vulnerability to such impacts. The IPCC (2022) defines vulnerability as the propensity or predisposition to be adversely affected by climate change. It also notes that vulnerability encompasses a variety of concepts and elements, including exposure to climate impacts, sensitivity or susceptibility to harm, and lack of capacity to cope and adapt. This notion is used to describe socio-economic, physical, and environmental determinants of levels of sensitivity or susceptibility of a country, town, community, or individual to specific impacts of climate change.

Key underlying drivers of vulnerability to climate change in Bekwai are:

- High socio-economic dependence (employment, income, food security) on climate-sensitive sectors such as agriculture.
- Unsustainable natural resources utilization (e.g., deforestation, illegal fishing, illegal mining, unsustainable agricultural practices).
- High poverty, unemployment, and migration rates (often influenced by climate change and hazards).
- Human settlements (villages, towns, cities) are not prepared for the changing climate (e.g., inadequate planning, congestion, construction techniques, poor infrastructure).
- Low adaptive capacity characterized by limited access to knowledge, technology, and financing.

Below are short descriptions of the main drivers of vulnerability in the Bekwai municipality, as determined through a literature review and inputs from stakeholders.

3.2.2.1 Rainfed Agriculture

The agriculture sector (crop, livestock, fishery) and forestry sector employ more than half of the total population of the municipality. Most of the farmers are smallholder farmers holding less than 5 acres of land (Bekwai Municipal Assembly, 2021). Major food crop items in the municipality include maize, cassava, plantain, and cocoyam. In addition, the municipality is noted for cocoa production and oil palm cultivation. The majority of respondents of the household survey who were from agriculture households (98.1%) engaged in crop farming and 21.6% engaged in livestock.

Farmers practise traditional irrigation on a limited scale while mechanized irrigation is almost completely lacking in the district. Most farmers are illiterate or have low levels of education, which limits their ability to uptake refined knowledge in the forms of science and technology. Also, diversification of livelihoods among rural farmers is an emerging coping mechanism that only a few farmers have adopted in the municipality. This means that most farmers and traders have their entire livelihood and income connected to rainfed agriculture. The agriculture sector is the primary provider of the municipality's food needs.

3.2.2.2 Unsustainable/Illegal Mining

Unsustainable and illegal mining is widespread in the municipality and is impacting crop production and water availability. Stakeholders at the participatory workshop indicated that mining pits are not rehabilitated or reclaimed and agricultural lands are being used for mining. Increased conversion of farmlands to mining fields means farmers have less land to cultivate and subsequently lower farm production and earnings. Similarly, water pollution from illegal mining activities reduces freshwater availability. Illegal mining exacerbates climate change impacts on the agriculture and mining sectors. Abandoned mining pits also present a serious threat to human and animal safety and especially during the rainy season when they get filled with water. Workshop participants recollected occasions where animals and humans fell into such traps.

An illegal mining site in the BMA. Credit: Ghana News Agency.

3.2.2.3 Poor Water Availability and Quality

Climate change influences the hydrological cycle, affecting groundwater systems, which are the major source of water for domestic and commercial activity in the Bekwai municipality. The Odo River is the major water body in the municipality and its levels are falling according to participants during the stakeholder workshop. Increasing temperature, coupled with unsustainable practices such as the over clearing of riverbanks for farming purposes especially among vegetable farmers, exposes a large surface area of the river to evapotranspiration and represents a major threat to water security in the municipality. The overreliance on scarce water resources by illegal miners in the district has already polluted some water sources and is likely to get worse if intervention actions are not taken.

3.2.3 Gender-Related Vulnerabilities

Understanding gender dynamics; the different rights, roles, and responsibilities of women and men in the municipality; and the relationships between and among them in the context of vulnerability to climate change is crucial for ensuring gender-responsive approaches to climate change adaptation and resilience building. The workshop consultation assessed differentiated gender roles in the municipality through:

- identification of the roles of men and women in family and community
- analysis of gender equality: income generating opportunities for women/men, unpaid work for women/men, daily wages for women/men
- examination of women's access to resources (especially of women heads of households) such as land, assets (house), and financing
- identification of socially and economically vulnerable groups such as minority groups and people with disabilities

Seventy-one percent of the males in the Bekwai Municipal are economically active out of which almost all (96% of the 71%) being employed (GSS, 2010).[1] Agricultural, forestry, and fishery occupations engage 53.6% of the male employed population and 52.6% of the female employed population. Around 69.1% of females are economically active out of which 95.3% are employed; 14.4% of females reported that they were not economically active because they engage in more domestic duties than their male counterparts (GSS, 2010). The data on economic status demonstrates an uneven economic opportunity between men and women. The expected roles of women, such as domestic duties, put them in a more climate vulnerable position than men. Workshop participants perceived less adaptability to the impacts of climate change among women compared to men because women typically have limited access to financial resources. Climate change is expected to increasingly affect women-led households by limiting access to essentials such as food, health care, and finance. The relative lack of financial resources for women in the Bekwai Municipality will also weaken their adaptability to climate variability and change. Gender-sensitive climate change adaptation strategies can improve gender equality and women's development. It is therefore important to integrate gender needs in climate-related adaptation planning in the Bekwai Municipality.

3.2.4 Vulnerable Locations

Participatory hazard/risk mapping involves mapping of the most exposed locations (of people, infrastructure and assets, crops, and livestock) affected by climate hazards. It illustrates the hazard-prone locations, as well as the people, ecosystems, and assets most at risk of hazards such as floods. Other information that could be mapped includes safe areas, routes to safe areas, and local capacities such as rescue posts. Workshop participants, working in groups, were provided with a pre-printed district-specific map and guidance to locate and map climate-vulnerable areas in the municipality. Based on past experiences and history of the occurrence of hazards, participants were able to produce a hazard/risk map as presented in Figure 17. Table 4 provides information on associated impacts of the hazards on identified locations as well as the human, natural, and infrastructural systems that will be affected.

Workshop participants using participatory mapping techniques to map out vulnerable locations, groups, and facilities in the municipality.

[1] According to Ghana Statistics Service, the economically active population consists of employed (i.e., the population above 15 years who work, did not work but had a job to go back to, or did voluntary work without pay) and unemployed (i.e., the population above 15 years who worked before, are seeking work and available, and are seeking work for the first time and available).

Figure 17. Map showing climate vulnerable areas in the Bekwai Municipality

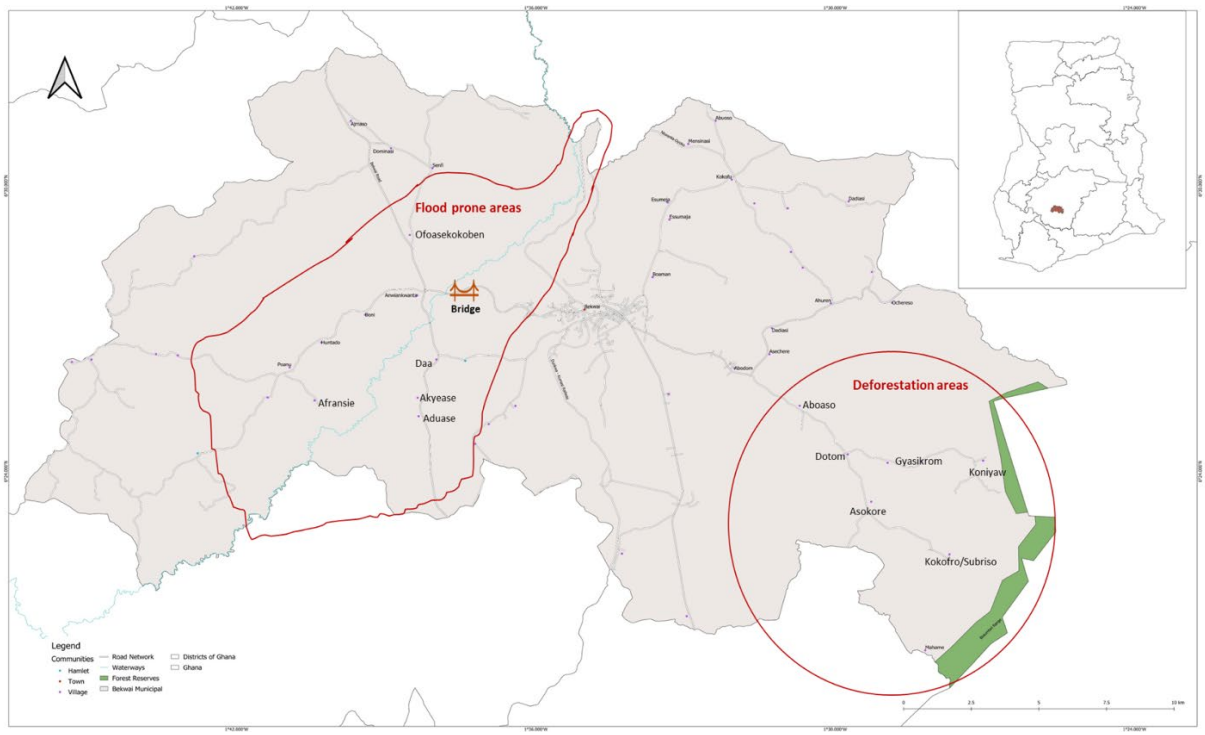


Table 4. Identified hazard prone areas in Bekwai Municipality

Climate hazard	Description	Potential impacts	Vulnerable people, communities, facilities
Flood	Floods resulting from Odo River (indicated as waterways on the map) overflowing its banks.	• Submergence of bridge linking Awiankwanta to Bekwai. • Destruction of farms along the river. • Displacement of homes in communities along the Odo River. • Destruction of infrastructure (hospitals, school, fuel station) in communities along the Odo River. • Pollution of water bodies.	**Communities:** Awiankwanta, Senfi, Ofoase Kokoben, Boni, Huntado, Poanu, Daa, Akyiase, Aframsie, Abenkyim **Facilities/Assets:** Schools, hospitals (Abenkyim), farms

Table 5. Human activities that might exacerbate climate change impacts

Human activity that will exacerbate climate hazard	Description	Potential impacts	Vulnerable people, communities, facilities
Deforestation by humans	Prevailing illegal mining leading to deforestation and disrupting provision of ecosystem services.	• Pollution of freshwater bodies from heavy metals used in mining will limit access to clean water. This will exacerbate climate change impacts on water as projected climate change shows an increase in temperature leading to high evapotranspiration rates and drying of the limited freshwater resources. • Destruction of farmlands by mining can exacerbate climate change impacts on farmers whose lands have been destroyed, as they have lower incomes from their farms, making it difficult to finance needed adaptation measures. • Trees from the forest are important to shield crops and infrastructure during strong winds and rainstorms. Deforestation has the tendency to expose farms and buildings to such climate hazards. • Deforestation will disturb the local rainfall and water availability that is influenced by forests.	**Communities:** Aboase, Dotom, Asokore, Gyasikrom, Kokofrom **Asset**: Farms

3.2.5 Assessing Resilience of Communities Using a Matrix of Functions

A Matrix of Functions (MoF) was used to assess community functions in the municipality. The MoF is a spatial planning tool that describes (i) the public services and functions that are available in each village/town of the municipality; (ii) the hierarchy and importance of these services; (iii) where functions are missing; and (iv) how balanced the spatial development of the municipality is (Fee, et al., 2017). The purpose of an MoF is to identify and assess the functions and qualities of an area to better plan investment. Applied to climate change, the information collected enables planners and policymakers to analyze the district's level of physical and socio-economic development, which helps to increase the understanding of how the current spatial structure and functions of a district enable or inhibit the building of resilience to the changes in climate and the adaptive capacity of the district's population, infrastructure, and systems.

The MoF was developed by collecting data with a simple questionnaire to determine which services and functions are available, and where Community representatives invited to the stakeholder workshop participated in an exercise that applied the MoF to several villages and towns within the municipality. Key functions were listed, processed, and mapped in a spreadsheet application (Figure 18). Click here to access the MoF of Bekwai in full detail.

An overview of the MoF (Figure 18) is described below:

- The columns show the "functions," ordered from left to right by frequency.
- The rows show the names of communities/villages, 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.
- Rows with more black cells (i.e., more functions present) indicate urban spaces. A decreasing presence of functions typically indicates that a community is more rural.
- Functionalities to the left are more basic and common across communities, while the ones to the right indicate functions that are more typically associated with 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:

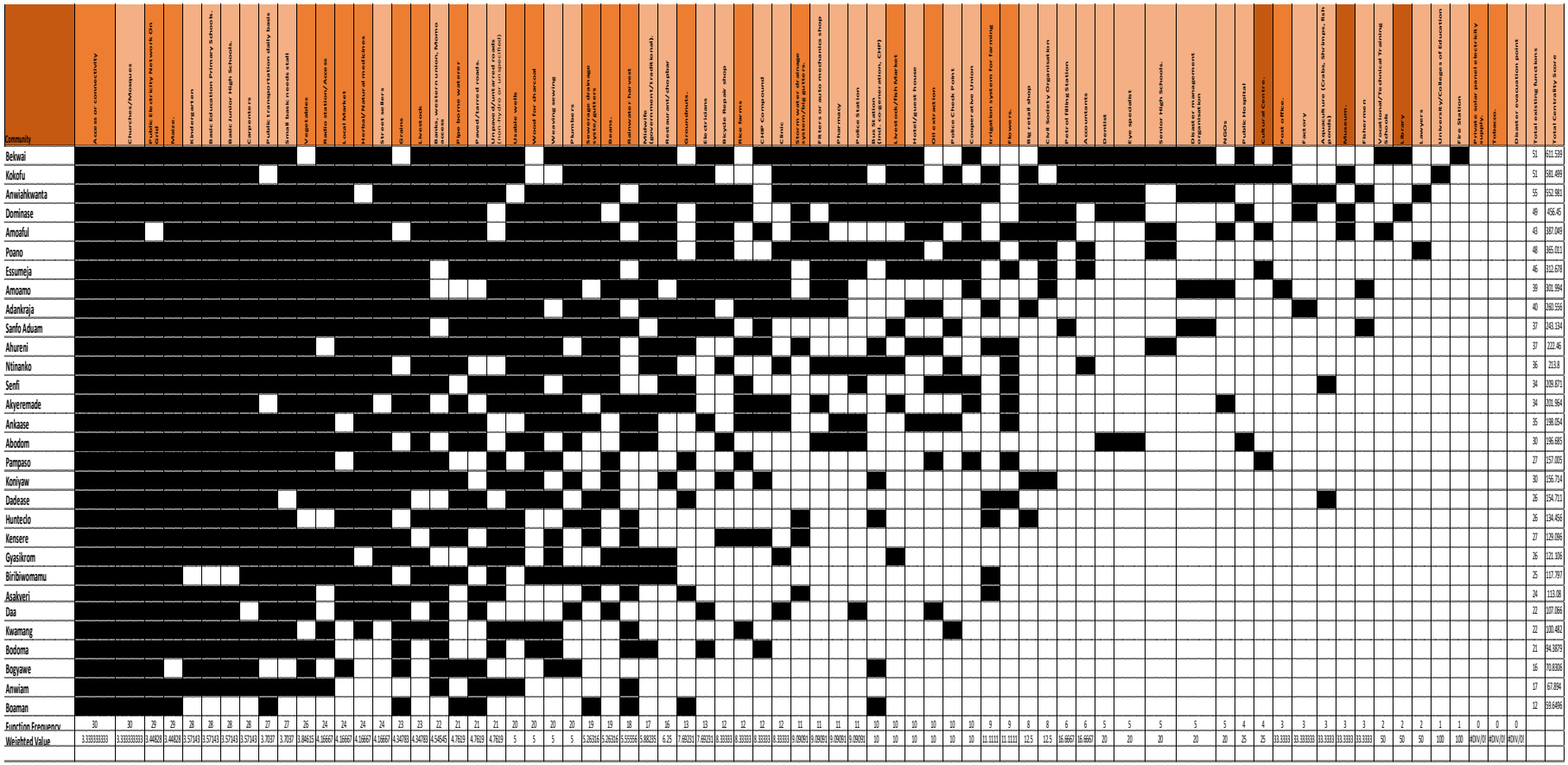
- The results show that the Bekwai district has relatively few urban areas (communities with more black cells) compared to rural areas. Bekwai, Kokofu, Anwiahkwanta, Dominase and Amoaful are the most urbanized communities. Urban areas tend to have certain characteristics that contribute to their relatively higher resilience to climate change compared to rural areas. These include better transportation networks, improved buildings and housing, access to clean water, sanitation systems, reliable energy sources, diverse economies, health care facilities, social networks, and institutions (including local government bodies). Such characteristics can help urban areas withstand and recover from climate-related events like floods, storms, and heatwaves more effectively. The high prevalence of rural areas in the Bekwai Municipality implies that most communities are not resilient to the impacts of climate change.
- All communities have the following functionalities: access or connectivity to internet network; churches and mosques; public electricity network on grid; access to kindergarten, primary schools, and basic junior high schools; public transportation on a daily basis; small basic needs stalls; radio access; and a local market. These functionalities have the potential to facilitate increased resilience. For example, radio access and internet connectivity can enable access to vital information, weather forecasts, early warning systems, and educational resources related to climate change. It can help community members stay informed about climate-related risks, adaptation strategies, and best practices. Internet and radio access also facilitates communication, coordination, and networking among community members, organizations, and authorities involved in climate change resilience efforts.
- Private solar panel electricity supply and disaster evacuation points are functionalities absent in all communities. The low solar electricity generation in the district implies total reliance on the national grid which predisposes the entire district (urban and rural areas alike) to climate change impacts on national grid electricity generation. The national grid has a significant mix of hydropower (37%) (Kuriakose et al., 2022) that can be affected by drying

of the reservoirs as result of extreme temperatures leading to a high rate of evapotranspiration. This will impact businesses such as cold store operators. Also, the lack of a designated location where people can be conveyed to, gather, and seek refuge during and after a disaster in the entire district implies there is no location away from the disaster zones where people can find shelter and be kept out of harm's way. Flood events were identified as the most common disaster in the municipality during the stakeholder workshop and the climate analysis also revealed that heavy rain events are on the rise. This has serious implications for most communities in the municipality.

- In terms of health, each town has access to health care (at least one of a community-based Health Planning and Services (CHPS) program, public hospital, or clinic) with the exception of Pampaso, Dadease, Hunteclo, Biribiwomamu, Kwamang, Bogyawe, Anwiam, and Boaman. Climate change can lead to an increase in extreme weather events, such as hurricanes, floods, and heatwaves. These events can result in injuries, illnesses, and other health emergencies. Health care centres provide immediate medical assistance and emergency response to individuals affected by climate-related disasters. Prompt medical attention can save lives and reduce the long-term health impacts of such events. Communities that lack health care centres would need to rely on facilities in nearby communities which could delay timely treatment and response and put pressure on the health care centres. Experts from the Ghana Health Services and the Department of Public Health of the municipality during the stakeholder workshop indicated the increasing prevalence of climate-related transmission and distribution of diseases, including vector-borne diseases like malaria, waterborne diseases, and respiratory illnesses. Health care centres play a vital role in disease surveillance, prevention, and control. They can provide vaccinations, conduct disease monitoring, educate communities about disease prevention measures, and offer treatment and care for those affected by climate-related health risks. Communities that do not have health care centres would have a delayed or no medical response, disease prevention, and awareness campaign in the district which increases their vulnerability.
- The MoF also showed that maize is a staple in all the communities as well as vegetables. Climate change impacts on maize and vegetable production in the municipality have potential food security implications (Cudjoe, Antwi-Agyei and Gyampoh, 2021).

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 on inviting representatives from all the communities in the municipality to participate in the workshop. The VA team and Planning Department of the municipality strategized to cluster communities with similar characteristics and sample from each cluster to represent the rest. Combining the MoF with a town-level or place-specific VA helped to highlight hotspots of vulnerability in the municipality that require more focused and inclusive adaptation planning.

Figure 18. Matrix of functions for selected towns in the Bekwai Municipality. Click here to access the MoF of Bekwai in full detail.



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

Both literature scoping and the participatory workshop have indicated that most economic sectors of the Bekwai Municipality are climate-dependent and climate-sensitive. Extreme weather events have greater impacts on sectors with closer links to climate, such as water, agriculture and food security, forestry, health, and tourism. Ghana's NAP Framework lists agriculture, water resources, biodiversity and forestry, transport, infrastructure, industry, and human health as the main sectors of socio-economic importance in Ghana. In the context of the Bekwai Municipality, the service sector which constitutes finance, trade, and industry was included as part of the employed population in the district. More than half of the total population are engaged in agriculture, forestry, and fishery. The remainder are in the service and craft-related trades. For these priority sectors, the prevailing climate hazards in the district, identified in the literature (Stanturf et al, 2011; Asare-Nuamah and Botchway, 2019; Ansah et al., 2020) and the participatory stakeholders' workshop, are floods, dry spells, storms, and rainfall variability. All are driven by temperature increases and changes to the rainfall system.

3.2.4.1 Climate Change Hazards and Associated Impacts on Agriculture (Crop, Livestock and Fishery)

Floods remain the greatest hazard to agriculture in the Bekwai Municipality. Frequent and high intensity rainfall trends cause significant flooding in parts of the municipality, especially in areas close to the Odo River and its tributaries. Extensive rainfall outside the municipality sometimes drains into the Odo River, causing it to overflow its banks and, in the process, causing severe damage to farms, communities and livelihoods. Farmers in communities around the river carry out cropping, fish farming, and livestock rearing activities and experience several disruptions and losses because of frequent flooding, which affects their ability to plant or harvest crops in time. Crops' life cycles must be synchronized with the right seasonal changes to maximize yield. Thus, planting and harvesting at the wrong times because of weather events is likely to affect crop development and yield, as well as damage soil stability and suitability.

The most critical period for seed germination and crop establishment is the first 4 weeks when favourable rainfall conditions are needed most. Hence, there is need for clarity and some level of certainty in seasons to assure farmers of when to prepare for planting and harvesting and how to maximize agricultural production. Cessation of the rainfall season is not as critical for plant growth as most plants can survive for several days with little or no rain while the soil moisture content is still high. However, early cessation and prolonged dry spells may result in poor yield which may have consequences for food security and public health. Farmers in the municipality indicated during the stakeholder engagement workshop that they are currently witnessing longer dry spells. The combination of the prevailing climate hazards will impact livelihoods, incomes, and food security of the municipality. The risk of extreme weather events for agriculture is not entirely caused by the magnitude and extent of the hazards, like the duration of floods and droughts, but is also governed by exposure to the hazards and the vulnerability of the system to that event. Therefore, farms closer to Odo River waterways are more exposed to the flooding hazard than those far from it. Moreover, farmers with irrigation systems will be less impacted by dry spells, making them less vulnerable. Although noted as a climate hazard to agriculture in the municipality during workshop, storms have a lower frequency of damaging crops. However, rainstorms and dust storms have the potential of breaking, uprooting, and transporting topsoil which will have negative consequences for agriculture production.

3.2.4.2 Climate Change Hazards and Associated Impacts on Forestry

Climatic warming through more frequent heatwaves, droughts and storms and accompanying pathogen attacks are critical causative agents in abiotic and biotic stress factors for forests (Keenan, 2015). Although these factors are currently minimal in the Bekwai municipality, projections of future climate in Ghana, and for the municipality, indicate likely increases in such occurrences. Illegal mining is another major anthropogenic driver of forest disturbance and destruction in the municipality. Ecological disturbances due to illegal mining activities affects ecosystem services such as the provision of freshwater through contamination with heavy metals used in mining activities. The unsustainable nature of the mining activities poses both environmental and socioeconomic threat to the municipality. Since the lands are not reclaimed, the environmental impact is also not reversed and as a result such lands cannot be used for agriculture to create jobs and livelihood for people. Forests influence the local climates. They moderate higher temperatures and heatwaves through reduced evapotranspiration and affect rainfall cycles. Prevailing deforestation in the municipality will exacerbate future temperature and rainfall trends within Bekwai in a negative way, including through increased daily temperatures and heatwaves, threatening human health.

3.2.4.3 Climate Change Hazards and Associated Impacts on Water and Sanitation

There are two main sources of water: surface water and groundwater. Surface water is found in lakes, rivers, and reservoirs. Groundwater lies under the surface of the land, where it travels through and fills openings in the rocks. Groundwater covers soil water, deeper vadose zone water, and unconfined and confined aquifer waters. Surface water in Ghana is made up of three discharge or outlet systems, namely: the Coastal River systems, which is the smallest; the Volta system, which is the largest; and the South-Western, which is the intermediate system. Pipe-borne water access in Bekwai is from groundwater sources while agriculture feeds on rains and river sources. All these sources are affected by climate change. Climate change influences the hydrological cycle and groundwater systems, changing soil infiltration, deeper percolation, and groundwater recharge. Also, rising temperature increases evapotranspiration over land, which limits the amount of water that can replenish groundwater (Cuthbert et al., 2019). Like surface water, groundwater will also be affected by climate change through drought. When drought conditions persist, the groundwater reserves are depleted and residual water is often of inferior quality. This is a result of the leakage of saline or contaminated water from the land surface, the confining layers, or the adjacent water bodies that have high concentrations of contaminants (Peters, 2005).

Bekwai district is already known for frequent water shortages, which leads to long queues at water supply points. Some residents allege that the Ghana water company intentionally cut water supply to control replenishment of underground water. Whether this is true or not, it gives a certain indication that future climate change, coupled with growing population and economic activities, could create a severe water shortage to make the communities more vulnerable – and could result in tensions and conflict.

Water availability and quality have significant implications for sanitation, hygiene, and health. Contamination could bring different health challenges. Any shortage of water will affect domestic water use and those with no money or means to afford quality water from private market sources may have to rely on poor-quality and unsafe water sources.

3.2.4.4 Climate Change Hazards and Associated Impacts on Human Health

It is becoming clearer that climate change poses serious threats to human well-being and health. Effects of climate change on human health may be direct or indirect. Direct effects of extreme weather events, such as heat waves, droughts, cyclones, and tropical storms, have led to loss of life (Franchini & Mannucci, 2015). Indirect effects related to climate changes, such as the worsening of ambient air quality and the impact on infectious and vector disease diffusion, also threaten human health. During the participatory stakeholder workshop, participants indicated the prevalence of skin rashes and respiratory diseases during the dry season and increases in malaria and cholera incidents during the rainy season in some local communities.

3.2.4.5 Climate Change Hazards and Associated Impacts on Infrastructure and Transportation

Climate extreme events such as floods and rainstorms have negative implications for infrastructure such as buildings, roads, and bridges. Impact ranges from limiting public access to critical infrastructure, to physical damage and destruction. For example, a 2017 flood submerged the bridge connecting Bewai and Awiankwanta, blocking access to the road, which is a major transportation route within the districts and between Bekwai and other parts of the country. Storms and rainstorms have caused the removal of roofs of schools and homes in the district, thereby causing suspension of school activities.

3.2.4.6 Climate Change Hazards and Associated Impacts on Finance, Trade, and Industry

Climate elements and associated hazards have little association with the finance, trade, and industry sectors. However, these sectors are heavily linked to sectors that are core climate dependent. For example, agriculture provides commodities for trade and raw materials for industry. Rural and commercial farmers also lend to other farmers. Impacts of climate change on these sectors could lead to loan defaults by borrowers or disrupt supply chains for traders and industries. Red oil processing from the palm tree is a major industry in Bekwai, and it contributes to local employment, particularly for women. The nursing and transplanting of palm seedlings is highly climate sensitive and if done inappropriately, severely impacts productivity and yield of the crop. Rainfall and seasonal changes resulting from climate change pose a great threat the palm oil value chain, which would have a significant impact on livelihoods of local women.

3.2.4.7 Ranking of Critical Sectors by Levels of Vulnerabilities

It is important to rank the vulnerability of Bekwai's key sectors to enable prioritization both in vulnerability assessment and adaptation planning. The five key sectors identified in the municipality are agriculture; forestry; water, health, and sanitation; infrastructure and transportation; and finance, trade, and industry. During the stakeholder engagement workshop, the participants ranked 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 with high = 5, medium-high = 4, medium = 3, medium-low = 2, and low = 1. The result is presented in Table 6.

Table 6. 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
Forest (biodiversity and ecosystems)	5	4	5	5	4.75
Water, health, and sanitation	5	4	5	5	4.75
Infrastructure and transportation	4	4	5	5	4.5
Finance, trade and industry	4	2	4	5	3.75

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

Forestry sector players discussing the sector's vulnerabilities and ranking.

3.3 Quantitative Assessment Vulnerabilities

3.3.1 Description of Climate Change Vulnerability Methodology

The participatory risk mapping and matrix of function activities as well as the literature review 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 services, trade, and finance. These sectors also reflect the sectors of focus of the NAP process in Ghana. Indicators were derived from the qualitative vulnerability assessment results in Phase II to quantitatively measure the identified vulnerabilities in these communities and sectors of the district. Questionnaires were derived based on the variable for each indicator and administered to a predetermined sample size households in each community. In total, 220 households were interviewed. Enumerators (primarily staff from the municipal assembly) were trained to visit the communities and interview households for the needed information. The information was collected by enumerators digitally and saved to a cloud database.

An enumerator interviewing household head.

The IPCC (2022) defines vulnerability as the propensity or predisposition to be adversely affected and encompasses three components namely exposure, sensitivity, and adaptive capacity. The components of vulnerability interact and such interactions determine the extent to which a system is vulnerable 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

Different indicators have different scales, unit, and magnitude; therefore, 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 to normalize the different 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

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

$X_{i,0\ to1}$ 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.

$$CI = \frac{(I_1 * w_1 + I_2 * w_2 + \cdots I_n * w_n)}{\sum_1^n w}$$ 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 organization, % 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 7 through the survey of 200 households. The parameters for exposure were derived from the data obtained from GMet.

Table 7. Vulnerability parameters

Vulnerability parameters	Scale	Variables	Spatial data
Exposure	District	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 precipitations	
		Annual minimum temperature	
		Annual maximum temperature	
		Frequency of occurrence of drought/dry spell events since 2012	
		Frequency of occurrence of extreme floods events since 2012	
Sensitivity	Community	% of community population with livelihood dependence of 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

Vulnerability parameters	Scale	Variables	Spatial data
		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 8. Example of the method used to calculate district-specific climate change vulnerability

Community	frequency of occurrence of extreme flood events (Mean)	Normalized Data	% of community population with livelihood dependence agriculture	Normalized Data	% of community population with access to credit	Normalized Data	CCV
Abenkyim	3.8	0.2	80%	0	0%	0	0
Aboaso	1.875	0.1	88%	0.6093	88%	1	-0.9390
Afransie	1.615385	0.1	92%	1	8%	0.08791	0.0120

3.3.2 Results of Quantitative Climate change vulnerability assessment

The results of the quantitative VA are presented in maps below. 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 size of the bubbles indicates it magnitude of vulnerability.

3.3.2.1 General Vulnerabilities

The four least vulnerable communities were Bekwai (Average CCV = -0.673809489), Kokofu (-0.488053888), Aboaso (-0.455260473) and Anwiankwanta (-0.420938128) (Figure 20). The four communities with the highest CCV scores were Boni (0.049767642), Dotom (0.011136096), Koneyaw (0.009830641) and Afransie (Average CCV = 0.000326384). Communities along the Odo River (Boni, Afransie, Abekyim) tend to have greater exposure and sensitivity to flooding which makes them more vulnerable to the impacts of climate change. Higher vulnerabilities in Dotom and Gyasikrom is driven by human unsustainable deforestation and degradation which increases their exposure to climate induced hazards.

Figure 19. Exposure (a), sensitivity (b), and adaptive capacity (c) distribution across selected communities in the municipality

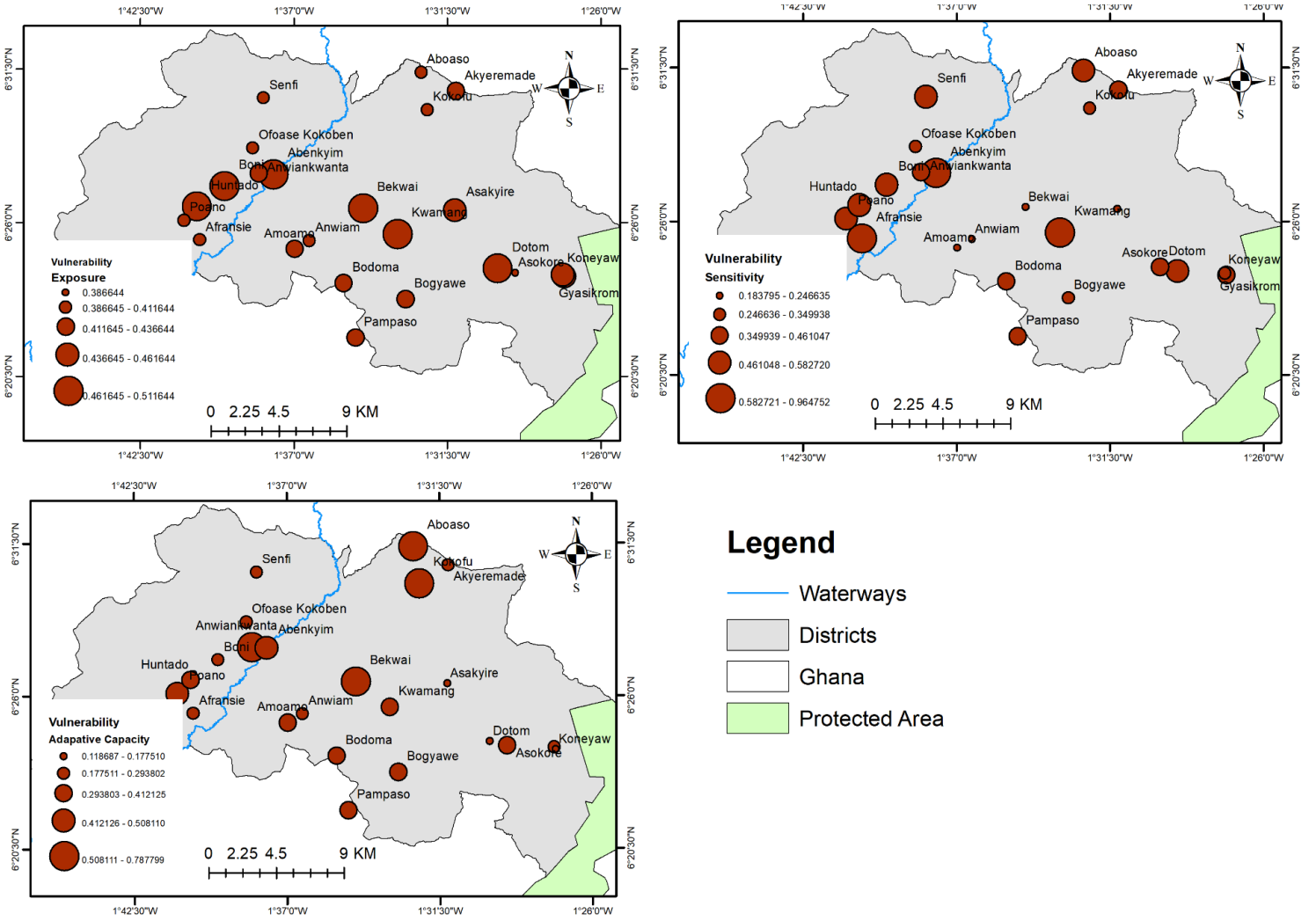
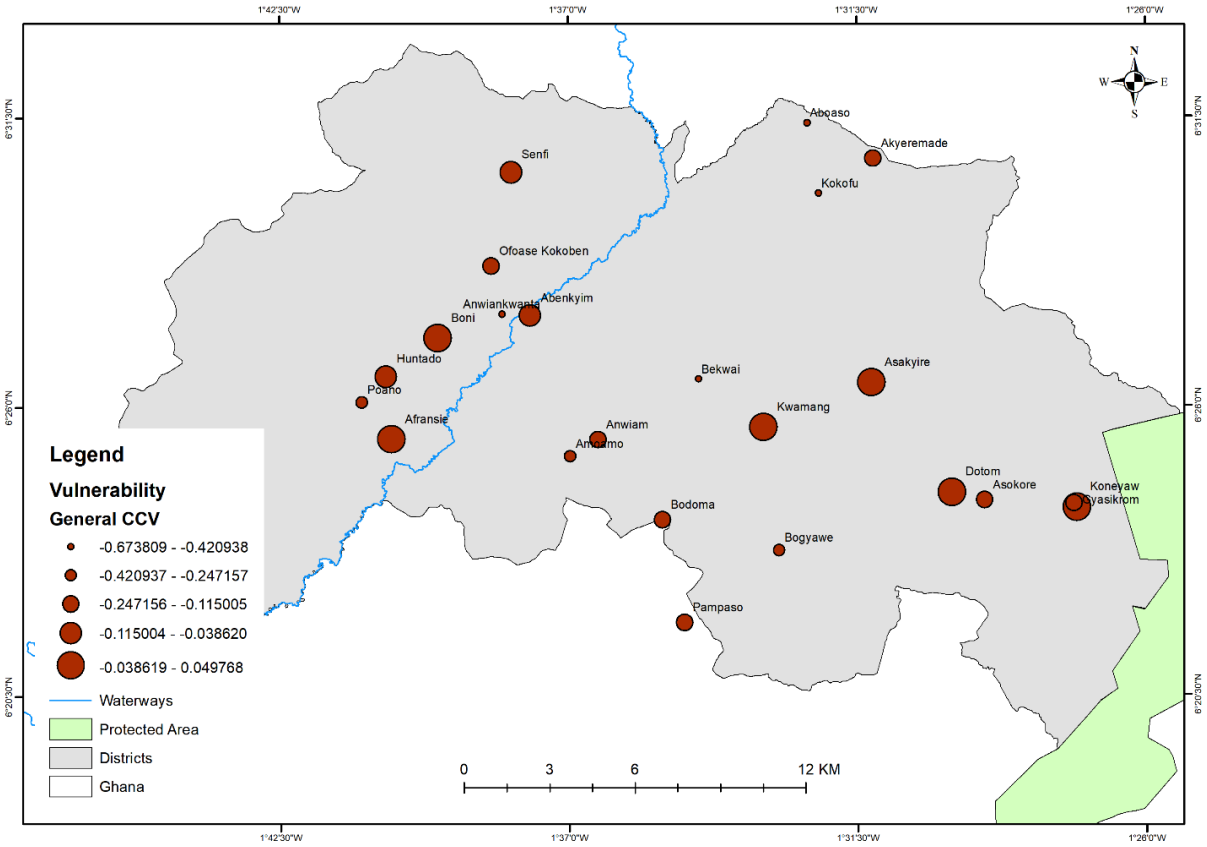


Figure 20. Vulnerability map of selected communities



Note: The larger the red circle, the greater the level of vulnerability in the community.

3.3.2.2 Vulnerability by Sector

Table 9. Sector-related breakdown of climate change vulnerability parameters

Sector	Exposure	Sensitivity	Adaptive Capacity	CCV
Agriculture	0.45	0.62	0.35	-0.07
Water, health, and sanitation	0.45	0.52	0.29	-0.06
Forest (biodiversity and ecosystems)	0.45	0.41	0.38	-0.20
Infrastructure and transportation	0.45	0.30	0.35	-0.21
Services, trade, and finance	0.45	0.23	0.33	-0.23

Note: The heatmap utilizes a colour gradient from deep red to deep green, with constant “Exposure” across all sectors represented in a uniform colour (green), “Sensitivity” and “CCV” showing higher values with red and lower values with green, and “Adaptive Capacity” depicted inversely with green indicating higher and red indicating lower adaptative capacity.

For sector-related vulnerabilities, exposure is constant for all the sectors as the GMet climate/weather data is provided at the municipal level.

The sector calculations were performed following the same procedure as the communities. The various indicators were aggregated for each vulnerability component and equation 3 was used to estimate the overall vulnerability for the sector.

Vulnerability was calculated using the equation: CCV = (Exposure x Sensitivity) – Adaptive Capacity. Agriculture remains the most vulnerable sector to climate change (Average CCV= -0.07) followed by Water, Health, and Sanitation (-0.06), Forestry (Biodiversity and Ecosystems) (-0.20), Infrastructure and Transportation (-0.21), and Services, Trade, and Finance (-0.23). This observation is explained by the identified sectoral drivers of vulnerabilities already explained in the preceding qualitative assessment section.

3.3.2.2.1 Focus on Agriculture

Vulnerabilities in the agriculture sector were highlighted due to the sector's contribution to the economy of the municipality and its vulnerability to climate change. Table 10 presents the indicators used in estimation of climate change vulnerability in the agriculture sector.

Table 10. Exposure, sensitivity, and adaptive capacity indicators for the BMA

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

In general, vulnerability of the agriculture sector is relatively highest among communities along the Odo River due to their high exposure and lower adaptive capacity. However, other locations such as Anwiam, Kwamang, Asakyire, Dotom and Koyeyaw have shown higher agriculture sector vulnerabilities. Their vulnerability is due to higher sensitivity influenced by human-induced unsustainable activities such as illegal mining that poses a threat to agriculture activity.

Figure 21. Agriculture sector-related exposure (i), sensitivity (ii) and adaptive capacity (iii) in the selected communities in the municipality

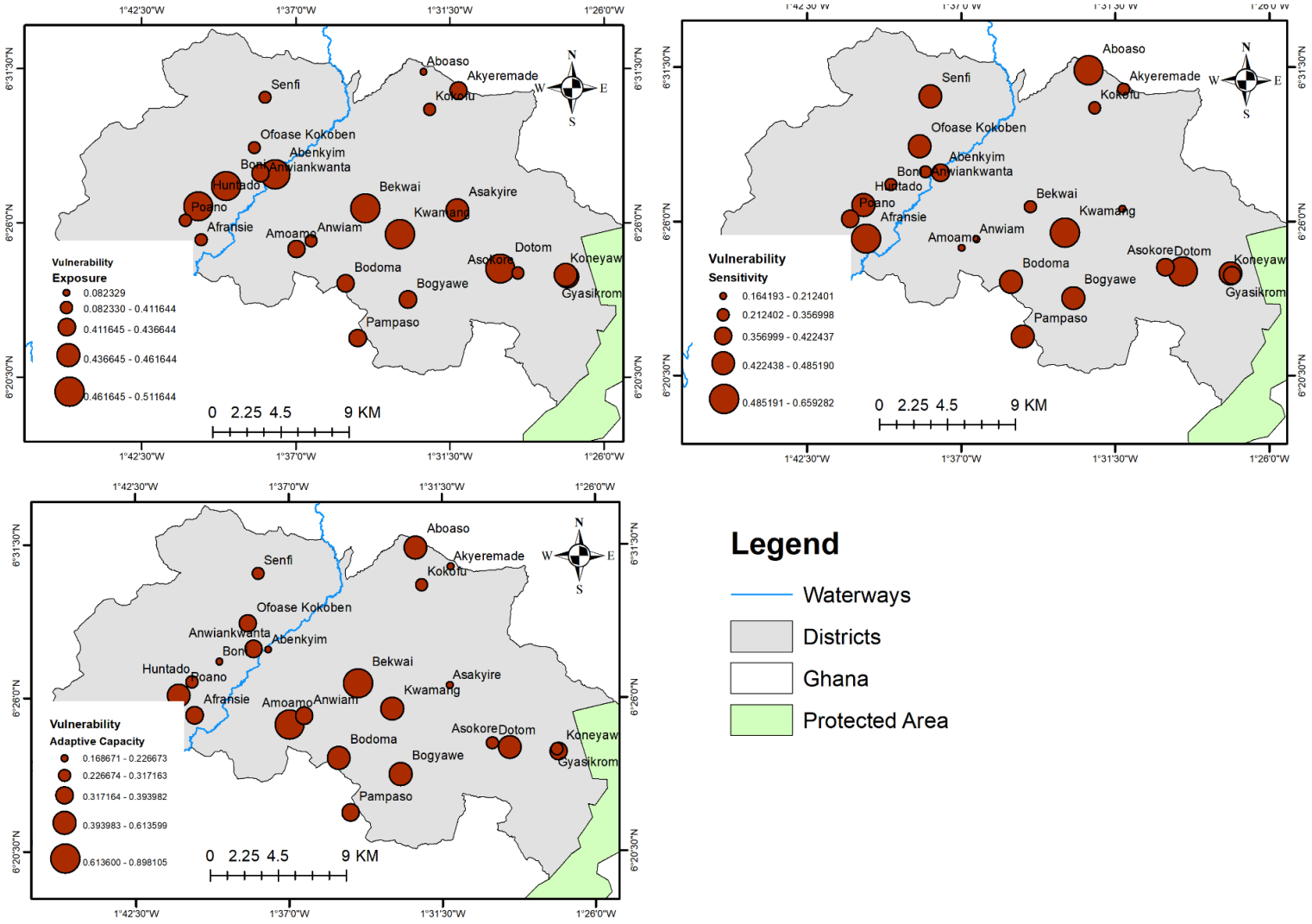
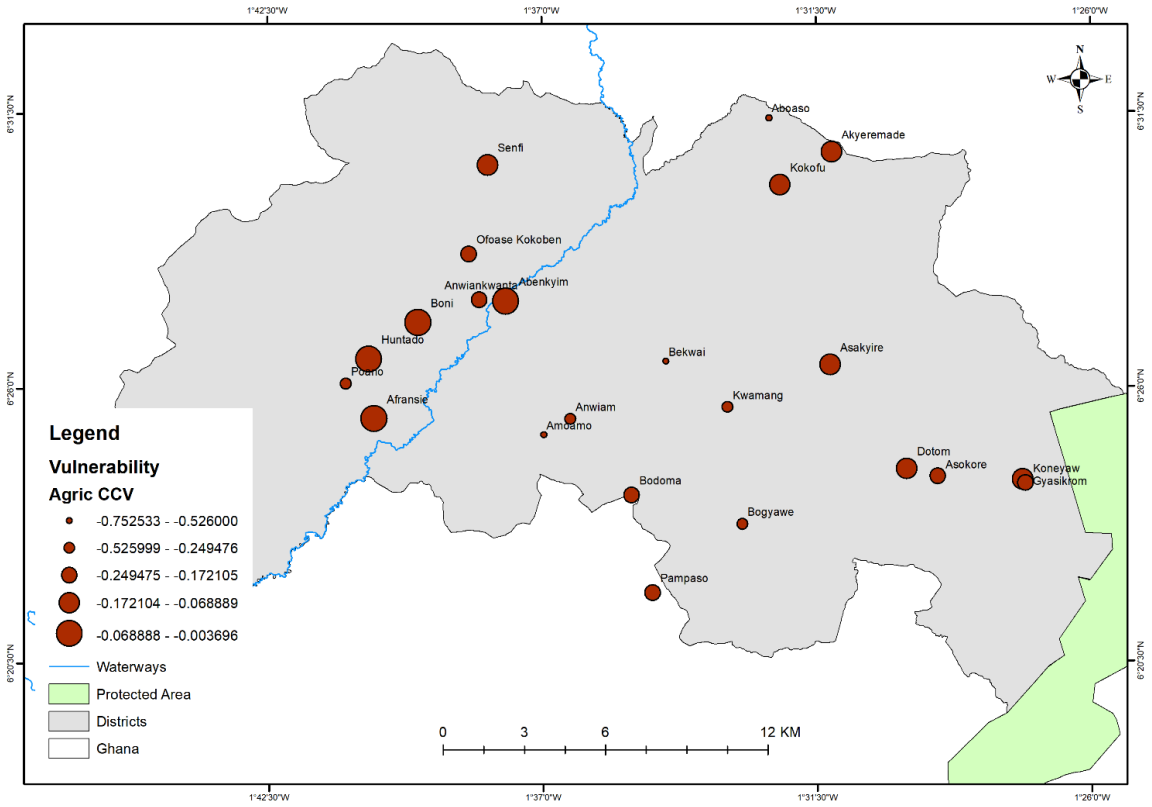


Figure 22. Agriculture sector-related vulnerability map of the selected communities



Based on the results of the CCV assessment, it is evident that climate change adaptation interventions are urgently required to enhance climate resilience in most parts of the Bekwai Municipal, especially in the agriculture sector.

4. Assessing Future Climate Change Risk

4.1 Climate Change Projections

Climate 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 covered two timeframes. The baseline was the period 1980-2020, whereas the future projections are up to the year 2100. The analysis projected future climate for the Representative Concentration Pathway (RCP) 4.5 and RCP8.5 emission scenarios. The RCP4.5 was assessed as a midway scenario and RCP 8.5 as a realistic business-as-usual scenario given the current trajectory of greenhouse gases emissions. The climate projection took the steps described below.

4.1.2 Data Collection for Climate Projection

Observational climatological data from 1980 to 2020 was derived from the 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

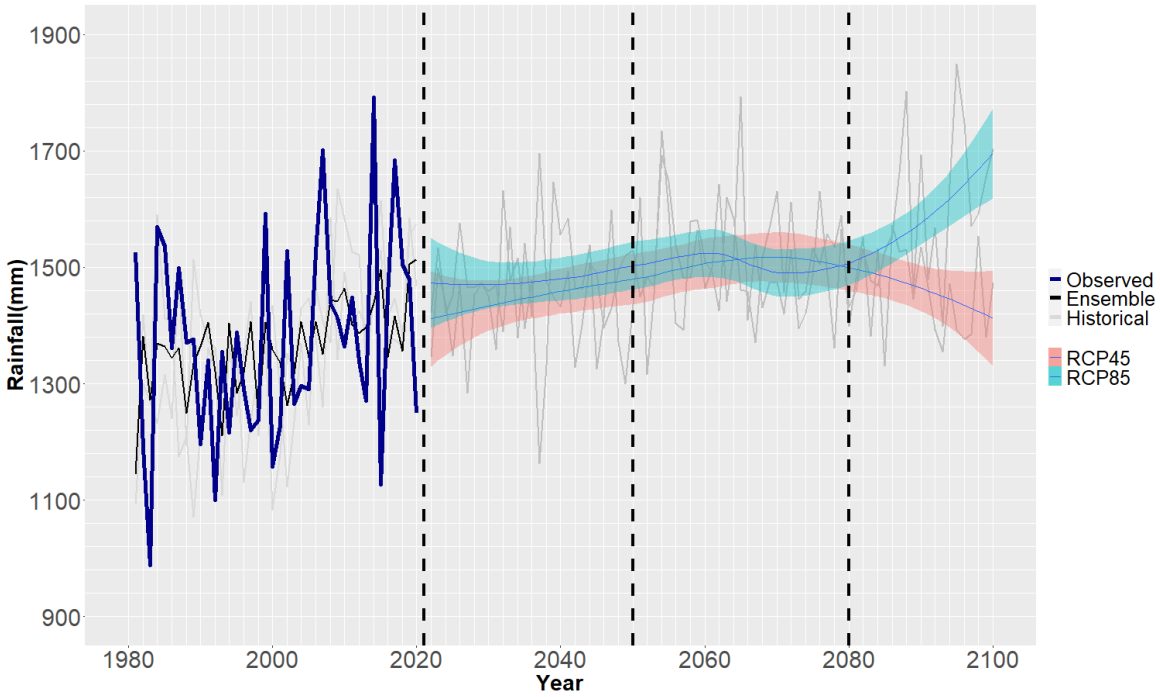
The VA research team downscaled daily rainfall, and maximum and minimum temperature data using the quantile-quantile transformation method. The projections (corresponding to 10 different combinations of General Circulation Models and Regional Climate Models) were produced for RCP 4.5 and 8.5 emission 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 the observed and projected data are summarized below.

Both RCP 4.5 and 8.5 emission scenarios project that rainfall will generally remain variable to the end of the century. The projections expect rainfall to increase steadily up to the end of the century with a brief decline in both variability and intensity in 2070s. The annual rainfall amount is expected to increase from 1,320 mm to 1,490 mm by 2060 (see Figure 23). The intensity of rainfall is expected to significantly increase beyond 2080 with a mean annual rainfall of 1,500 mm. The consistent inter-annual variability is most likely a signature of heavy events and dry spells. Long dry spells, particularly in the wet season, are likely to characterize years with low annual rainfall, whiles years with heavy rainfall will most likely be prone to floods events. Climate extreme events will be characterized by wet years and dry years. It is very likely that Asante Bekwai will have rainfall amounts higher than the means discussed.

Figure 23. Projected annual rainfall over Asante Bekwai



Nighttime temperature is expected to rise significantly until the end of the century. From the current annual mean of 21°C, nighttime temperatures are expected to rise to an annual mean of 22.4°C by 2050. This is expected to increase by another 1°C by the end of the century, and the annual mean could be as high as 24°C under a RCP8.5 emissions pathway. The increase in night temperature seems to be at a higher rate than daytime temperature, as shown in Figures 24 and 25. This means that the temperature at night will continue to be warm, while the number of cold nights will continue to decline. Warm nights are therefore expected in future.

Projections of daytime temperatures are similar to that of nighttime temperatures, i.e., daytime temperature is expected to increase till the end of the century (see Figure 25). The mean annual temperature is expected to increase from 31.5°C to 32.5°C by 2050. This will likely increase further by a fraction of a degree by the end of the century, or over 33°C under a RCP8.5 emissions pathway. The continuous warming during the day indicates that cold days will continue to decrease while warm days will increase.

Figure 24. Projected mean annual minimum temperature over Asante Bekwai

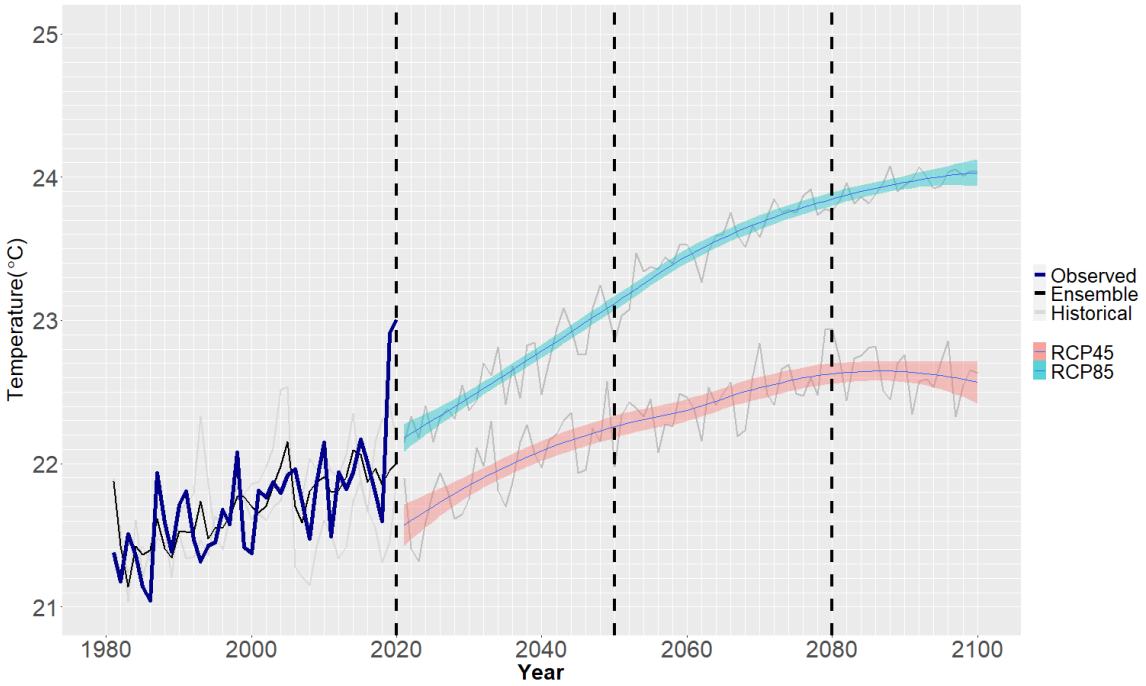
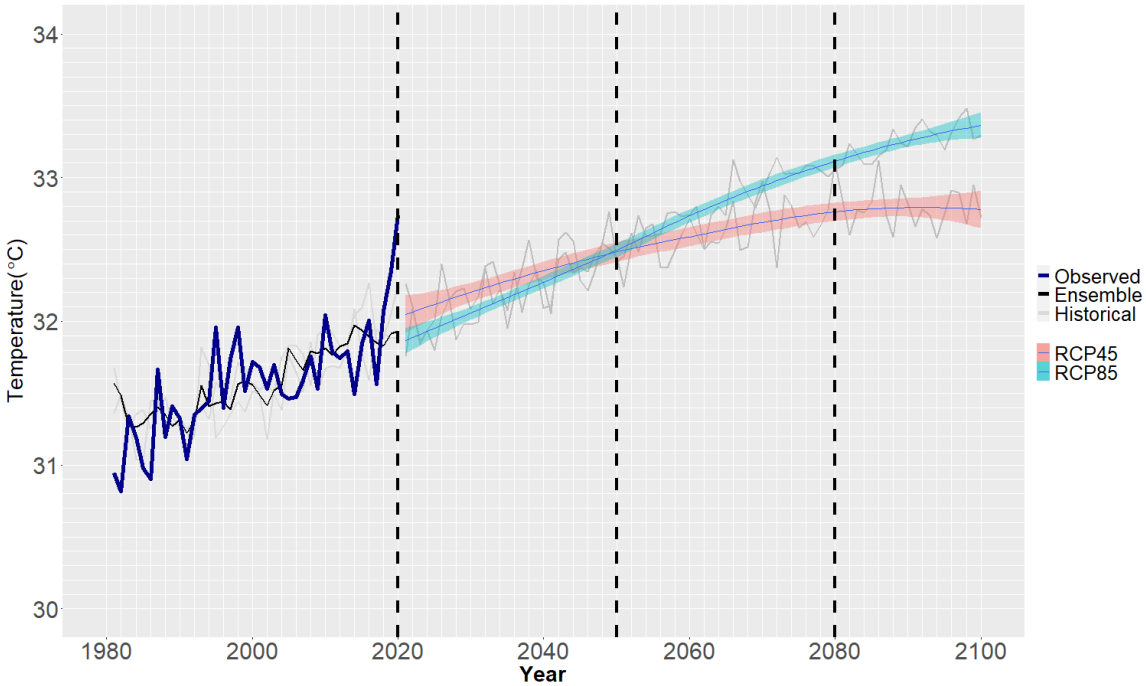


Figure 25. Projected mean annual maximum temperature over Asante Bekwai



4.1.5 Summary of Climate Change Projections

Asante Bekwai is expected to experience a steady increase in rainfall amounts and variability. Annual variability of rainfall will likely translate into intermittent rainfall as well as prolonged dry and wet spells over the municipality. The variation in rainfall will likely reveal itself at the start of the rainy seasons with higher risk of an increased occurrence of floods. Some years may have an early onset of the season, while others may delay. There is likely going to be a steady rise in both daytime and nighttime temperatures over Asante Bekwai. The frequency of cold days and nights are projected to continue to decline, while warm nights and days will continue to rise over Asante Bekwai.

4.2 Potential Impacts and Future Climate Change Risk

Both the projected steady increase in rainfall amounts (i.e., an increase from 1,320 mm to 1,490 mm by 2060 and a mean annual rainfall of 1,500 mm by 2080) and variability as revealed by this assessment has socioeconomic consequences for the people living in the municipality. Future temperatures are projected to increase by 1°C by 2050. The combination of increasing rainfall intensity and variability as well as temperature will affect the economic sectors, as discussed below.

4.2.1 Agriculture

Annual floods are expected to result from the expected increase in wet spells in wet years; and annual droughts are also expected to significantly increase with the expected increase in dry spells. Continued reliance on rainfed agriculture is expected to lead to decreases in crop production (EPA, 2021, p. 206).

These climate impacts will exacerbate the vulnerabilities of the agriculture sector in the municipality, particularly along the Odo River where the occurrence of floods and subsequent destruction of crops is expected to increase. Long dry spells are expected to affect all farming areas in the district. Consequently, crop production and yields will decline in the district, thereby affecting livelihoods. Also, the impacts of climate change could lead to an increased risk of loan default and higher cost of and less access to credit and loans for agricultural activities. Critical communities that will be affected, as determined through the vulnerability mapping described in Section 3.2.2.2.2, are: Senfi, Ofoase, Kokoben, Boni, Huntado, Poano, Daa, Akyiase, Afransie, Abenkyim, Aboase, Dotom, Asokore, Gyasikrom, and Kokotro.

4.2.2 Water Resources

Water-related impacts – such as water scarcity – are expected to be district wide. Groundwater resources constitute the greater source of water for domestic and commercial activity in the municipality. A growing population and increased economic activities coupled with projected increases in temperature and drought frequency and intensity will make the municipal groundwater supply system increasingly vulnerable to changes in climate. With a lack of diversified sources of water, increasing temperatures are expected to contribute to water scarcity in the municipality in both wet and dry years due to low water storage and high evapotranspiration.

4.2.3 Human Health

Cases of tropical diseases (e.g., cholera, typhoid fever, bacillary dysentery, hepatitis, giardiasis, scabies, lice, trachoma, ascariasis, bilharzia [schistosomiasis], threadworm, yellow fever, and malaria) are expected to surge up in the coming years due to increasing temperatures and rainfall. There is also the likelihood of the emergence of novel diseases. Increasing temperature and erratic rainfall patterns, compounded by high levels of humidity, can affect health and productivity of people. Human health-related impacts will be district wide.

4.2.4 Forestry

Climate vulnerability in the forestry sector is exacerbated by unsustainable human activities such as timber extraction, logging, and illegal chainsaw operation. Excessive logging makes forests more susceptible to fire by causing logging residues which dry up and become more combustible. Projected increasing temperature are expected to increase the frequency of bush fires. This will exacerbate already existing impacts such as disappearance of some communal resources such as snails, mushrooms, and wildlife which could satisfy the food needs of local people. Communities that live close to forest areas will be greatly impacted.

4.2.5 Infrastructure

Poor housing and building conditions such as exposed foundations, leaking roofs, cracked walls, and dilapidated wooden structures; and untarred roads that are deteriorated and not well maintained exist in some communities of the municipality. Annual floods are projected to significantly increase in the communities of the Bekwai Municipality located beside rivers. Occupants of such weak housing infrastructure and people who travel on poor roads for business will be impacted in the future. Also, the destruction of forests with tall trees that serve as wind breaks could leave households, schools, and public buildings vulnerable to climate-related risks such as the uprooting of trees and thunderstorms. Participants indicated during the stakeholder engagement workshop that the current state of the bridge connecting Bewai and Awiankwanta would not be able to bear future floods and could easily be washed away as recent floods are of greater magnitude. All these impacts have negative implications for sustainable development in the Municipality as funds meant for new projects could be redirected to fixing damaged infrastructure.

4.2.6 Service Sector

The impacts of projected climate on other sectors such as agriculture, water, forestry, and infrastructure will come to play in the service and commence sector. Agriculture and forestry produce raw materials for industry and traders. Impacts upstream will therefore affect productivity downstream. Also, the sector constitutes the second largest employer in the district and provides jobs that could serve as alternative livelihoods to cushion people whose primary income is from agricultural production. Impacts – such as reduced agricultural productivity – will affect several businesses and could lead to higher costs of goods and services.

4.2.6. Energy

The projected increase in daytime and nighttime temperatures would lead to a surge in the demand for cooling during both day and night, which will most likely increase pressure on the already strained electricity generation sector.

4.2.7 Gender

Women form most of the agricultural labour force and undertake activities spanning from land preparation to processing of produce. They are constrained by limited access to credit facilities. In Bekwai, the processing of palm nut into oil and soap serves as employment for a significant number of women. Projected climate change impacts on agriculture will therefore have a large effect on women.

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 BMA MTDP (2022-2025) the following scenarios and created together with corresponding adaptation options to consider in building resilience building to climate change.

Table 11. Scenarios for climate response

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 no action is taken. **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 Bekwai Municipality recognizes the urgent need to address climate change and implement some district-level projects in the course of fulfilling its responsibilities to improve the well-being of its citizenry, ranging from agricultural-related supports to the provision of health and infrastructural 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 Bekwai Municipal prioritizes climate change action and considers it as a development issue by mainstreaming adaptation and low carbon economy issues into district development policies, programmes, and projects in a manner that promotes gender inclusivity. **Impact:** The Bekwai Municipality will attain a 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 projected climate change beyond 2050.

The assessment of the BMA MTDP (2022-2025) suggests the Municipal Assembly is on the pathway of scenario B. The pathway of scenario C is most desirable and to be on that pathway will require strong leadership, anticipatory capabilities, stakeholder participation, and financial investment.

5.2 Recommended Adaptation Options

This section provides preliminary adaptation options to address some of the vulnerabilities identified in the BMA. The measures here are only preliminary recommendations based on experts' opinion and literature review. The team acknowledged that this VA is to identify, highlight vulnerabilities, and inform a comprehensive adaptation planning process that commenced in 2022.

- **Climate Information Services:** The assessment reveals that about 45% of households have no access to climate information services, which reduces their adaptive capacity to deal with climate variability. With a projected increase in rainfall variability in the future, it is imperative that efficient and effective climate information services be delivered to the inhabitants of the municipality to foster strategic planning of economic and agricultural activities. It is desirable that models such as co-production of climate information services are adopted.
- **Improved Seeds:** The climate projections reveal an increase in the occurrence of long dry spells in the future. High-yielding, early maturing, and drought-resistant seedlings should be developed for and accessible to farmers.
- **Smart Agriculture and Conservation Practices:** Innovative smart agricultural and environmental conservation practices should be introduced to farmers. The municipal's MTDP contains a program to educate farmers on "No Till Agriculture" and establish demonstration programs on Conservation Agriculture. This must be considered with the necessary urgency.
- **Afforestation:** Tree planting should be encouraged in addition to securing existing patches of forest over the area. The Municipal Assembly's MTDP outlined a programme to undertake afforestation. Afforestation should include tall trees that serve as wind breaks to protect weak housing infrastructure.
- **Enforcing Forest Management Regulations:** Unsustainable human environmental degradation in communities such as Dotom and Gyasikrom has increased their sensitivity to climate change impacts through the destruction of soil quality. Therefore, forest management regulations must be enforced to protect forest biodiversity and ecosystem services that support farming communities in the district.
- **Irrigation Systems:** The results of the assessment indicated that only about 15% of surveyed farming households had irrigation facilities which were predominantly traditional and not modern. Modern irrigation systems should be constructed and made accessible to farmers. These could be powered through solar panels.
- **Research and Development:** In an ever-changing climate, which is fast rendering existing solutions ineffective and insufficient, it is prudent to ensure continuous research for new, innovative, and climate-resilient solutions. This will require timely and appropriate investments through creative partnership arrangements.
- **Alternative Livelihoods:** Agriculture forms the primary occupation of households in the municipality. The assessment shows that only 41% of agricultural households are engaged in alternative livelihoods. This implies that households should be equipped to undertake other less climate- sensitive alternative livelihood activities.

- **Crop Insurance:** Only 2% of farming households surveyed had crop insurance. Risk transfer mechanisms such as crop insurance should be introduced to farmers to provide some recovery in extreme climate events.
- **Access to Credit:** About 15% of households surveyed had access to credit facilities, and access to credit is an important determinant of farmers engaging with crop insurance (Balmalssaka et al., 2016). The projected climate change impacts with the increase the risk of lending in the agriculture sector could make it more challenging for farmers to access credit facilities in the future. Increasing and easing access to credit for farmers is important to enable them to make investments that improve their resilience to climate change. This could be achieved through the Ghana Incentive-Based Risk Sharing System for Agricultural Lending (GIRSAL). The GIRSAL provides credit risk guarantees to financial institutions to increase lending to the agricultural sector in Ghana.
- **Climate Change Education and Sensitization:** The BMA MTDP includes programmes to sensitize the public on issues of health and sanitation. This should be intensified, and climate change-related health issues should be integrated in these programmes.
- **Rainwater Harvesting and Increasing Storage Capacity:** The culture of rainwater harvesting must be instilled in the citizenry to address the limited water resource sources available to the district and the projected impacts on this sector in the future. Large storage facilities should be constructed to capture and store rainwater for distribution, which would lessen pressure on the water tables.

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Appendix 1. Stakeholder List

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

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 and Coordination Unit (MPCU)**	Municipal Planning 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	• 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	• Coordinates and implements agricultural policies and practices in the municipality.	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 (NCCE)	NCCE Officer	• 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	• Increased awareness raising and climate change education.
Regional Coordinating Council (RCC)	RCC Director	• Promotes the implementation of activities that address the rights of women, children, and youth.	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	• 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 gender vulnerabilities to be addressed.
Ghana Health Service**	Municipal Environmental Health Officer	• Coordinates UNFCCC-led policies and programs • Supports the global response to the threat of climate change	W; I	• A strategic focus will be given to them for priority health vulnerabilities to be addressed.
UNFCCC Focal Point	UNFCCC Focal Person	• Promotes the implementation of activities that address the rights of women, children, and youth.	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				
None identified yet	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 Bekwai 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	
Global Affairs Canada	Representative		W; I	
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				
Dess 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 2. Research Questionnaire for Vulnerability Assessment at the BMA

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 3. Stakeholder List

1. Farmers Group
2. Ghana Federation of Disability Organization
3. Bekwai Youth Group
4. Ghana Education Service (GES)
5. Ghana Health Service (GHS)
6. Zoolmion Ghana Limited
7. Bekwai Municipal Assembly
8. Ministry of Food and Agriculture (MOFA)
9. Forestry Commission
10. National Disaster Management Organization (NADMO)
11. Department of Parks and Gardens
12. Ghana National Fire Service (GNFS)
13. Statistical Service
14. University Ghana
15. Kwame Nkrumah University of Science and Technology
16. Assembly Men/Women
17. Traditional Authority
18. Bekwai Women Farmers Association
19. Traders Association
20. Meteorological Service
21. Campaign for Female Education (CAMFED)
22. Environmental Protection Agency (EPA)


BEKWAI MUNICIPAL ASSEMBLY
AMANSIE PIESIE


FREEDOM
AND
JUSTICE