Climate Change Vulnerability Assessment for the Bibiani-Anhwiaso-Bekwai Municipal Assembly

March 2024 | Final Report

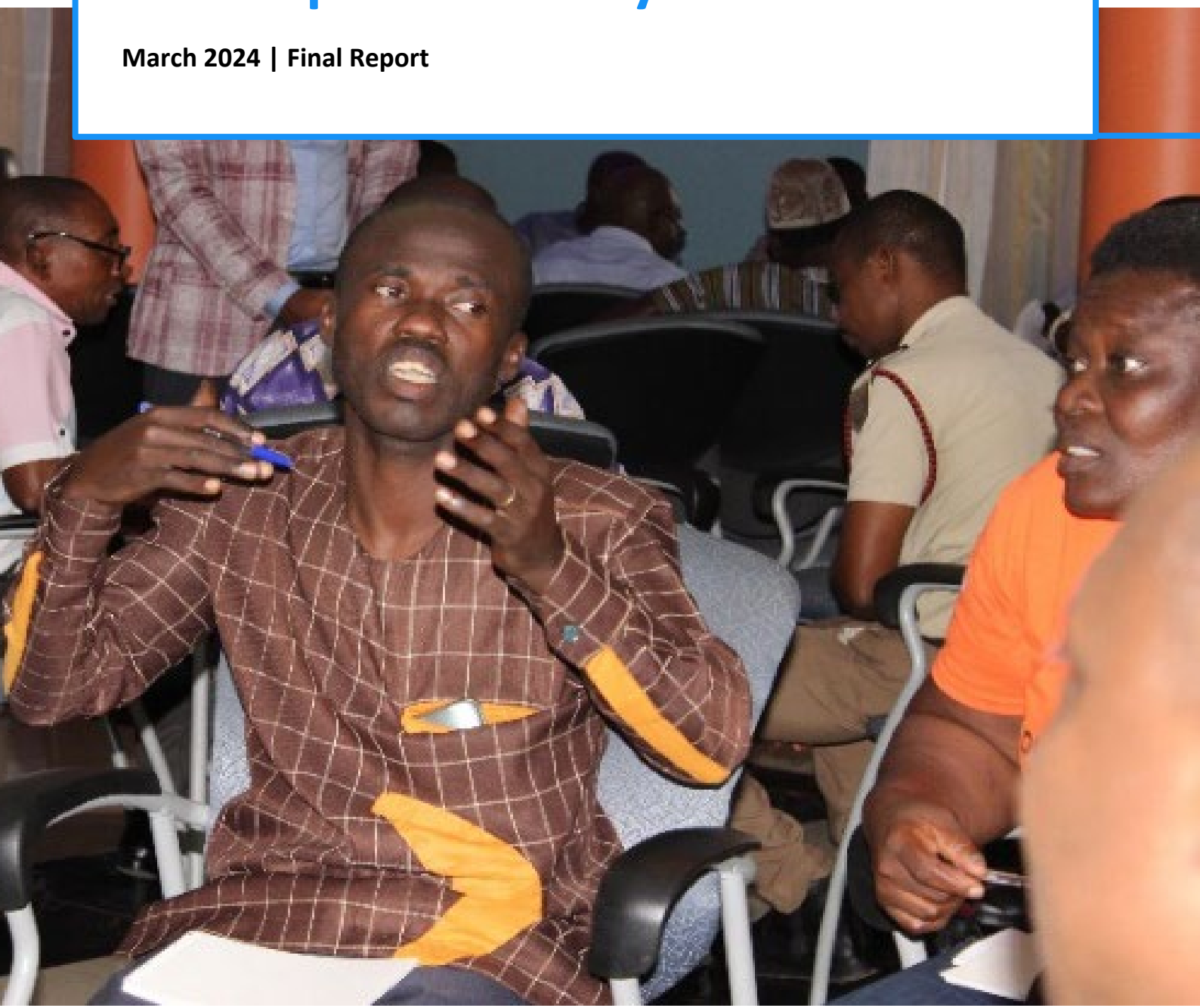

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Photo credit: EPA

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Foreword

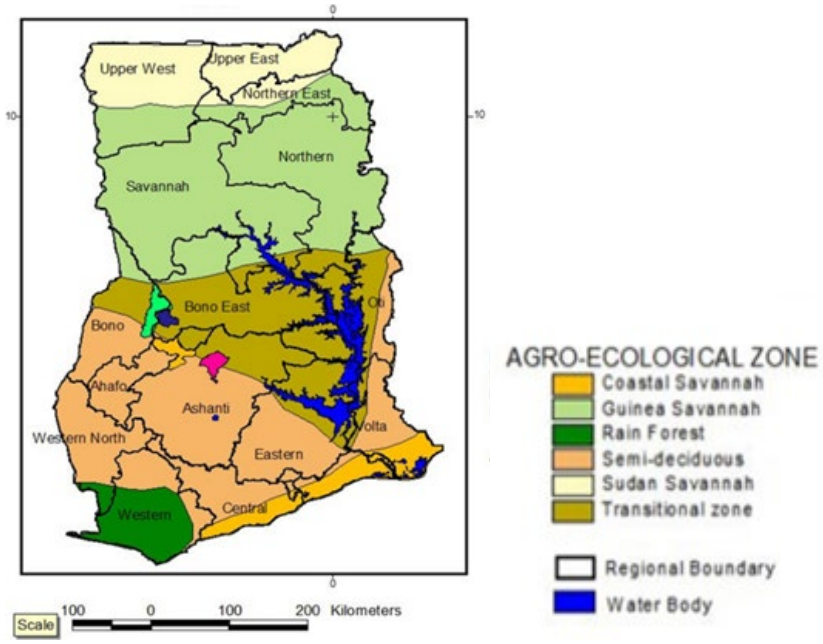
The Government of Ghana prepared six district-level climate vulnerability assessments, each for a municipal assembly located in one of the country's agroecological zones as part of the National Adaptation Planning (NAP) process. These vulnerability assessments aimed to improve the national and subnational 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 Bibiani-Anhwiaso-Bekwai Municipal Assembly (BABMA) and is representative of a district located in the Rain Forest 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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1. 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, and health. Impacts such as drought, floods (both coastal and inland), and heat waves 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 impact 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.

Effective adaptation planning should be built on a deep understanding of current and expected climate impacts and associated vulnerabilities. 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.

The concept of "vulnerability," which is defined here as the *propensity or predisposition to be adversely affected by climate change impacts* (Intergovernmental Panel on Climate Change [IPCC], 2022), is central to adaptation planning. An insightful understanding and appreciation of the nature and drivers of vulnerabilities in specific places and contexts is particularly helpful in the creation of context-responsive adaptation measures. There is no one-size-fit-all in adaptation planning; any effort to homogenize adaptation actions or measures will be premised on flawed understandings of climate change and its impacts across different social and ecological contexts.

Ghana's NAP process 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 (Antwi-Agyei, 2018). To achieve this, Ghana's NAP process has adopted a district-focused adaptation planning process that uses district-level vulnerability assessments to ground adaptation planning for key climate-sensitive sectors such as agriculture (fisheries, crops, and livestock), forestry, water, energy, gender, and health. The aim is to use information on district-level vulnerabilities and geographical considerations to develop standalone adaptation plans for each district in Ghana.

This vulnerability assessment was prepared for the Bibani-Anhwiaso-Bekwai Municipal Assembly and is representative of a district located in the Rain Forest agroecological zone (Figure 1).

1.2 Purpose and Objectives of the Framework

The overarching purpose of this Vulnerability Assessment (VA) Framework is to present tentative conceptual guidelines that inform district-level assessments of climate change vulnerability across Ghana's different districts and as part of Ghana's NAP process. The emerging information will be key to developing standalone district-level adaptation plans. This process also aims to enhance the capacity of various levels of government for effective monitoring, evaluation, and learning (MEL) of the NAP process by providing a trusted knowledge base.

1.3 Objectives of the Vulnerability Assessment

The overarching objective of this VA process is to assess the vulnerabilities and identify human and natural systems as well as economic sectors in the Bibiani-Anhwiaso-Bekwai municipality that are particularly vulnerable to climate variability and change and need special attention. This will help the municipal and national governments to make informed policy decisions when channeling funds for adaptation activities. The specific objectives are:

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

1.4 Outputs of the Vulnerability Assessment

This VA produced seven outputs that are discussed in the following sections of this report:

- Output 1: Development of **Climate Projections and Scenarios** for the Bibiani-Anhwiaso-Bekwai Municipal Assembly – Section 4.2.1.
- Output 2: Description and creation of **representative district-level vulnerability narratives** – Section 4.1.3.
- Output 3: Projections and description **of potential future vulnerabilities** – Section 4.2.2.
- Output 4: Analysis of pathways that link current vulnerabilities to the future – Section 5.2.
- Output 5: Description of **prioritized vulnerabilities** in key climate-sensitive sectors – Section 3.4.1
- Output 6: Creation of a **map of vulnerability hotspots** in the Bibiani-Anhwiaso-Bekwai municipality – Section 3.4.3.
- Output 7: Identification of **available options to help people and communities adapt** to the effects of climate variability and change – Section 5.3.

1.5 Guiding Principles

The preparation of this vulnerability assessment was guided by the following principles (Table 1):

- **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.
- **Inclusivity**: The VA process made conscious efforts to identify, engage, and include all or most of the institutions, sectors, communities, and groups (including women, youth, and marginalized stakeholder groups) who are currently impacted or projected to be impacted by climate change both in the design and implementation of the assessment.
- **Relevant to the NAP and national priorities**: The VA process was aligned with and advanced Ghana's NAP process, as well as other national and Bibani-Anhwiaso-Bekwai Municipal Assembly's development priorities. The VA incorporated sectors and areas of developmental priority in Bibani-Anhwiaso-Bekwai and considered how the results of the VA could inform adaptation action in these sectors.
- **Utilize existing structures and resources:** The Green Climate Fund (GCF) NAP Readiness Programme has been running in Ghana for some time and has generated knowledge, established stakeholder relationships, and built collaboration fora. The VA process utilizes existing structures to save time and costs and contribute to and strengthen existing structures, thereby ensuring the sustainability of this and future VA exercises**.**
- **Gender-sensitive approach:** The VA process sought to understand and consider the different rights, roles, and responsibilities of women and men in the community and the relationship between them in the context of vulnerability to climate change and hazards. Gender-sensitive vulnerability analysis implies that both qualitative and quantitative data used in the vulnerability assessment, disaggregated by gender and age, have been gathered and analyzed. This is in recognition that vulnerable groups (either by age, capabilities, gender, or economic standing) are affected in different ways by climate change and that these differentiated vulnerabilities must be integrated into the analysis. Both men and women were consulted together and separately, for example in focus group discussions, about their perceptions of climate change, climate hazards and risks, and current and potential impacts of climate change on livelihoods and well-being. The Government of Ghana has produced a gender assessment of its NAP process, which informed the VA process (EPA, 2020).

Table 1. Application of the VA guiding principles

Guiding Principle	How applied
District-specific and needs-driven	The VA identified climate vulnerability in the Bibiani-Anhwiaso-Bekwai municipality, which is in the Equatorial Rain Forest agroecological zone. The assessment selected six out of the nine zonal councils within the municipality to examine the vulnerability of each zone relative to the others.
Inclusivity	The VA process engaged 56 key stakeholders (37 men and 19 women) from selected institutions and interest groups in the municipality. The selection of these stakeholders was based on their personal knowledge or work concerning climate change in the Bibiani-Anhwiaso-Bekwai Municipality.
Relevant to the NAP and national priorities	The VA process considered the NAP priority sectors namely, agriculture, water resources and sanitation, human health, transportation, infrastructure, as well as forestry and biodiversity.
Utilize existing structures and resources	The VA process relied on local expertise to identify vulnerability hotspots and to select specific zonal councils to be studied.
Gender-sensitive approach	Throughout the VA process, the selection of stakeholders as well as survey respondents was carefully designed to give representation to both men and women. Additionally, data, especially in Chapter Four on vulnerability to current and future climate change, was disaggregated along gender lines to assess gender dimensions of vulnerability.

Source: Author.

1.6 Definition of Key Terms

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

- **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 exploit beneficial opportunities." In natural systems, adaptation is "the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects."
- **Exposure** is defined as "the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected" by climate risks and 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 damage, to take advantage of opportunities or to respond to consequences" of climate change – including climate variability and extremes.

2. Profile of the Bibiani-Anhwiaso-Bekwai Municipality

2.1 Background

The Bibiani-Anhwiaso-Bekwai Municipal Assembly (BABMA) is one of the 261 Metropolitan, Municipal, and District Assemblies (MMDAS) in Ghana and forms part of the nine MMDAS in the Western North Region. The municipality was carved out of Sefwi-Wiawso District in 1988 by the Legislative Instrument (LI) 1387. The municipality is located in the northeastern part of the Western North Region with Bibiani as its capital and lies between latitude 6°3' north and longitude 2°3' west (Ghana Statistical Service [GSS], 2014). The municipality shares boundaries with Atwima Mponua district to the north, Wassa Amenfi to the south, Sefwi-Wiawso district to the west, and Upper Denkyira West to the east. The municipality has a total land area of 873 km^2 (BABMA, 2023).

2.2 Physical and Environmental Features

2.2.1 Vegetation

The municipality is found within the Equatorial Rain Forest Zone. The moist-deciduous forest is the natural vegetation in the municipality. Trees including sapele, mahogany, and odum are widespread in the municipality. This tree species constitutes the bedrock of the thriving timber industry of Ghana. Hence, the municipality serves as an appropriate spot for the establishment of timber companies. The municipality boasts 6 forest reserves (Table 2) (namely: Merewa forest reserve, Afao Hills Reserve, Anhwiaso South Reserve, Anhwiaso East Reserve, Anhwiaso North Reserve, and Tano Suraw Extension Reserve). The district is endowed with numerous water bodies with Ankobra being the key river that drains the municipality. Other tributaries that make up the Ankobra basin are Awa, Krodua, Atronsu, Subriso, Kroseini, Suraw, Chira, and Akataso. The presence of these water bodies provides opportunities for the development of dry-season farming, rice and sugarcane cultivation, and fish farming (GSS, 2014).

Table 2. Forest reserves in the district

Location	Area (km^2)	% of total land size
Anhwiaso East	87	10
Anhwiaso North	41	4.6
Anhwiaso South	22	2.5
Afao Hills	35	4
Tano Suraw Extension	75	8.6
Sumtwitwi	4	0.5
Total	**264**	**30.2**

Source: BABMA, 2023.

2.2.2 Local Climate and Exposure to Climate

The municipality is found in the equatorial climatic zone with mean annual rainfall between 1200 mm and 1500 mm (GSS, 2014). The municipality experiences a bimodal pattern of rainfall which falls from March to August and from September to October. The humidity of the municipality is relatively high with an average of about 75% and 95% in the afternoons and nights or early mornings respectively (GSS, 2014). Additionally, the mean annual temperature of the municipality is estimated to have increased by about 0.04°C over the past two decades (Affi-Donkor, 2021). However, recent changes in climatic conditions such as the long dry season (harmattan) and heavy and prolonged rains have had adverse impacts on economic activities in the district.

The municipality has a large proportion of its population depending directly on agriculture. The impacts of localized disasters are likely to be greater on rural livelihoods over time as a consequence of climate change. Additionally, the high age dependency ratio of 79.56% in 2021 (percentage of working age population or the ratio of dependents under the age of 15 and over 65 compared with the total population aged 15 to 64) (BABMA, 2022) indicates that climate change will have a protracted impact on the municipality, particularly since the economically active population in the municipality is engaged in activities that are highly susceptible to climate variability.

2.3 Demographic Overview

2.3.1 Population Size and Density

Figures from the 2021 Population and Housing Census indicate that the Bibiani-Anhwiaso-Bekwai municipality had a total population of 167,971 comprising 82,798 (49.4%) men and 85,173 (50.7%) women. The municipality's population comprised 19.1% of the total population in the Western North Region. There was a total of 46,198 households in the municipality in 2021 with an average household size of 3.6 persons. The municipality had a population density of 201.9 persons per square kilometer (GSS, 2021).

2.3.2 Population Growth

The population of the municipality has grown significantly since the first Population and House Census was undertaken in 1988 after the creation of the municipality. The 2000 Population and Housing Census recorded the total population of the municipality to be 103,256 people. Within 2 decades of its creation, the population of the municipality had grown by over 50% to 167,971 people in 2021. Table 3 shows the growth in the population of the municipality over the years.

Table 3. Population size of Bibiani-Anhwiaso-Bekwai municipality in 2000, 2010 and 2021

	Men		Women		
Year	Frequency	Percentage	Frequency	Percentage	Total
2000	52,867	48.7	52,867	51.2	103,256
2010	60,855	49.4	62,417	50.6	123,272
2021	82,798	49.3	85,173	50.7	167,971

Source: Ghana Statistical Services. National Population and Housing Censuses 2000, 2010 and 2021.

2.3.3 Distribution of Population by Location

The municipality is witnessing rapid urbanization of its population in line with global and national trends. The municipality was largely rural in the first decade of its creation with about 71.5% of its population residing in rural areas. However, the second decade has seen a drastic reduction in the municipality's rural population, which accounted for 58.3% of the population in 2021. Table 4 presents the distribution of the population of the municipality by rural and urban locality.

Table 4. Population by rural and urban locality in 2010 and 2021

Year	Type of locality	
	Rural	Urban
2010	88,135 (71.5%)	35,135 (28.5%)
2021	97,888 (58.3%)	70,083 (41.7%)

Source: Ghana Statistical Services. National Population and Housing Censuses 2000, 2010 and 2021.

2.3.4 Migration Trends

The migration of people into the municipality is largely inter-regional (Old Western Region). There was a total of 34,055 migrants representing 27.6% of the total population in the Bibiani-Anhwiaso-Bekwai municipality in 2010 (GSS, 2014). Most migrants were from the Ashanti region while a sizable proportion was from Northern Ghana. The high number of migrants in the municipality could be attributed to the presence of mineral deposits such as gold and the availability of arable land for the cultivation of cash crops, particularly cocoa. Table 5 shows the total number of migrants and their duration of stay in the municipality in 2010.

Table 5. Period of stay in the municipality, 2010

Number	Duration of residence				
	Less than 1 year	1 – 4 years	5 – 9 years	10 – 19 years	20+ years
34,055	14.5	32.1	18.5	17.1	17.8

Source: Ghana Statistical Services. National Population and Housing Censuses 2010.

2.4 Economic Overview

2.4.1 Economy of the Municipality and Economic Activity Status of Residents

The economy of the municipality revolves around agriculture (mainly food and cash crops), minerals (gold, bauxite, manganese), and an emerging services sector. The municipality is one of the leading producers of cocoa in Ghana and has the highest concentration of bauxite. The presence of the rich tropical forest makes the municipality one of the largest producers of raw and sawn timber as well as processed wood products.

Figures from the 2010 Population and Housing Census indicated that 69.8% of the total population 15 years and older in the municipality were employed. About 70% of men in the municipality were employed compared to 69.7% of women (GSS, 2014), indicating that there was little difference between men and women in the municipality in terms of employment.

2.4.2 Major Sectors of the Local Economy

Agriculture is the mainstay of the local economy and employed about 76% of the economically active population in 2014 (GSS, 2014). Crop farming in the dominant activity in the sector, with other agricultural activities undertaken in the municipality include agro-processing and livestock rearing. Mining, forestry, and tourism are also important economic sectors of the municipality.

2.4.2.1 Agriculture

About 82.5% of rural households and 57.4% of urban households were regarded as agricultural households in the municipality in 2014. This is an indication that despite the rising migration from the rural areas of the municipality, over 50% of the population in the urban areas of the municipality still engaged in agriculture for their livelihood. Crop farming and animal rearing were the two main agricultural activities of agricultural households in the municipality. About 98.2% of agricultural households were engaged in crop farming in 2014 while 33.1% were engaged in animal rearing (GSS, 2014).

Households engage in the production of staple crops such as cassava, plantain, rice, maize, etc. Commonly produced cash crops in the municipality include cocoa, coffee, oil palm, rubber, citrus, and black pepper. A variety of livestock and poultry are reared for commercial purposes.

2.4.2.2 Forestry (Timber Industry)

The numerous forest reserves in the municipality are exploited for timber. Timber harvested from the municipality undergoes value addition in Sefwi-Wiawso and Kumasi for both the domestic and foreign markets (MoFA, 2022). Harvested trees from the municipality are used mainly to produce furniture, moldings, and floorings. Residents living close to these forest reserves usually use herbs and tree bark from the forest for medicinal purposes.

2.4.2.3 Tourism

The natural forests, water bodies (particularly the River Ankobra), and unique landscape (specifically the AttaNyamekrom peak at 660 m above sea level), coupled with mining sites in the municipality, offer an alternative destination for both local and international tourists (BABMA, 2023).

2.4.2.4 Mining

The municipality is characterized by oxysol soil which is rich in mineral deposits. As such, mining is an important sector of the municipality's economy. Three major mining companies are operating within the municipality: Noble Gold Mines Limited, Chirano Gold Mines Limited, and the Awaso Bauxite Company. These mining companies contribute to the economy of the municipality by providing employment to some of the youth in the municipality as well as providing revenue in the form of property taxes to the municipal assembly.

2.5 Administration and Governance

2.5.1 Political Administration

As outlined on the BABMA's website, the Municipal Chief Executive is the political head of the municipality. The Chief Executive is appointed by the President and approved by not less than two-thirds of the Assembly members. The Municipal Coordinating Director is the Administrative Head of the Municipal bureaucracy and chief advisor to the Municipal Chief Executive. They are also the Secretary to the Assembly and ensure the effective implementation of the policies and decisions of the Municipal Assembly. Politically, the Municipality has one constituency with an Assembly of 54 members which include the elected Member of Parliament for the area.

The Executive Committee is responsible for the performance of the executive and administrative functions of the Assembly. The Executive Committee is made up of 18 members and has the Municipal Chief Executive as its Chairperson. The municipality is further subdivided into eight Area Councils and one Town Council which assist in the performance of key roles (BABMA, 2023).

2.5.2 Traditional Authority

Besides the political administration of the municipality, Bibiani-Anhwiaso-Bekwai also has effective traditional leadership for the effective and efficient mobilization of local resources. The municipality is made up of three traditional areas, each with its own Traditional Council. The three traditional areas in the municipality are the Anhwiaso Traditional Area, Sefwi Bekwai Traditional Area, and Chirano Traditional Area. Each traditional area is headed by a Paramount Chief. The Traditional Councils are the decentralized units of administration by traditional rulers and are used to mobilize the people at the local and community levels for development (BABMA, 2023).

3. Vulnerability Assessment to Current Climate Change

3.1 Analysis of Observed Climate Changes

The rainfall regime over Bibiani is characterized by the North-South movement of the Inter-Tropical Convergence Zone and associated wet (March to October) and dry (November to December) seasons. The rainfall season begins in March and progresses as it reaches its peak in June, after which there is a decline until August when the first rainfall season ends. The second rainfall begins in September and peaks in October, and then the dry season starts in November. Bibiani receives rainfall for about 7 months out of the 12 months of the year. The highest number of days with rainfall events in a year over the period under review is 136 of 365 and the lowest has been 88. The gap between 136 rain days in 1980 and 88 rain days in 1997 indicates huge variation (a range of 48) in rain days over time in Bibiani.

The seasonal night temperature cycle over Bibiani is similar to the daytime but differs in peak months. For example, the coldest period for both night and day temperatures occurs in August. Minimum temperature variability has the first peak in March-April at 23.5°C and a slightly lower peak in December at 23.0°C. The lowest minimum temperature is recorded in August as 22.3°C. The maximum temperatures typically occur in February (35.5°C) and December (33.0°C). Bibiani records the lowest maximum temperature in August as 30°C.

3.2 Stakeholder Workshop for Assessing Vulnerability

The results presented in the following sections of chapter three are based on data generated during a participatory stakeholder workshop in the Bibiani-Anhwiaso-Bekwai Municipality. The 36 stakeholders involved in the workshop work in areas concerning climate change in the Bibiani-Anhwiaso-Bekwai Municipality. The identification of these key stakeholders was based on their experience, role, knowledge, and relation with the expected impacts of climate change and the associated policy environment in Ghana in general and the municipality in particular. A series of exercises were undertaken during the workshop to identify the impacts of climate change on key sectors of the local economy, rank the vulnerable sectors of the local economy, and identify vulnerable communities based on the absence of important infrastructure.

3.3 Climate Change Impacts

The Bibiani-Anhwiaso-Bekwai Municipality is located in the Equatorial Rain Forest Zone of Ghana with a moist-deciduous forest. About 63% of its population is engaged in economic activities such as agriculture, forestry, and fishing (GSS, 2014). This is a cause for concern, given the vulnerability of these sectors to climate change and variability (IPCC, 2014). Stakeholders engaged in the municipality observed that climate change has had numerous impacts on various sectors of the local economy. Table 6 sets out climate hazards and climate impacts, which are briefly discussed in this section.

Being the main sector of the municipality's economy, agriculture was noted to be heavily impacted by climate change. For example, it was observed that climate change – including the impacts of drought and heavy rainfall – has increased crop infestation by pests and diseases, resulting in reduced crop yields and reduced income for farming households. Additionally, climate change has had an adverse impact on livestock by increasing the incidence of livestock diseases.

The municipality is home to many cocoa-producing farms. Cocoa production, which is a major source of livelihoods in the municipality, is vulnerable to climate change, with rainfall and drought affecting cocoa production (Anim-Kwapong and Frimpong, 2004; Oppong and Atuah, 2016). Oppong and Atuah (2016) further noted that severe droughts contribute to wildfires that threaten cocoa farms in the district. Increased incidences of pests and diseases have also been noted to significantly affect cocoa production in the municipality. Anim-Kwapong and Frimpong (2004) noted that climate change has affected the stages and rates of development of cocoa pathogens as well as host resistance, making cocoa trees more susceptible to damage.

Erratic rainfall and drought significantly affect forest cover in several ways. Droughts may contribute to reduced forest cover and loss of biodiversity through wildfires, which may burn down forest reserves, while rainfall variability can increase the conversion of undisturbed forests into grassland. The conversion and depletion of such forest cover trickles down to the tourism sector, as tourists visit the municipality specifically for sightseeing in the forest reserves.

Table 6. Climate hazards and their impact on sectors of the municipality

Sector	Key impacts of climate change on livelihoods in the municipality
Agriculture (crop & livestock)	• Reduction in crop yields • Decreased income of farmers • Increased food prices • Increased cases of crop failures • Reduction in livestock productivity • Increased incidence of livestock diseases • High prevalence of food shortages • Wilting of crops • Low crop yields • Low farm income • Dryness of rivers/streams leading to inadequate water for irrigation • Bush fires • Lodging of crops (e.g., plantain) • Flooding of farmlands • Destruction of livestock farms • Destruction of farm access routes • Undermining of agricultural livelihoods • Changes in crop growth • Changes in planning and harvesting schedules • Increased production costs • Difficulty in drying grains/legumes/cocoa beans

Sector	Key impacts of climate change on livelihoods in the municipality
Forestry and biodiversity	• Decreased non-timber forestry products such as snails and mushrooms • Changes in the length of the growing seasons for plants • Loss of plant species • Increased wildfires/death of medicinal trees because of wildfires • Destruction of forest resources • Destruction of wildlife habitat • Undermining of forest-based livelihoods • Destruction of animal species • Increased mortality of young tree seedlings • Reductions in the growth of trees • Increased difficulty in predicting when to start a nursery
Transport and infrastructure	• Damage to infrastructure, including buildings, roads, and energy networks • Increased dust contributing to road accidents • Increased cost of maintenance • Increased public and domestic spending on utilities • Increased erosion • Increased cost of infrastructure • Delayed construction • Delayed transport; buses, public vehicles running late
Water resources and sanitation	• Increased water shortages during very high temperatures • Increased demand for water • Drying up of natural water sources • Increased water-related conflicts • Smoke and dust nuisance • Increased contamination and pollution of water • Water security threats to people and animals • Accumulation of waste materials in drains • Increased water-borne diseases
Human health	• Increased infections such as malaria • Increased heat-related infections such as rashes. • Increased skin diseases • Increased communicable or contagious diseases • Increased respiratory diseases • Heat and discomfort • Rise in communicable diseases • Increased disease vectors (e.g., increasing insect populations from standing water) • Dampness of buildings resulting in rheumatism/pneumonia conditions

Source: Stakeholder workshop in Bibiani.

3.4 Identifying Vulnerable Locations, Sectors, and Groups

3.4.1 Ranking of Sectors Based on Perceived Vulnerability

The major sectors of the municipality's economy were ranked based on their perceived vulnerability to climate change by key stakeholders in the municipality. The identified sectors were ranked based on four criteria: certainty of impact, timing of impact, severity of impact, and importance of resource. These were ranked on a scale of 1 to 5 with high vulnerability ranked 5 and low vulnerability ranked 1. The ranking provides insight into the most vulnerable sectors as perceived by stakeholders in the municipality and hence sectors requiring action to be taken to address such vulnerability. Table 7 presents the ranking of the sectors.

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

Sector	Certainty of Impact	Timing of Impact	Severity of Impact	Importance of Resource	Weighted Average
Agriculture (crop & livestock)	5	5	5	5	5.00
Human health	5	5	5	5	5.00
Forestry	5	4	5	5	4.75
Water resources	4	4	5	5	4.50
Biodiversity	4	2	4	5	3.75
Fisheries	1	1	5	3	2.50
Tourism	2	1	1	4	2.00

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

Source: Stakeholder workshop in Bibiani.

- **Agriculture** was ranked the most vulnerable sector to the impacts of climate change. Agriculture in the Bibiani-Anhwiaso Bekwai Municipality is largely rainfall-dependent and as such any variations in rainfall could have a devastating impact on agricultural output. Additionally, severe rainfall poses the challenge of causing flooding, which has washed away farms on several occasions.
- The **human health** effects of climate change range include increased respiratory and cardiovascular disease, injuries, and premature deaths associated with extreme weather events, and changes in the prevalence and geographical distribution of food-, water-, and vector-borne illnesses and other infectious diseases.
- **Forest** resources were also susceptible to the adverse impacts of climate change, including the threat of increasing temperature which sometimes results in wildfires. This is because the forests offer a home to much of the municipality's diverse array of plants and animals and provide essential natural resources from timber and food to medicinal plants.
- **Water resources** were also highly vulnerable to the impacts of climate change in the municipality because the Ankobra River, which serves the majority of the municipal's populace, is susceptible to climatic changes.

3.4.2 Assessing Community 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, it 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. Stakeholders from the municipality participated in an exercise that applied the MoF to several villages and towns within the municipality.

The outcomes of the MoF are presented in Figure 2, and an overview of the MoF is set out below:

1. The columns show the "functions," ordered from left to right according to their frequency.
2. The rows show the name of communities/villages, ordered from top to bottom as per the highest number of functions.
3. 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.
4. Rows with more black cells (i.e., more functions present) indicate more urban spaces. A decreasing presence of functions typically indicates a community is more rural.
5. Functions to the left are more basic and common to communities, while the ones to the right indicate functions more common in urban areas.

Figure 2. Matrix of Functions for selected communities in the Bibiani-Anhwiaso-Bekwai Municipality. Click here to access the MoF of CCMA in full details

Source: Stakeholder workshop in Bibiani.

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:

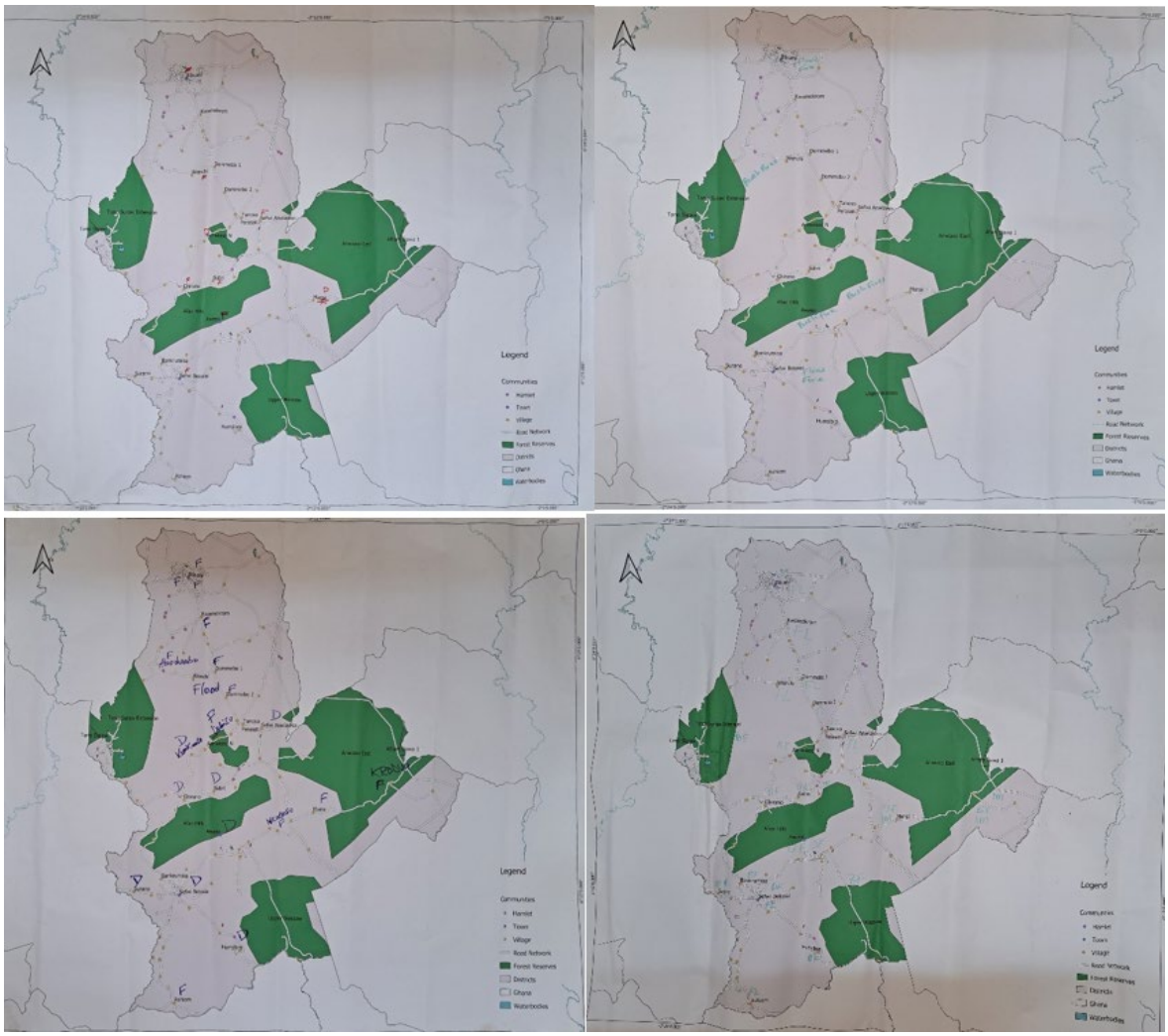
- The municipality has relatively few urban areas (communities with more black cells) and is predominantly rural. Urban areas tend to be more resilient to climate impacts. Bibiani, Sefwi Bekwai, and Asawinso are the most urbanized communities.
- All communities, except Kwazo, had access to radio.
- Kwamekrom and Kwazo are the only communities without internet connectivity and access.
- Agyenia and Kwazo are the only communities without a basic school.
- Lineso and Subru Nkwanta are the only two communities with irrigation systems for agriculture, while also being the only two communities with no paved or tarred roads.
- The only university in the municipality is in Bibiani. The two technical schools are in Bibiani and Oheabenika.
- Maize is a staple and vegetables a main crop in most of the communities.

A limitation of the MoF as applied in this setting is that it does not cover all villages and towns within the municipality, however, it provides some information on communities that might be more vulnerable (i.e., communities with fewer functions) to climate change. We infer that communities with less infrastructure and/or services are more vulnerable compared to communities with such infrastructure and services. In that regard, rural communities in the Bibiani-Anhwiaso-Bekwai municipality are more vulnerable to climate change than their urban counterparts who enjoy the presence of several infrastructures and services. This VA used this information to identify highly vulnerable areas in the municipality that require focused and inclusive adaptation planning.

3.4.3 Hazards and Associated Vulnerable Locations

Stakeholders undertook participatory mapping to identify vulnerable locations within the municipality. Based on their experience as residents and officers within the community, the stakeholders were able to identify locations that are associated with climate hazards, namely, floods, droughts, and bushfires. The mapping exercise revealed that flooding occurred most often within Bibiani township as well as areas such as Kwamekrom, Dommeno 1 & 2, Wenchi, Mansi, and Debiso. Droughts were mostly experienced in the areas of Chrano, Bekwai, Subri, and Awaso. Bushfires were mostly experienced in communities that experienced prolonged droughts and were more evident in areas with forest reserves such as Awaso (Afao Hills) and Tano Suraw extension reserve, among others. The mapping of other communities is presented in Figure 3.

Figure 3. Mapping of vulnerable locations in the municipality



Source: Stakeholder workshop in Bibiani.

4. Vulnerability Assessment to Current and Future Climate Change

4.1 Quantitative Vulnerability Assessment

4.1.1 Description of Vulnerability Assessment Methodology

This report adopted the Livelihoods Vulnerability Index -IPCC (LVI-IPCC) approach to compute the vulnerability index of the Bibiani-Anhwiaso-Bekwai municipality. The LVI-IPCC approach was developed by Hahn et al. (2009) as an alternative means of calculating the LVI by incorporating the IPCC 2007 definition of vulnerability, sensitivity, and adaptive capacity. Since the LVI-IPCC approach is an extension of the LVI approach, we adapted the LVI approach used by Hahn et al. (2009) and Mohan and Sinha (2010) to our study area. We expanded the seven major components of the LVI (i.e., socio-demographic profile, livelihood strategies, social networks, health, food, water, and natural disasters and climate variability) to include other major components such as forestry, services, infrastructure, and household assets in computing the vulnerability index of the Bibiani-Anhwiaso-Bekwai municipality.

The LVI uses a balanced weighted average approach (Sullivan et al., 2012) where each sub-component contributes equally to the overall index even though each major component consists of a different number of sub-components. The sub-components of each major component were measured on a different scale; thus, it was necessary to standardize each index. We standardized each index using equation (1) in a similar approach to the Human Development Index (UNDP, 2010). The equation for standardization was given by Hahn et al., 2009 as:

$$I_B = \frac{I_\alpha - I_{min}}{I_{max} - I_{min}} \qquad (1)$$

Where I_B is the standardized value of the sub-component, I_α is the original value of the sub-component, I_{min} is the minimum value of the sub-component, and I_{max} is the maximum value of the sub-component across all respondents.

NB: The minimum and maximum values of sub-components that were measured in frequency were set at 0 and 100, respectively.

After standardization, the index for each of the 12 major components was calculated by averaging their sub-components using Equation 2.

$$M_B = \frac{\sum_{i=1}^{12} I_{Bi}}{n} \qquad (2)$$

Where M_B is one of the 12 major components [natural disasters, climate variability, agriculture, health, water, forestry, services, infrastructure, socio-demographic profile, livelihood strategies, social networks, and household assets], I_{Bi} represents the sub-components, indexed by *i,* which make up each major component, and *n* is the number of sub-components in each major component.

The major components were subsequently combined using equation (3) according to the categorization scheme in Table 8. Combining the major components based on the categorization in Table 8 resulted in obtaining the index for the three contributing factors of the LVI-IPCC index.

Table 8. Categorization of major components into contributing factors from the IPCC definition of vulnerability for calculating the LVI-IPCC

IPCC contributing factors to vulnerability	Major components
Exposure	Natural disasters
	Climate variability
Adaptive capacity	Socio-demographic profile
	Livelihood strategies
	Social networks
	Household assets
Sensitivity	Agriculture
	Forestry
	Services
	Heath
	Infrastructure
	Water

Source: Adapted from Hahn et al. (2009).

$$CF_B = \frac{\sum_{i=1}^{n} w_{M_i} M_{Bi}}{\sum_{i=1}^{n} w_{M_i}} \qquad (3)$$

Where CF_B is an IPCC contributing factor (exposure, adaptive capacity, or sensitivity), M_{Bi} are the major components, w_{M_i} is the weight of each major component, and n is the number of major components in each contributing factor. Once exposure, sensitivity, and adaptive capacity were calculated, the three contributing factors were combined using equation (4).

$$LVI - IPCC_B = (E_B - A_B) * S_B \qquad (4)$$

Where *LVI–IPCC*$_B$ is the vulnerability index expressed using the IPCC vulnerability framework, *E* is the calculated exposure score (equivalent to the natural disaster and climate variability major component), *A* is the calculated adaptive capacity score (weighted average of the socio-demographic, livelihood strategies, social networks, and household assets major components), and *S* is the calculated sensitivity score (weighted average of the agriculture, forestry, services, health, infrastructure, and water major components). We scaled the LVI–IPCC from -1 (least vulnerable) to 1 (most vulnerable).

4.1.2 Data Sources and Sampling Procedure

Two main sources of data were used for the calculation of the LVI-IPCC vulnerability index. Data on climate variability in the municipality, particularly rainfall data, temperature data, and data on consecutive dry days, consecutive wet days, and the number of warm days ranging from 1980 to 2020 were obtained from the Ghana Meteorological Agency (GMet). A household survey was conducted in December 2022 to obtain primary data for the other components of the LVI.

A total of 313 households were sampled across the municipality through a multi-stage sampling approach. In the first stage, six zonal councils were selected randomly through balloting from the nine zonal councils within the municipality. Two communities were further selected from each zonal council. Within each community, a random walk approach was used to select households to be included in the study. A breakdown of the number of households selected in each zonal council is provided in Table 9.

Table 9. Number of respondents selected from sampled zonal councils

Zonal council	Number of respondents	Percentage
Sefwi Bekwai	45	14.4
Awaso	29	9.3
Anhwiaso	51	16.3
Wenchi	46	14.7
Lineso	64	20.4
Bibiani	78	24.9
TOTAL	**313**	**100**

Source: Survey data.

The questionnaire used for the study consisted of 10 sections: the respondent profile, livelihood strategies, household assets, social networks, availability and access to credit, climate exposure, health, water, food/agriculture-dependent sector, and non-food/services sector (Appendix 7). Each interview lasted on average 45 minutes. The survey was conducted in Twi and English depending on the preferred language of the respondent. Appendix 5 provides a detailed breakdown of the vulnerability-contributing factors, major components, sub-components, units of measurement, and sources of data used in the computation of the LVI-IPCC vulnerability index.

4.1.3 Results of the Vulnerability Assessment of Bibiani-Anhwiaso-Bekwai Municipality

This section provides an analysis of the key components used to generate the vulnerability index. Table 10 presents summary statistics of socio-demographic characteristics of the selected sample. A total of 313 respondents were selected for the study comprising 142 (45.5%) women and 171 (54.6%) men. A majority of the sample (62.9%) were within the active working age group (31 – 60) while about 23% fell in the age category as youth i.e., below 31 years. A greater proportion of man respondents (70.7%) reported as being married compared to about 46.5% of woman respondents. Greater proportions of woman respondents were either divorced (14.8%) or widowed (11.2%) compared to the men, who recorded smaller proportions for divorced (5.3%) or widowed (0.6%). Education levels were low among woman respondents compared to their man counterparts. About 30% of woman respondents had no form of education compared to about 10% of men. Most respondents reported having received basic education. More men (24.6%) had secondary education compared to women (12.7%) in the municipality.

Table 10. Characteristics of sampled respondents

Variable	All (*n* = 313)	Gender	
		Woman (*n* = 142; 45.4%)	Man (*n* = 171; 54.6%)
Age category			
Below 31 years	72 (23)	34 (23.9)	38 (22.2)
31 – 60 years	197 (62.9)	85 (59.9)	112 (65.5)
Above 60 years	44 (14.1)	23 (16.2)	21 (12.3)
Marital status			
Single	80 (25.6)	39 (27.5)	41 (23.9)
Married	186 (59.4)	66 (46.5)	120 (70.2)
Divorced	30 (9.6)	21 (14.8)	9 (5.3)
Widow	17 (5.4)	16 (11.2)	1 (0.6)
Education level			
No education	60 (19.2)	43 (30.3)	17 (9.9)
Basic	181 (57.8)	78 (54.9)	103 (60.2)
Secondary	60 (19.2)	18 (12.7)	42 (24.6)
Tertiary	12 (3.8)	3 (2.1)	9 (5.3)

NB: Numbers outside the parentheses are frequencies while those in brackets are percentages.

Source: Author's computation based on survey data.

4.1.3.1 Exposure Profiles: Natural disasters and climate variability

The exposure of zonal councils within the municipality was largely driven by two major components: natural disasters and climate variability. It was assumed climate variability was similarly experienced in all zonal councils, so municipal averages were used to represent the climate variability of all zonal councils. That is, the mean annual average rainfall, mean annual average maximum and minimum temperatures, the average number of consecutive dry and wet days, the average number of warm days, and the average number of heavy precipitations between the years 1980 and 2021 were the same across all zonal councils of the municipality. However, differences in the natural disaster component of exposure resulted in variations in the exposure level of the zonal councils within the municipality.

A ranking of the exposure levels of the zonal councils indicates that the Awaso Zonal Council was the most exposed to climate variability and change within the municipality (Table 11). The second and third most exposed zonal councils were the Wenchi and Bibiani Zonal Councils respectively. Lineso Zonal Council was the least exposed to climate variability and change within the municipality. A graphical representation of the level of exposure is presented in Appendix 1.

Table 11. Exposure level of zonal councils

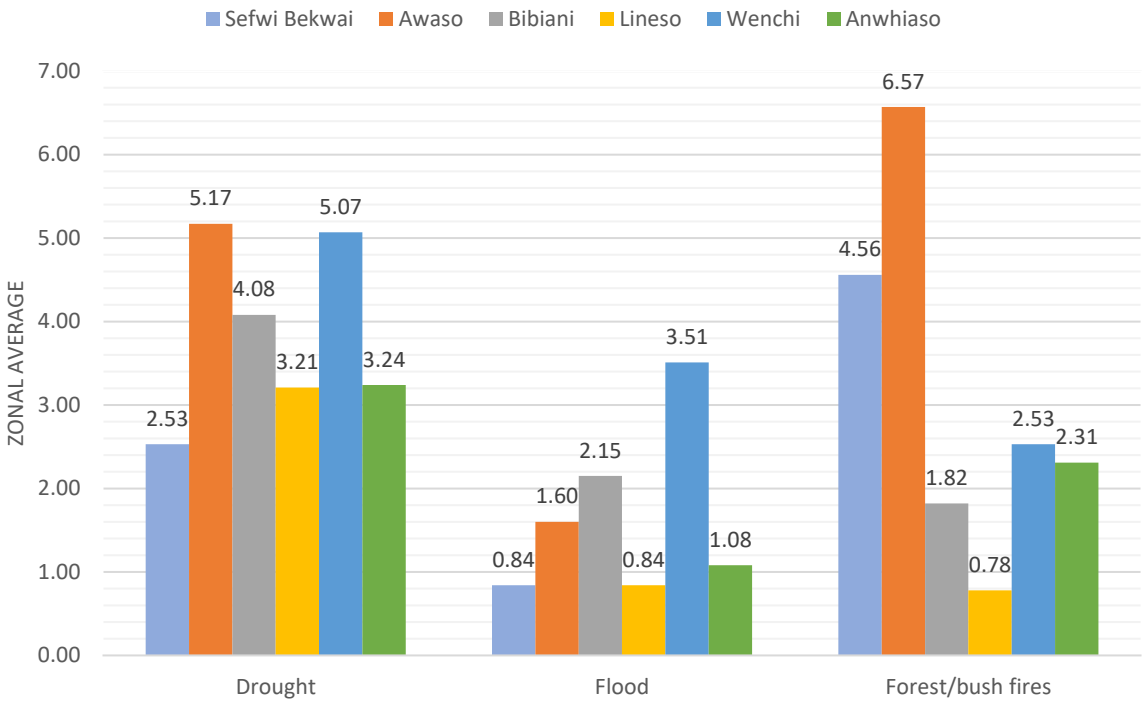
Zonal Council	Exposure Index	Rank
Awaso	0.540	1
Wenchi	0.496	2
Bibiani	0.480	3
Sefwi Bekwai	0.474	4
Anhwiaso	0.472	5
Lineso	0.471	6

Source: Author's computation based on survey data.

The differences in the average number of natural disasters that have occurred within each zonal council within the past 10 years as reported by respondents accounted for the disparities in exposure of the various zonal councils. The high level of exposure of the Awaso Zonal Council was due to high relatively high number of forest/bushfires and droughts that have occurred within the zonal council over the past decade (Figure 4). Respondents from the Awaso Zonal Council reported that forest or bushfires recorded in the area over the past 10 years ranged from a minimum of 0 to a maximum of 10 per year. On the other hand, the exposure of the Wenchi and the Bibiani Zonal Councils can be attributed to the relatively high number of droughts and floods that occurred within the areas over the past decade. In the case of Wenchi, drought events that have occurred within the area over the past 10 years ranged between a minimum of 2 per year to a maximum of 10. Respondents from the Bibiani Zonal Council recollected that drought over the past 10 years ranged between 0 and 10 times.

Although the Anhwiaso and Lineso Zonal Councils reported relatively high numbers of drought over the past decade, they recorded very low levels of flood and forest/bushfire incidents. Respondents indicated that they could recollect about 0 to 7 flooding incidents in the Lineso Zonal Council over the past 10 years. Residents from the Anhwiaso Zonal Council reported that flooding events within the area ranged from zero to six times over the past decade. The Sefwi Bekwai Zonal Council experienced relatively high numbers of forest/bushfires but very low flood and droughts. Residents in the Sefwi Bekwai Zonal Council revealed that forest/bush fires occurring within the area over the past 10 years ranged from 0 to a maximum of 20 times.

Figure 4. Average number of natural disasters per zonal council

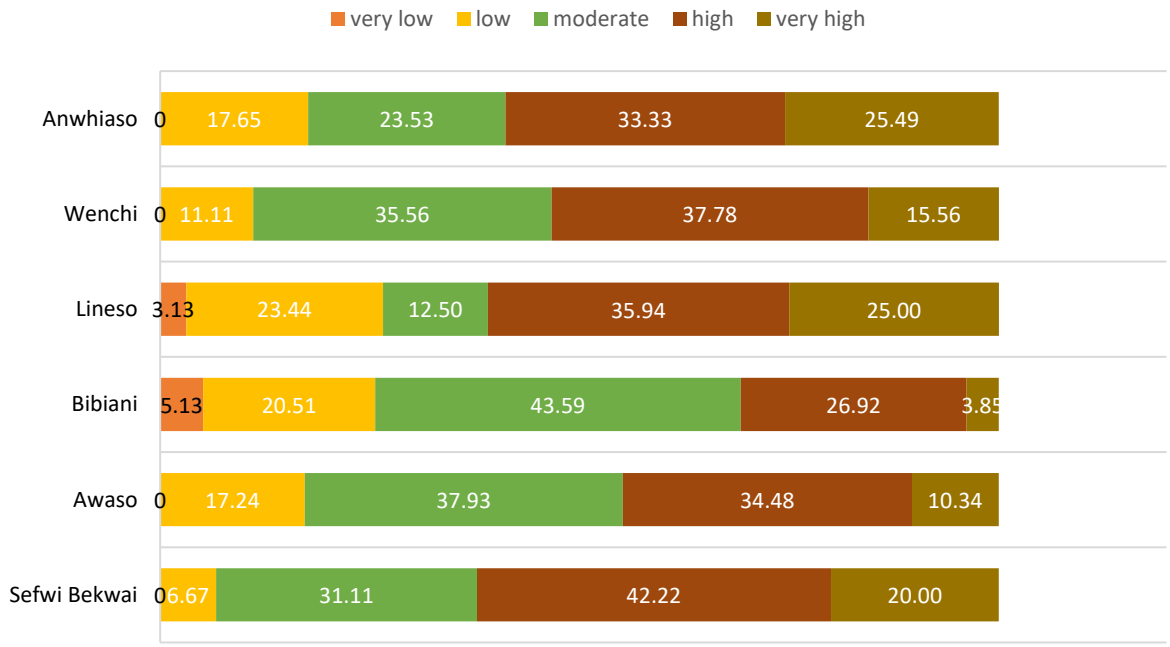


Source: Author's computation based on survey data.

There were significant differences among the zonal councils in terms of respondents' perceived exposure to climate-induced events such as floods, drought, bushfires, changes in seasonal calendar, windstorms, high temperatures, and destruction to infrastructure. About a quarter of respondents from the Anhwiaso and Lineso Zonal Councils indicated that their exposure was very high compared to just about 20% of respondents from Sefwi Bekwai, 16% from Wenchi, 10% from Awaso, and 4% from the Bibiani Zonal Councils (Figure 5). Several respondents from Anhwiaso (33%), Wenchi (38%), Lineso (36%), and Sefwi Bekwai (42%) indicated that their exposure to climate-induced events was high. 43.59% of respondents from Bibiani Zonal Council and 37.93% of respondents from Awaso Zonal Council stated that their level of exposure was moderate.

Over 20% of respondents in the Bibiani and Lineso Zonal Councils indicated that their exposure to climate-induced events was low. Additionally, 3% of respondents from the Lineso Zonal Council and 5% of respondents from the Bibiani Zonal Council reported that their exposure to climate-induced events was very low. This may be the case because climate events such as flood and climate-induced forest/bushfires that lead to massive destruction of properties were reportedly less prevalent in these two zonal councils.

Figure 5. Extent of exposure to climate-induced events



Source: Author's computation based on survey data.

4.1.3.2 Sensitivity Profiles: Agriculture, water, health, forestry, services, and infrastructure

Five major components contributed to the computation of the sensitivity of the various zonal councils within the municipality. The differences in each major component at the zonal level resulted in differences in the overall sensitivity index for the zonal councils. It was observed that the Awaso Zonal Council (0.540) was the most sensitive to climate change followed by the Wenchi (0.538) and Bibiani (0.516) Zonal Councils in second and third positions respectively (Table 12). The Anhwiaso, Sefwi Bekwai, and Lineso Zonal Councils recorded sensitivity indexes of less than 0.5 indicating that they were relatively less sensitive to climate variability and change. Graphical representations of the level of overall sensitivity and the sensitivity of sectors are presented in Appendix 2.

Table 12. Sensitivity level of zonal councils

Zonal Council	Sensitivity Index	Rank
Awaso	0.540	1
Wenchi	0.538	2
Bibiani	0.516	3
Anhwiaso	0.488	4
Sefwi Bekwai	0.483	5
Lineso	0.468	6

Source: Author's computation based on survey data.

The sensitivity level of the Awaso Zonal Council was largely driven by the sensitivity of the agriculture/ food sector and infrastructure in the area (Figure 6). All the respondents from the zone who were engaged in agricultural activities indicated that they had no irrigation system on their farms, implying that their crop cultivation depended entirely on rainfall. This means that any extensive changes in the rainfall pattern of the area could lead to a total crop failure among residents. Additionally, none of the respondents from the zonal council was aware of the existence of agricultural insurance. This invariably translates into all farms within the zone being uninsured against climate risks. Over 90% of respondents also indicated that they did not belong to farmer-based organizations and that they relied on seeds from the current harvest as an input for the following crop season. In terms of infrastructure, all respondents indicated that they had no access to a good road network, restricting their access to essential services. About 87% of respondents indicated that they had no access to a ready market for their agricultural produce. Furthermore, about 89% of respondents indicated that they had not insured any of their properties.

Unlike Awaso, the water and agriculture sectors were the joint leading contributors to the sensitivity of the Wenchi Zonal Council (Figure 6). About 98% of respondents reported having engaged in or witnessed water conflict within the area. Additionally, 60% of the residents indicated that they had no consistent supply of water to their households. However, the average time to the main source of water for households within the zone was 15 minutes with differences in time ranging between a minute to 50 minutes. The sensitivity of the agriculture/food sector of the zone was largely due to the unavailability of an irrigation system (100%), reliance on old seeds (100%), lack of water for dry season farming (92%), lack of agriculture insurance (92%) and households depending solely on foods from their family farms (83%).

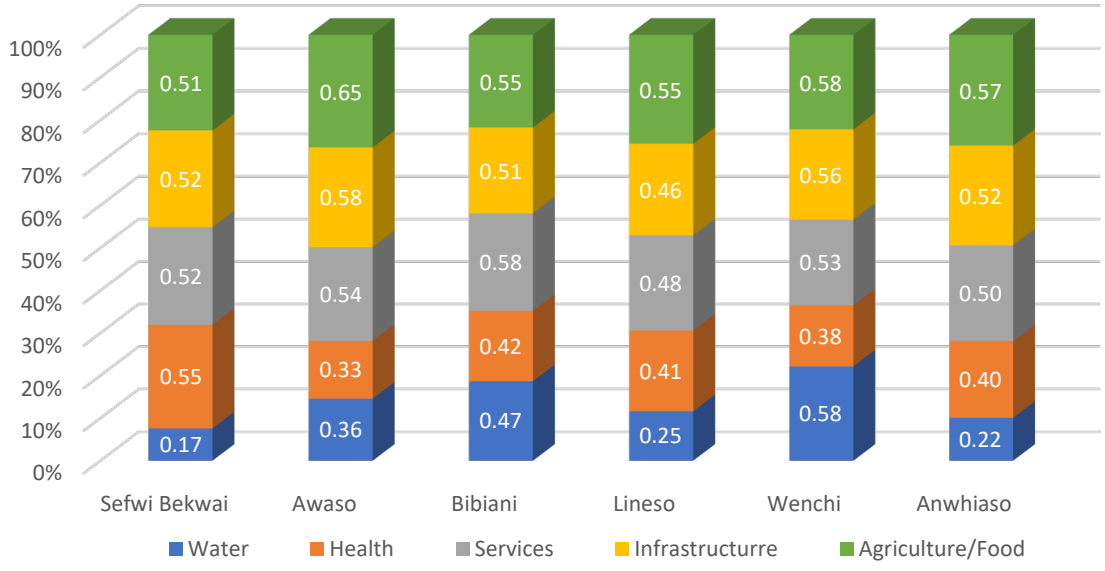
Services and agriculture were the main driving factors of the sensitivity of the Bibiani Zonal Council (Figure 6). About 24% of businesses in the service sector in the zonal council relied on agriculture for their raw materials. This indicates that any climate-induced failure of agriculture will likely lead to the failure of such businesses. Additionally, 17% of businesses within the zone are situated in flood-prone areas that make them highly sensitive to climate events such as flooding. Over 90% of businesses in the service sector within the zonal council were neither insured nor members of any business cooperative. This means that, in the case of any eventuality, such businesses could not access support from either insurance companies or cooperatives. Similarly, the sensitivity of agriculture in the Bibiani Zonal Council is associated with the lack of irrigation systems (97%), lack of agriculture insurance (90%), reliance on old seeds (79%), and households losing about 26% of their agricultural output due to post-harvest losses.

The sensitivity of the Anhwiaso Zonal Council was driven mainly by agriculture and infrastructure (Figure 6). Concerning agriculture, none of the respondents had irrigation systems on their farm, making agriculture in the area fully dependent on rainfall. Additionally, about 94% of respondents reported having no idea of the existence of agricultural insurance schemes. It was also revealed that about 91% of households within the area relied on food from family farms to feed themselves, which is an indication that any crop failure will gravely affect access to food for most residents in the area. In terms of infrastructure, no respondent from the zonal council had insured any of their properties although most of their infrastructure was not disaster resilient. About 96% of the respondents indicated that they do not have access to good road networks within the area. Furthermore, about 13% of respondents indicated that part or all of their house had collapsed due to heavy rainfall.

Health, services, and infrastructure were the main drivers of sensitivity in the Sefwi Bekwai Zonal Council (Figure 6). The Sefwi Bekwai Zonal Council had the joint highest percentage (18%) of respondents not covered by the national health insurance scheme. This means that residents who fall sick must pay money at health facilities to get access to health care. The zonal council also had the highest average time (34 minutes) to access the nearest health facility. This implies that residents in the area took a relatively longer time to access health care than their counterparts in the other zonal councils. About 42% of respondents reported having a family member with chronic illness while 44% of respondents indicated that they had no access to safe sanitation facilities. The sensitivity of the services sector within this zonal council was due to the lack of insured businesses in the service sector and the majority of respondents with businesses who did not belong to any business cooperative. The lack of disaster-resilient infrastructure (96%), uninsured properties (91%), and poor road networks (73%) coupled with about 20% of houses being located in flood-prone areas were the main drivers of sensitivity of infrastructure within the zone.

The Lineso Zonal Council was the least sensitive to climate change in the Bibiani-Anhwiaso-Bekwai municipality. The relatively low sensitivity of the municipality was driven by agriculture and infrastructure. The sensitivity of agriculture in the zone was mainly because about 82% of respondents in the area indicated that they do not get information on improved production practices. Additionally, about 79% of respondents in the area depended solely on family farms for their food while 58% of respondents indicated that they do not have an adequate food supply for the whole year. This implies that the food supply in the zonal council is highly susceptible to changes in the climate of the area. In terms of infrastructure, no respondents had insured any property although about 20% of respondents reported having had part or all of their house collapse due to heavy rainfall. Additionally, none of the respondents reported having disaster-resilient infrastructure. Fifty-five percent of respondents indicated that they had no access to a good road network in the area. This, therefore, limited their access to other important facilities within the municipality.

Figure 6. Sensitivity of sectors of the zonal councils



Source: Author's computation based on survey data.

4.1.3.3 Adaptive capacity profiles: socio-demographics, livelihood strategies, social networks, and household assets

The adaptive capacity of each zonal council was determined by four major components, namely socio-demographic profile, livelihood strategies, social network, and household assets. Differences in the socio-demographic profile, livelihood strategies, social network, and household assets among respondents from the various zonal councils resulted in differences in the adaptive capacity of zones within the municipality.

A ranking of the adaptive capacity levels of the zonal councils revealed that Awaso Zonal Council had the highest adaptive capacity index of 0.669. Awaso was followed by Sefwi Bekwai (0.661), Lineso (0.658), Anhwiaso (0.658), Bibiani (0.636) and Wenchi (0.632) in that order (Table 13). Graphical representations of the level of overall adaptive capacity and the components of adaptive capacity are presented in Appendix 3.

Table 13. Adaptive capacity level of zonal councils

Zonal Council	Adaptive Capacity Index	Rank
Awaso	0.669	1
Sefwi Bekwai	0.661	2
Lineso	0.658	3
Anhwiaso	0.658	4
Bibiani	0.636	5
Wenchi	0.632	6

Source: Author's computation based on survey data.

Social networks played a significant role in the adaptive capacity level of all the zonal councils (Figure 7). Most respondents indicated that they belonged to a social organization within their locality. Social organization membership among respondents ranged from 97% in Awaso, 94% in Bibiani, 84% in the Anhwiaso, 82% in Wenchi, 80% in Sefwi Bekwai, to 77% in the Lineso Zonal Council.

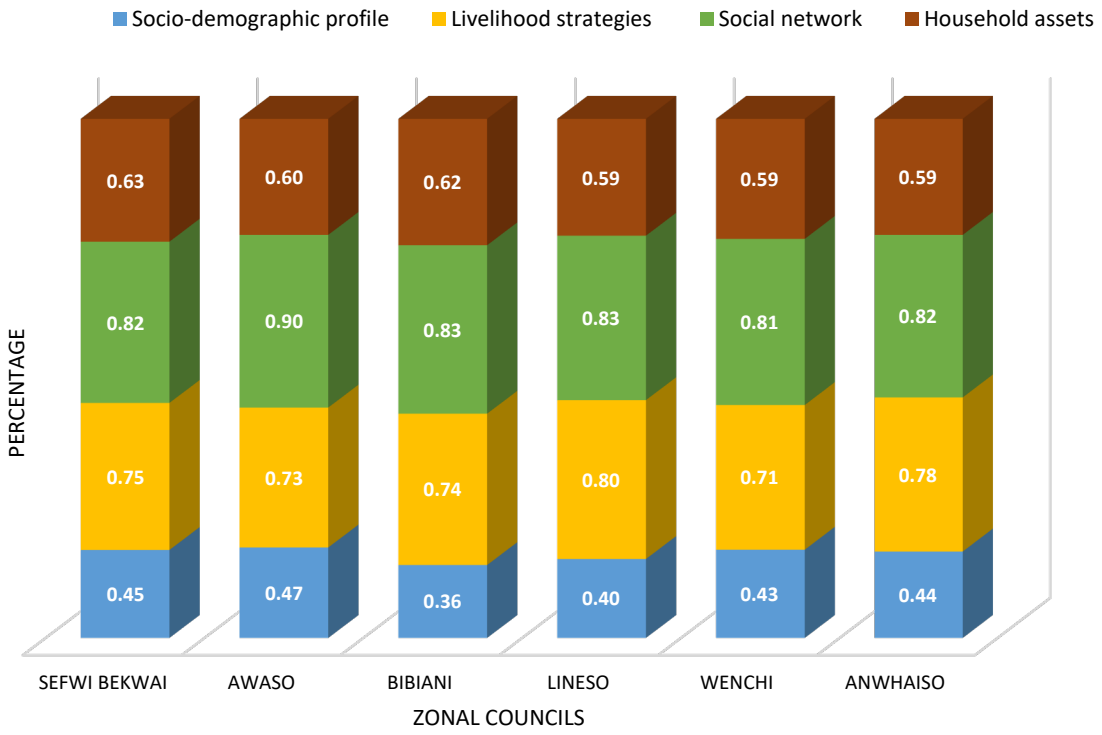
In terms of livelihood strategies, the Lineso Zonal Council had the largest proportion (88%) of respondents who depended on one single source of income compared to 80% in Anhwiaso, 76% in Bibiani, 62% in Sefwi Bekwai, 57% in Awaso, and 44% in Wenchi. Tourism served as an income source for 1% of respondents in Bibiani and about 2% of respondents in Lineso and Anhwiaso Zonal Councils. Cumulatively, about 4% of respondents in all the zonal councils obtained income from the mining and forestry sectors.

The ownership of household assets is essential to building the adaptive capacity of households. This is because households with such assets can fall on such assets in difficult times and the presence of such assets enhances the ability of a household to access important information and eases movement. In this regard, the ownership of household assets was not significantly different between the zonal councils. Cumulatively, ownership of assets was higher in terms of communication devices such as mobile phones (95%), television (86%), and radio (60%). This implies that most respondents in the municipality could assess relevant information relating to climate change. On the other hand,

there was lower ownership in terms of transportation assets such as bicycles (14%), motors (13%), cars (6%), and tricycles (4%). By implication, respondents in the municipality mainly depend on commercial modes of transportation.

The socio-economic profile of respondents in each zonal council was a major contributor to the overall adaptive capacity of each zone (Figure 7). Socio-demographic factors such as the number of dependents significantly influence the savings and number of resources available to a household. It was observed from the survey that Anhwiaso had the highest average number of dependents per household (6 persons) with the number of dependents ranging from 0 to 15 persons. Wenchi recorded the lowest average number of dependents (4 persons) with the number of dependents ranging between 0 and 10 persons. Bibiani recorded the highest number of dependents per household of 20 persons within the entire municipality. In terms of household headship, 64% of households in the Sefwi Bekwai Zonal Council had female heads compared to 60% in Awaso, 44% in Bibiani, 39% in Anhwiaso and 38% in both the Lineso and Wenchi Zonal Councils. The level of education of an individual is positively correlated with the person's adaptive capacity. The survey showed that Bibiani had the highest proportion (30%) of formally uneducated individuals within the municipality. Additionally, the Lineso and Sefwi Bekwai Zonal Councils had about 20% of respondents being uneducated followed by Anhwiaso (16%), Awaso (13%), and Wenchi (7%).

Figure 7. Components of adaptive capacity within the zonal councils



Source: Author's computation based on survey data.

4.1.3.4 Vulnerability Index

Table 14 shows that Awaso was the most vulnerable zonal council in the Bibiani-Anhwiaso-Bekwai municipality. Despite recording the highest adaptive capacity index, the Awaso Zonal Council was coupled with equally high levels of exposure and sensitivity. Although Awaso recorded high levels of social network, the high sensitivity of the zonal council's agriculture and infrastructure coupled with high numbers of natural disasters made the area relatively vulnerable compared to the other zonal councils within the municipality. Wenchi was relatively the second most vulnerable zonal council within the municipality. The vulnerability of the area was largely driven by a relatively high level of sensitivity and low adaptive capacity in comparison to the other zonal councils of the municipality. The sensitivity of the area was largely driven by the water and agriculture sectors. The over-dependence on household farms for food and the incessant water conflict endemic in the area increased the vulnerability of the zonal council. Graphical representations of the contribution of the various components of vulnerability are presented in Appendix 4.

The vulnerability of the Bibiani and Lineso Zonal Councils can be regarded as relatively moderate in comparison to the other zonal councils. The moderate vulnerability of these zonal councils results from their relatively low exposure and sensitivity coupled with a relatively high adaptive capacity level. The low exposure and sensitivity of Bibiani may be because the area is highly urbanized as the municipal capital and as result does not overly rely on agriculture as the main source of livelihood. Additionally, as a municipal capital, the area is characterized by the presence of infrastructure that makes residents less exposed and sensitive to climate change. In the case of Lineso, the area was relatively closer to the municipal capital and as a result, had access to better infrastructure.

The Sefwi Bekwai and Anhwiaso municipal councils were the least vulnerable within the municipality. The low vulnerability of these zonal councils was due to the relatively low levels of exposure and sensitivity coupled with relatively high levels of adaptive capacity. The low exposure levels were due to the lower numbers of natural disasters particularly floods and forest/bush fires. Despite the poor infrastructure particularly road networks in these zonal councils, the availability and proximity to critical facilities such as health centers greatly reduced their overall sensitivity and further enhanced their adaptive capacities. Indices for all the major components for each zonal council are presented in Table A2 in Appendix 6.

Table 14. LVI-IPCC of zonal councils in the Bibiani-Anhwiaso-Bekwai municipality

Zonal Council	Exposure	Adaptive Capacity	Sensitivity	LVI-IPCC Vulnerability	Rank
Awaso	0.540	0.669	0.540	-0.069	1
Wenchi	0.496	0.632	0.538	-0.073	2
Bibiani	0.480	0.636	0.516	-0.081	3
Lineso	0.471	0.658	0.468	-0.087	4
Sefwi Bekwai	0.474	0.661	0.483	-0.090	5
Anhwiaso	0.472	0.658	0.488	-0.091	6

The LVI-IPCC is on a scale from –1 (least vulnerable) to 1 (most vulnerable).

Source: Author's computation based on survey data.

4.1.3.5 Gender Dimensions of Vulnerability in the Bibiani-Anhwiaso-Bekwai Municipality

Overall, 45.4% of the households sampled for this assessment were female-headed households. The majority of the female respondents were engaged in agriculture just as their male counterparts; however, a significantly higher proportion of female respondents (14.1%) were not engaged in any economic activity compared to their male counterparts (3.5%). It was also revealed that relatively more men (17%) were engaged in private sector production services than women (8%). Furthermore, while the men in the private sector were engaged in artisanal works like masonry and plumbing, their female counterparts were engaged as petty traders. Additionally, significantly fewer female (25%) respondents indicated that they had a secondary source of income compared to their male counterparts (33%).

Regardless, more women (88%) indicated that they belonged to one form of social network or the other as compared to their male counterparts (83%). Again, there was relatively less difference in the proportion of female and male respondents who reported the ownership of household assets. Table 15 further illustrates that relatively more women had their houses in flood-prone areas than their male counterparts. Concerning agricultural production, female respondents engaged in agriculture possessed relatively smaller farm sizes compared to male farmers. It was observed that the average farm size of female respondents was 4.8 acres compared to that of male farmers of 6.3 acres. These farm sizes ranged between 0.5 to 15 acres for women and 1 to 20 acres for men. This indicates that men were more likely to be engaged in commercial farming by their farm sizes relative to women.

Inferring from the dynamics in Table 15 as discussed above, it can be observed that men in the Bibiani-Anhwiaso-Bekwai municipality were better equipped to cope with the impacts of climate change. Additionally, men are less exposed to climate hazards than women.

Table 15. Gender distribution of indicators

	Woman-headed households (142)	Man-headed households (171)
The main source of income		
Agriculture	56 (39.4%)	97 (56.7%)
Private sector	12 (8.4%)	29 (17.0%)
Unemployed	20 (14.1%)	6 (3.5%)
Secondary income source	36 (25.4%)	56 (32.8%)
Social network	125 (88.0%)	142 (83.0%)
Household assets	138 (97.2%)	168 (98.3%)
House in flood-prone area	41 (28.9%)	33 (19.3%)
Farm size		
Average	4.8	6.3
Minimum	0.5	1
Maximum	15	20

Source: Author's computation based on survey data.

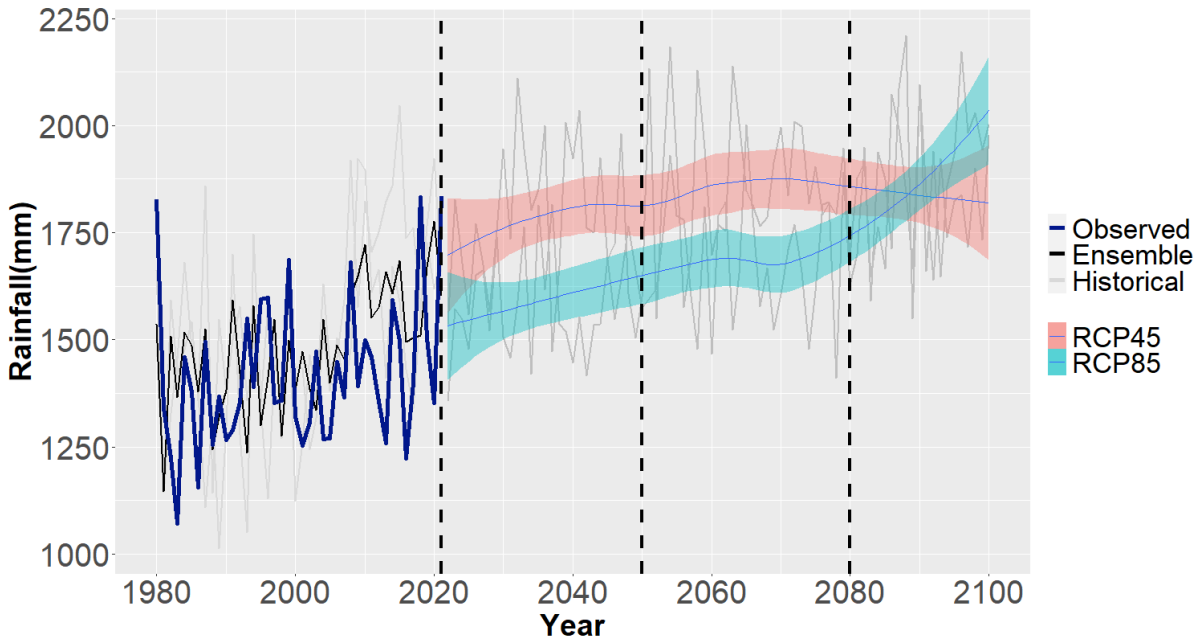
4.2 Assessing Future Climate Change Risk

4.2.1 Summary of Climate Change Projections

Climate change projections for the municipality were made based on historical observed climate data (1980 – 2020) to the end of the 21st century. Scenarios for the future climate (specifically, rainfall and temperature) of the municipality were generated by the VA team using observational climatological data from 1980 to 2020 as provided by the Ghana Meteorological Agency. The scenarios used the Representative Concentration Pathways (RCPs) 4.5 and 8.5, which comprise the largest ensemble common for the two emission scenarios pathways. The RCP 4.5 was assessed as a midway scenario and RCP 8.5 as a realistic business-as-usual scenario given the current trajectory of greenhouse gas emissions.

Rainfall over the Bibiani-Anhwiaso-Bekwai municipality is projected to remain variable at decadal and annual time steps through 2050 and to the end of the century (Figure 8). Annual rainfall is projected to increase from 1484 mm in 2021 to 1678 mm by 2050. Amid the increasing trend in rainfall, there will be intermittent dry and wet years over the municipality because of rainfall variability. Such variations will likely affect rainfall distribution, heavy events onset, cessation, and dry spells. Some years may have an early onset of the rainy season, while others may experience delays in the onset that season. Some years are likely to have prolonged dry spells compared to other years; this may be the case especially in years with low annual rainfall.

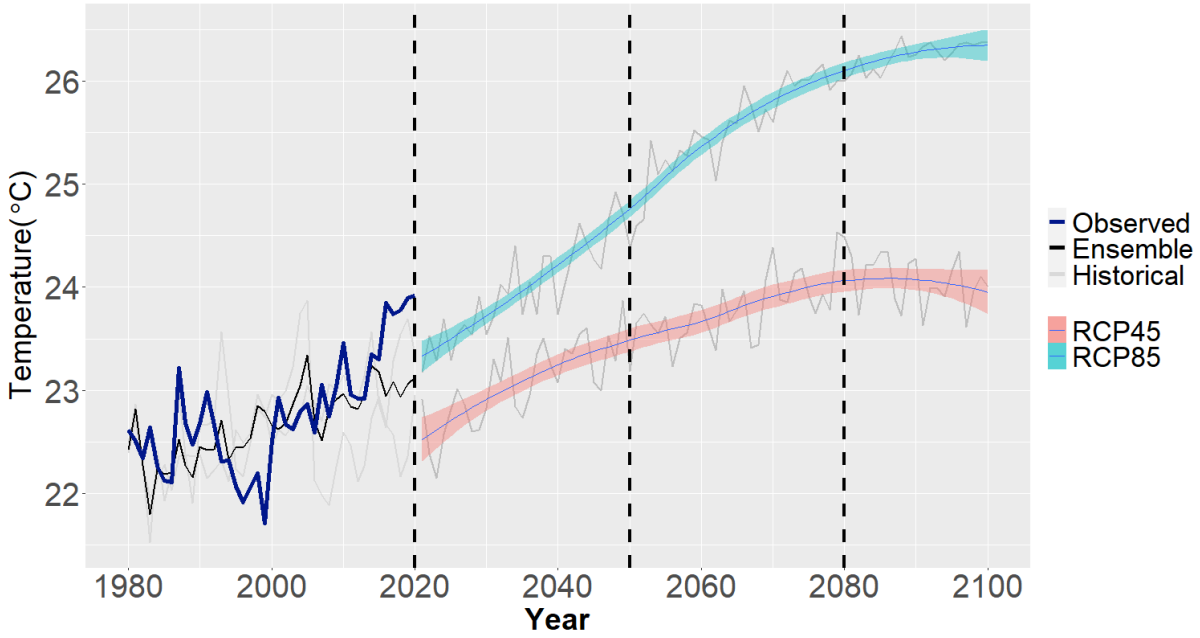
Figure 8. Projected annual rainfall over Bibiani



Source: Klutse NAB & Asare, K. (2022).

The day and night temperatures of the municipality are expected to continue rising until the end of the century. Night-time temperature will increase by 1°C from the current night temperature of 23°C to 24°C by the middle of the century. This is expected to further increase by an additional 1°C by the end of the century (Figure 9).

Figure 9. Projected annual minimum temperature over Bibiani

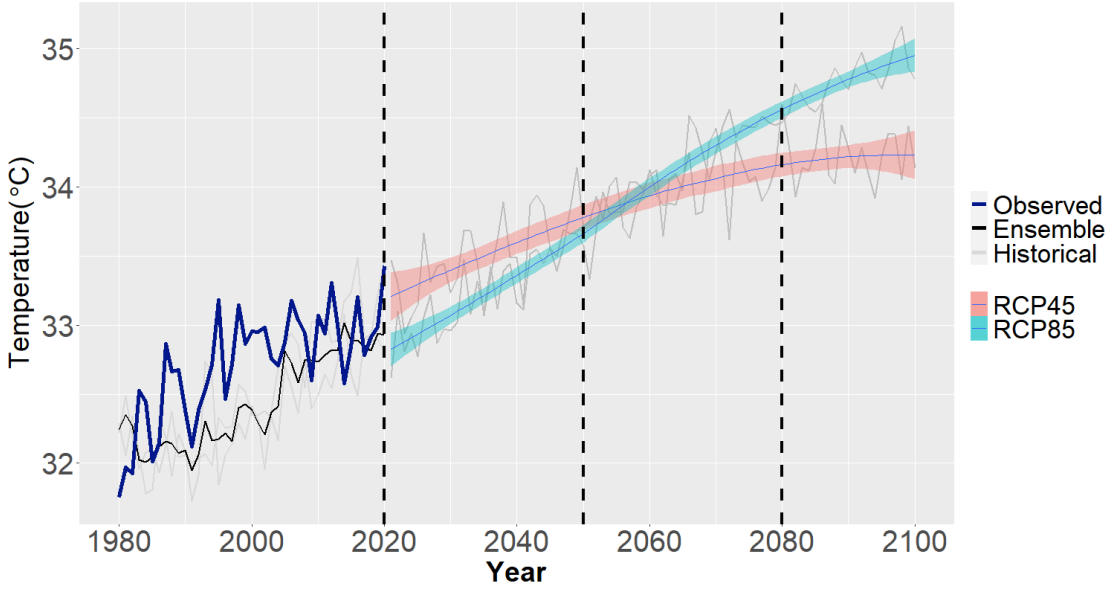


Source: Klutse NAB & Asare, K. (2022).

The mean night-time temperature over the municipality is therefore projected to vary between 22.7°C to 24.3°C by 2050. By implication, the temperature at night will continue to be warm while the number of cold nights will continue to reduce, giving way to warmer nights.

Daytime temperature is also expected to increase by 1°C by mid-century and a further 1°C by 2100 (Figure 10). Annual mean day temperature is expected to increase from the current 32.4°C to 33.4°C by 2050. To this end, the number of cold days will continue to decrease, while the number of warm days rise.

Figure 10. Projected mean annual maximum temperature over Bibiani



Source: Klutse NAB & Asare, K. (2022).

4.2.2 Potential Impacts and Future Climate Change Risks

The projected change in climatic conditions for the century in the Bibiani-Anhwiaso-Bekwai municipality indicates a high likelihood of the occurrence of flooding in some places for wet years and prolonged dry spells for dry years. The occurrence of natural disasters is expected to continue rising as there will be more droughts and heavy rainfall events. Extreme weather events such as heavy rainfall leading to floods and prolonged droughts will continue to adversely affect sectors such as agriculture, water, health, forestry, services, and infrastructure.

An increasing number of heavy rainfall events will put significant pressure on existing drainage systems in the municipality. The occurrence of flooding is expected to increase, particularly in urban areas. Flooding is likely to increase in communities along the banks of the rivers in the municipality because heavy amounts of rainfall can cause rivers to overflow into nearby towns and villages.

Higher temperature levels will lead to an increased number of droughts and result in high numbers of bushfires.

The livelihoods of residents in the municipality are likely to be impacted negatively by climate change through the middle to the close of the century. Agriculture, the mainstay of most people in the municipality, will suffer severely from both rising temperatures and excessive rainfall variability. Prolonged dry spells will make it difficult for farmers to cultivate their crops, while excessive rainfall may lead to flooding of farms.

The projected trend of climate change is expected to exacerbate water shortages in most parts of the municipality because most people rely on natural water sources for their daily use. Continuous prolonged dry spells will lead to the drying of rivers and wells that provide water to most people in the municipality. Additionally, most boreholes are expected to become less functional in the future as groundwater that is close to the surface may dry up due to excessive evapotranspiration, especially during the dry season. The potential scarcity of water is likely to lead to an increase in water conflicts among residents of the municipality.

Other potential impacts and future risks of climate change on the municipality include

- An increase in the demand for energy for cooling during both days and nights because of an increasing number of warm nights and days.
- An increase or emergence of diseases that thrive on high temperatures potentially leading to deteriorating health conditions among residents of the municipality.
- Negative impacts on health and subsequently the productivity of individuals. Negative health impacts may also increase pressure on health facilities.
- Natural ecosystems of the municipality will be stressed because of rising temperatures.

5. Adaptation Policy and Planning Implications of VA Results

5.1 Scenarios for Climate Change Adaptation Planning

To fully utilize the results of the vulnerability assessment of the Bibiani-Anhwiaso-Bekwai municipality to inform adaptation policy and planning at the local level, it is essential to develop scenarios about the vulnerability of the municipality given expected climate trends and the municipality's ability to adopt different adaptation policy and planning options. The lack of data and localized climate models makes predictions of the impacts of climate change in sub-Saharan Africa highly uncertain (Adenle et al., 2017) and this makes it difficult for policy-makers to plan adequately. Scenario planning makes decision making about increasing the adaptive capacity of local communities possible in such uncertain conditions (Kahane, 2012). In light of this, the current vulnerability and climate projections of the municipality are used under different adaptation planning scenarios to predict the impacts of climate change on the municipality by the middle of the century.

5.2 Impact of Climate Change Under Different Adaptation Policy Options

5.2.1 Business-As-Usual Scenario

Under this scenario, adaptation policy and planning follow the current trend going into the future, which is a lack of urgency in addressing the impact of climate change, and few adaptation projects and programs. As a result, the adaptive capacity of people within the municipality remains the same with very little improvements due to individual efforts.

With little or no change in the adaptive capacity of people in the municipality and a projected increase in temperature and rainfall variability with its associated heavy rainfall events, the municipality will become increasingly exposed to climate change. The current exposure level of 0.473 is likely to increase under the business-as-usual scenario because there will be increases in natural disasters amid a highly variable climate. With no conscious effort to address the impacts of climate change, the rise in heavy rainfall events will increase the number of floods experienced in the municipality.

The projected trend of climate change in the municipality will further increase the sensitivity of already-highly-sensitive sectors such as services, agriculture, and infrastructure. The services sector in particular will see a rise in its sensitivity because there will be no conscious effort to have businesses insured against climate-related disasters and there will still be a large number of businesses with little or no information about relevant government regulations. In the agricultural sector, there will be no change in the number of households that receive information on improved production methods and the number without access to farm inputs, adequate food for the whole year, irrigation systems, and agricultural insurance. The result will be a highly sensitive agriculture sector that cannot provide enough food for the numerous households that depend on their smallholder farms for their food. This will further deepen the food insecurity situation of the municipality.

The adaptive capacity of the municipality is likely to decline in the business-as-usual scenario. This may arise from changes in the socio-demographic profile of the municipality. Given the current trends, there will be an increase in the average number of dependents in the municipality, causing pressure on households' already strained resources. Additionally, there is no likelihood of an increase in the number of educated household heads and the proportion of married residents in the municipality. The combination of these factors implies that households will not be able to adapt fully to the impacts of climate change. The projected change in climate will adversely affect the livelihood strategies of households in the municipality. The proportion of household members working outside the community may decline because of dwindling opportunities across the country due to climate change. The overall vulnerability of the municipality will worsen by 2050 if a business-as-usual path to adaptation policy and planning is taken. This is because the exposure and sensitivity components of the overall vulnerability will increase while the adaptive capacity component reduces.

5.2.2 Building Resilience to Maintain Current Living Standards by 2050 Scenario

In the second scenario, the municipality takes moderate steps to enhance the adaptive capacity of its people and maintain their current living standards by 2050. To achieve this, measures need to be taken to improve the four major components of adaptive capacity in response to increases in the exposure and sensitivity components of the VA.

Exposure and sensitivity of the various sectors of the municipality's economy will continue to rise because actions to mitigate climate change will not produce the desired result by 2050. Natural disasters are expected to continue rising as there will be more droughts and heavy rainfall events. Extreme weather events such as floods and prolonged droughts will continue to adversely affect sectors such as agriculture, water, health, forestry, services, and infrastructure. Resources committed to develop of measures to reduce exposure and sensitivity to climate change are not sufficient and they do not yield the expected outcomes in 2050.

The adaptive capacity of the municipality will see a moderate increase by mid-century under this scenario. Extensive campaigns and investment in controlling population growth in the municipality will yield moderate results by mid-century thereby reducing the average number of dependents in the municipality. This will translate into improved living conditions for households as there will be proportionally slightly more resources for members of smaller households. Additionally, targeted assistance programs for woman-headed households will enhance the resources available to woman-headed households who ordinarily would have had fewer resources. Under this scenario, measures are taken to improve household access to credit, which will help to ensure that households can purchase food and other needed supplies to supplement those that are harvested from their farms. Additional measures taken to ensure subsidies are made available to farm households will also improve food access and further increase the income of households. Finally, measures to improve livelihood diversification will yield results, and as such more households in the municipality will not rely on only one source of livelihood for their income.

Overall, the vulnerability of the municipality may stay unchanged with the municipality being regarded as less vulnerable. The overall effect of improved adaptation planning and policy is that increases in exposure and sensitivity may be offset by increases in adaptive capacity resulting in improved adaptation policy and planning in the municipality.

5.2.3 Build Resilience to Enable Economic and Social Development Scenario

In the third scenario, the municipality takes bold steps to build the resilience of the municipality to enable economic and social development despite climatic changes by 2050. To achieve this feat, steps are being taken to enhance the adaptive capacity of residents in the municipality to enable them to cope with the expected changes in the climate.

In terms of exposure, the projected trend of climate variability will continue with likely increases in natural disasters such as floods, droughts, and bushfires. Extreme rainfall events will continue to affect the municipality adversely. However, sufficient investments in the development of early warning systems will yield positive results as fewer people will be affected by natural disasters because of the existence of an effective and efficient early warning system. This will translate into the barest minimum of residents being exposed to flooding and bushfires.

The sensitivity of the municipality to the impacts of climate change will decrease beyond 2050 with the level of investment under this scenario. Although the temperatures in the municipality will rise and precipitation will be more variable, the sensitivity of sectors such as services, agriculture, and infrastructure will be lower due to investments in building the capacity of residents in the municipality. The services sector under this scenario will see a decline in its sensitivity because successful efforts will encourage businesses to get insured against climate-related disasters. Additionally, a greater proportion of businesses will have information about government regulations concerning their businesses. The municipality will have a reduced proportion of households with inadequate food for the whole year thanks to increased access to irrigation systems and agricultural insurance. Investment in agricultural infrastructure will enhance food security in the municipality. Moreover, the fragile infrastructure of the municipality will now be improved to become climate-resilient and hence become less sensitive to climate risks. Finally, the health and sanitation systems of the municipality will see improvements making them less sensitive while reducing the pressure on the existing facilities due to a possible rise in climate-related diseases.

The adaptive capacity of the municipality will be increased immensely beyond 2050 under this scenario. Extensive campaigns and investment in controlling population growth in the municipality will yield high results beyond the middle of the century, thereby reducing the average number of dependents per household. This will translate into improved living conditions for households as more resources will be freed up due to the smaller household sizes. Targeted gender-specific assistance programs will enhance the resources available to woman-headed households that ordinarily would have had fewer resources. Under this scenario, credit is made readily available to households who can now rely on such credit in times of need. The improved household access to credit ensures that households have enough resources at their disposal to meet both their emergency and daily needs. Economic and social development plans will ensure that a greater proportion of the population of the municipality is educated and is therefore employed in other sectors of the economy that are not solely dependent on agriculture. Overall, these adaptation plans and policies will enhance the adaptive capacity of the municipality to climate change.

The effect of this scenario will be an overall decrease in the vulnerability of the municipality to climate change. The investment in social and economic development will cause exposure to reduce slightly or stay the same while sensitivity is reduced. The adaptive capacity will see a sharp increase indicating that the municipality is capable of coping with climate change beyond 2050.

5.3 Implications for Policy

Results from the VA revealed district-specific areas of possible adaptation policy intervention entry points. Based on the results of our assessment, we provide the following recommendations for policy actions in the municipality.

Livelihood diversification: It was observed that 71% of households had only one source of livelihood, mainly agriculture. This implies that only about 29% of households had alternative livelihoods they could rely on in case their agriculture enterprise failed due to climate change. The municipality should take measures such as alternative skills training to help households venture into alternative livelihoods that are particularly less climate-sensitive.

Feeder roads: The assessment indicated that only about 27% of households reported having access to good road networks. This implies that most households within the municipality have difficulty accessing critical facilities such as health centers. To ease the burden of movement, the municipality should make efforts in constructing feeder roads to less accessible communities in the municipality.

Gender-specific aid: Over 70% of households indicated that they did not know of gender-related organizations providing aid to vulnerable sections of the municipality. Given the relatively high proportion of woman-headed households and other vulnerable groups within the municipality, it is recommended that the municipality collaborate with development partners to develop gender-specific aid programs that can provide resources for vulnerable groups.

Early warning systems: Over 88% of households indicated that they have never received any warning about an impending flood or drought event. This further increased the exposure level of households within the municipality. It is therefore recommended that the municipality adopt an early warning system that can provide information on potential climate events to enable households to fully prepare.

Sustained education on forest/bushfires: The number of forest/bushfires recorded over the past decade as recalled by households ranged from 0 to 20. Being a municipality with several forest reserves and many cocoa farms, sporadic bushfires pose a great danger to the livelihoods and resources of both households and the municipality at large. Efforts should therefore be made for sustained education on forest/bushfires particularly during the dry seasons to help avert any potential disasters.

Promotion of climate-smart agriculture: Given that agriculture is the main source of livelihoods of households in the municipality, there should be a conscious effort to promote climate-smart agriculture among farming households. This will help farmers to cope with the highly variable rainfall patterns experienced within the municipality.

Irrigation systems: It was observed that only 1% of households in the municipality had any form of irrigation system on their farm. Given the expensive nature of developing irrigation systems individually, the municipality can facilitate the process of developing irrigation systems for farmers especially since the municipality has numerous streams and rivers.

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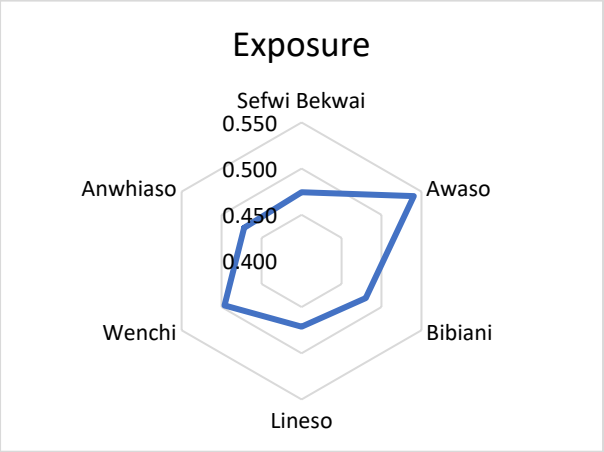
Appendix 1. Exposure of Zonal Councils

Figure 11. Exposure of zonal councils



Appendix 2. Sensitivity of Zonal Councils

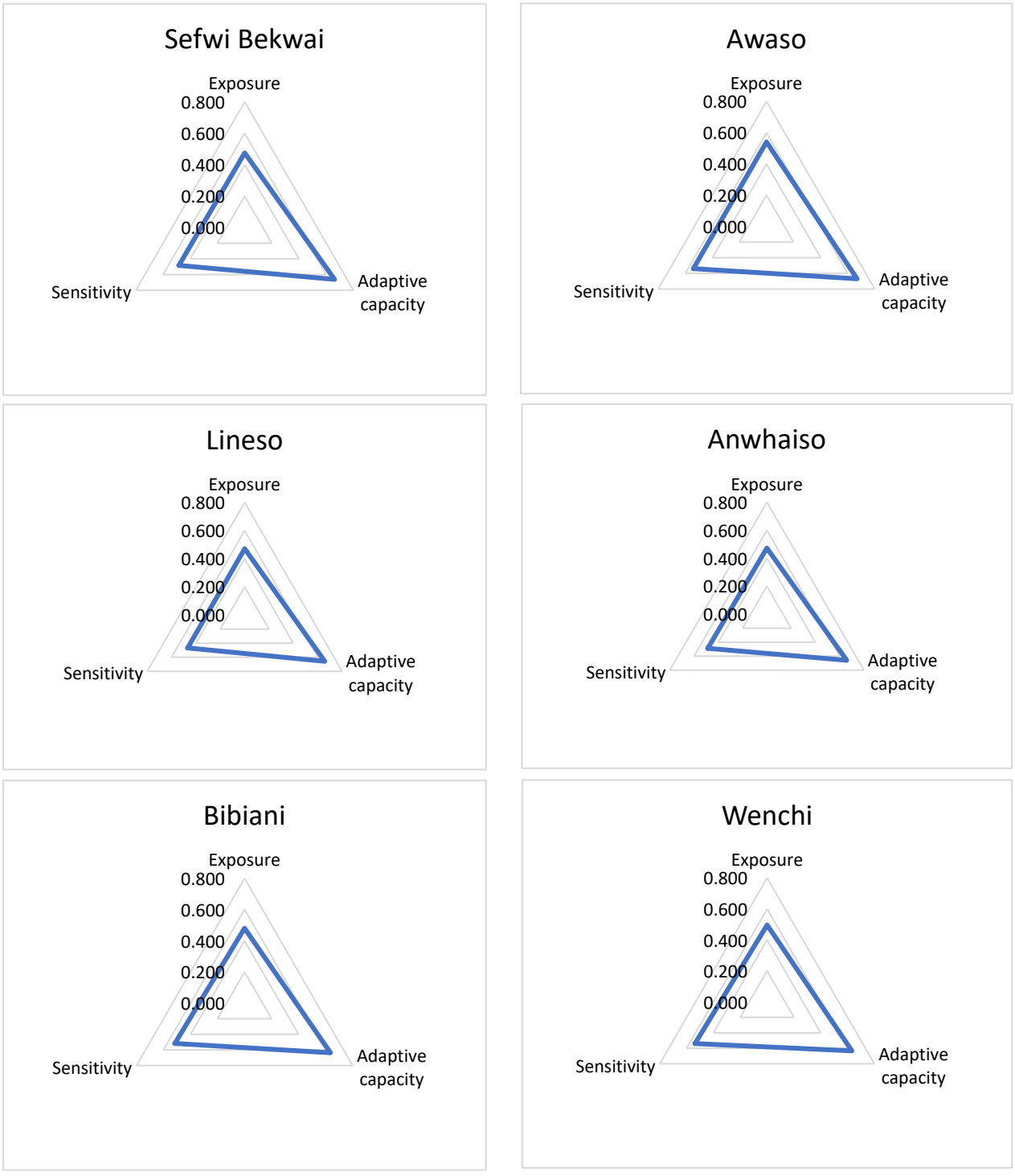
Figure 12. Sensitivity of zonal councils

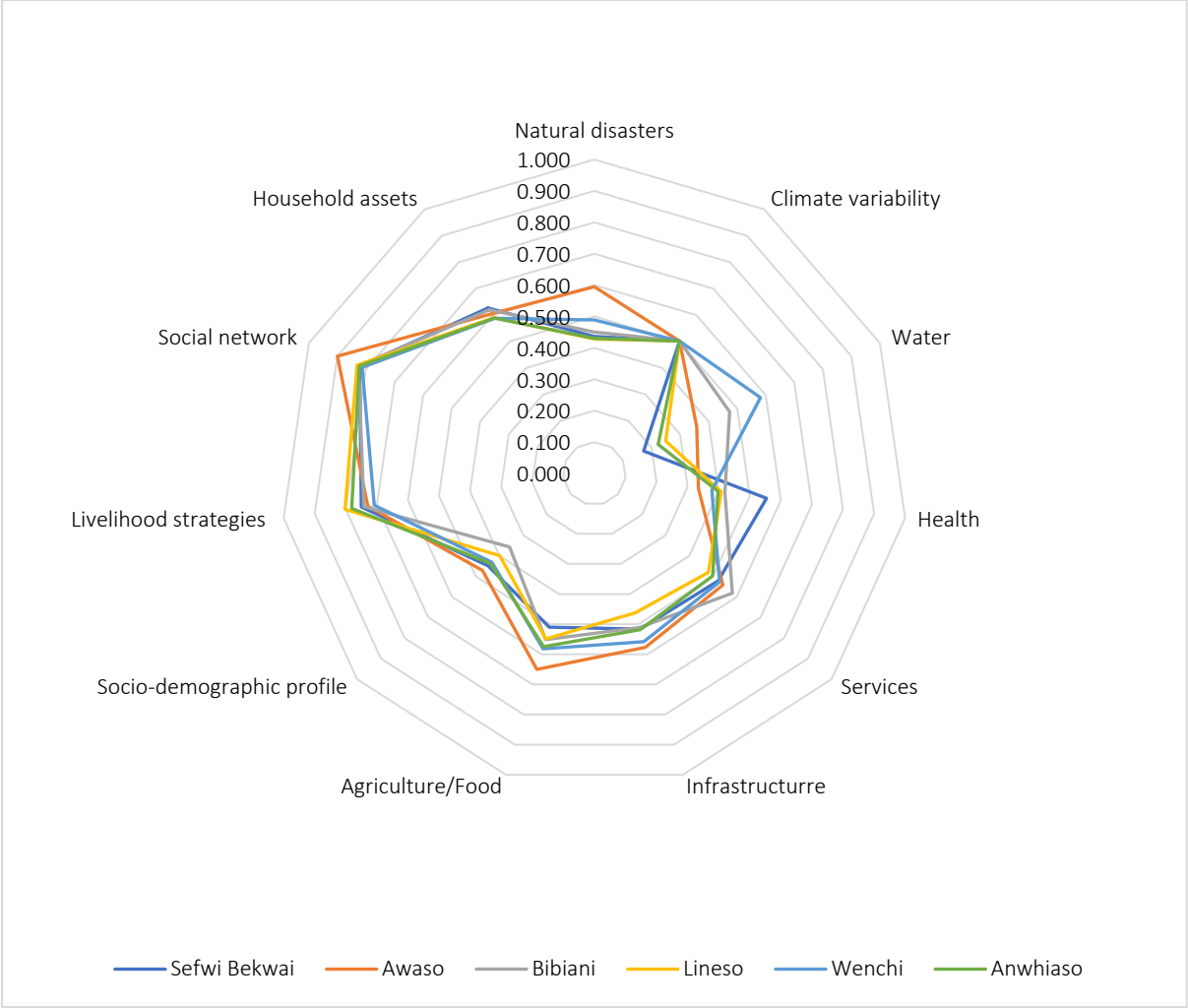
Appendix 3. Adaptive Capacity and Major Components of Adaptive Capacity of Zonal Councils

Figure 13. Adaptive capacity and major components of adaptive capacity of zonal councils

Appendix 4. Components of Vulnerability of Zonal Councils

Figure 14. Components of vulnerability of zonal councils




Natural disasters
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Climate variability
Water
Health
Services
Infrastructurre
Agriculture/Food
Socio-demographic profile
Livelihood strategies
Social network
Household assets
Sefwi Bekwai
Awaso
Bibiani
Lineso
Wenchi
Anwhiaso

Appendix 5. Components of the LVI-IPCC Vulnerability Index

Table 16. LVI-IPCC components

Vulnerability Contributing Factors	Major Components	Subcomponents (Indicators)	Unit	Source
Exposure	Natural Disasters	Average number of drought events reported in the past 10 years	Count	Survey
		Average number of flood events reported in the past 10 years	Count	Survey
		% Households that did not receive warning about expected natural disasters/events	Percent	Survey
		Extent of exposure to climatic changes	Count	Survey
		Average number of forest fires in the past 10 years	Count	Survey
	Climate Variability	Mean annual average rainfall from 1980 – 2020	Millimeters	Model data
		Mean annual average Maximum Temperature (Tmax) from 1980 – 2020	Celsius	Model data
		Mean annual average Minimum Temperature (Tmin) from 1980 – 2020	Celsius	Model data
		Average number of Consecutive Dry Days (CDD) from 1980 – 2020	Days	Model data
		Average number of Consecutive Wet Days (CWD) from 1980 – 2020	Days	Model data
		Average number of warm days from 1980 – 2020	Days	Model data
		Average number of very heavy precipitation from 1980 – 2021	Days	Model data
Sensitivity	Water	% Households that reported water conflicts	Percent	Survey
		% Households not having access to potable water	Percent	Survey
		% Households without consistent water supply	Percent	Survey
		Average time to water source	Count	Survey
	Health	% Households without health facilities in communities	Percent	Survey
		% Households without National Health Insurance Scheme?	Percent	Survey
		Average time to health facility (minutes)	Count	Survey
		% Households with family member with chronic illness	Percent	Survey

Vulnerability Contributing Factors	Major Components	Subcomponents (Indicators)	Unit	Source
		% Households not sensitized on climate-related diseases	Percent	Survey
		% Households without safe sanitation facilities	Percent	Survey
	Services	% Households that depend on agriculture for raw materials in their businesses	Percent	Survey
		% Households with business in a flood-prone area?	Percent	Survey
		% Households who have not insured their business?	Percent	Survey
		% Households not associated with any business cooperative	Percent	Survey
	Infrastructure	% Households who have not insured any of their properties (buildings, cars, etc.)	Percent	Survey
		% Households without disaster-resilient infrastructures?	Percent	Survey
		% Households not having access to good road network	Percent	Survey
		% Households house in a flood-prone area	Percent	Survey
		% Households house collapsed as a result of heavy rainfall/flooding	Percent	Survey
		% Households not having access to ready market in this community	Percent	Survey
		% Households not having cement blocks as the main building material of their house	Percent	Survey
		% Households without access to internet connectivity	Percent	Survey
		Average time to market	Count	Survey
	Agriculture	% Households that do not get information on improved production methods	Percent	Survey
		Production output lost to post harvest losses	Count	Survey
		% Households not having access to farm inputs/equipment	Percent	Survey
		% Households not having adequate food for the whole year	Percent	Survey
		%Households without livestock/poultry	Percent	Survey
		% Households not having irrigation system on their farm?	Percent	Survey
		% Households not having access to water for dry season farming	Percent	Survey

Vulnerability Contributing Factors	Major Components	Subcomponents (Indicators)	Unit	Source
		% Households not belonging to Farmer Based Association (FBO)	Percent	Survey
		% Households without access to/contact with Agricultural Extension Agents	Percent	Survey
		% Household's farm in a flood-prone area	Percent	Survey
		% Households saving some of the crops you harvest to eat in a different year	Percent	Survey
		% Households saving seeds to grow the next year	Percent	Survey
		% Household not aware of agricultural insurance	Percent	Survey
		% Households dependent solely on family farm for food	Percent	Survey
		Average number of months without food	Count	Survey
Adaptive capacity	Socio-Demographic Profile	Average number of dependents	Count	Survey
		% Woman - headed households	Percent	Survey
		% Household head who has not attended school	Percent	Survey
		Average number of years lived in community	Count	Survey
		Average age of respondent	Count	Survey
		% respondents who are natives	Percent	Survey
	Livelihood Strategies	% Households without member working outside community	Percent	Survey
		% Households with only one source of income	Percent	Survey
		% Households not having access to credit for economic activities	Percent	Survey
		% Households not receiving information on weather forecasts for their livelihood activities	Percent	Survey
		% Households not depending on ecosystem services (eg. fuelwood) from the forest	Percent	Survey
		% Households not obtaining income from engagement with the forestry	Percent	Survey
		% Households not obtaining income from engagement with the mining sector	Percent	Survey
		% Households not obtaining income from engagement with the tourism sector	Percent	Survey

Vulnerability Contributing Factors	Major Components	Subcomponents (Indicators)	Unit	Source
	Social Network	% Households belonging to any social organization	Percent	Survey
		% Households not aware of any active gender related organizations and associations in the community?	Percent	Survey
		% Households not having access to any gender related government social interventions	Percent	Survey
		% Households not having access to government subsidy	Percent	Survey
		% Households not receiving remittances/assistance from family or friends	Percent	Survey
	Household Assets	% households who do not own a radio	Percent	Survey
		% households who do not own a television	Percent	Survey
		% households who do not own a mobile phone	Percent	Survey
		% households who do not own a bicycle	Percent	Survey
		% households who do not own a tricycle	Percent	Survey
		% households who do not own a motorbike	Percent	Survey
		% households who do not own a car	Percent	Survey

Appendix 6. Indices for All Major Components per Zonal Council

Table 17. Major LVI components

Zonal Council	Natural disasters	Climate variability	Water	Health	Services	Infrastructure	Agriculture	Socio-demographic profile	Livelihood strategies	Social network	Household assets
Sefwi Bekwai	0.436	0.502	0.173	0.554	0.522	0.516	0.510	0.45	0.75	0.82	0.63
Awaso	0.595	0.502	0.358	0.335	0.542	0.577	0.650	0.47	0.73	0.90	0.60
Bibiani	0.451	0.502	0.473	0.420	0.582	0.511	0.551	0.36	0.74	0.83	0.62
Lineso	0.429	0.502	0.249	0.408	0.481	0.462	0.549	0.40	0.80	0.83	0.59
Wenchi	0.489	0.502	0.582	0.378	0.528	0.558	0.582	0.43	0.71	0.81	0.59
Anhwiaso	0.430	0.502	0.223	0.398	0.499	0.518	0.575	0.44	0.78	0.82	0.59

Appendix 7. Questionnaire

Research Questionnaire for Vulnerability Assessment at the Local Level

Score is assigned to an indicator based on the stakeholders' assessment of the indicator's performance against the criteria.

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

A. Respondents Profile

A1. Name of respondent: …….. Contact phone No: ……

A2. Age of respondent: .....Years

A3. Gender of respondent: [ ] 1=Female 2=Male

A4. Marital status of respondent: [ ]
1 = Single 2 = Married 3= Divorced/Separated 4 = Widowed

A5. Highest level of formal education of respondent: [ ] 1 = None 2=Basic (Primary/Middle/JHS). 3 = Secondary (Secondary/vocational) 4 = Tertiary (Training college/Polytechnic/University)

A6. Period of stay in community/town/village: _____ Years

A7. Origin of respondent: [ ]
1 = Native 2 = Settler/Migrant 3=Other (specify)_____

A8. What is the total number of your dependents: _____

B. Livelihood strategies

B1. Primary occupation of respondent: [ ]
1 = Agriculture 2 = Civil service 3 = Private sector (businessman/woman)
4 = Unemployed 5 = Other (specify) _____

B2. Are you engaged in other income generating activities? [ ] 1 = Yes 2 = No

B3. If yes, which other income generating activities are you engaged in? [ ]
1 = Agriculture 2 = Civil service
3 = Private sector (businessman/woman) 4 = Other (specify) _____

B4. Does any member of your household work outside this community? [ ]
1 = Yes 2 = No

B5. Do you depend on ecosystem services (eg. fuelwood etc) from the forest? [ ]
1 = Yes 2 = No

B6. Do you obtain income from engagement with the forestry? [ ]
1 = Yes 2 = No

B7. Do you obtain income from engagement with the mining sector? [ ]
1 = Yes 2 = No

B8. Do you obtain income from engagement with the tourism sector? [ ]
1 = Yes 2 = No

C. Assessment of assets

C1. Which of these assets does your household own? [ ]/ [ ]/ [ ]/ [ ]/ [ ]/ [ ]/ [ ]/ [ ]
1= Radio 2 = T.V. 3 = Mobile phone 4= Bicycle 5= Tricycle 6= Motorbike
7= Car 8= Others (specify) _____

C2. How often do you use the communication gadgets to access information on weather/production methods and activities [ ]
1 = Very often 2 = Not often 3 = Sometimes 4 = Not at all

C3. Do you have access to good road network? [ ] 1 = Yes 2 = No

C4. What material is your house made of?
1 = Cement 2 = Bricks 3 = Mud 4 = Cement/Brick/Mud
5 = Other (specify)

C5. Is your house in a flood prone area? [ ] 1 = Yes 2 = No

C6. Has any part (or all) of your house collapsed as a result of heavy rainfall/flooding? [ ]
1 = Yes 2 = No

C7. Do you have access to internet connectivity? [ ] 1 = Yes 2 = No

C8. Do you have access to ready market in this community? [ ] 1 = Yes 2 = No

C9. If yes, how long (minutes) do you have to travel to the market? _____ minutes

D. Social network

D1. Are you a member of any social organisation? [ ] 1 = Yes 2 = No

D2. Are you aware of any active gender related organizations and associations in the community? [ ] 1 = Yes 2 = No

D3. Are there any gender related government social interventions (e.g., LEAP, subsidy, land tenure arrangement) in the community [ ] 1 = Yes 2 = No

D4. Have you ever received support from any Research and Development Institution (s) [ ]
1 = Yes 2 = No

D5. Have you ever received support from any governmental organization(s)? [ ]
1 = Yes 2 = No

D6. Have you ever received support from any non-governmental organization(s)? [ ]
1 = Yes 2 = No

D7. If you have received support from any of the organizations/institutions above, did you receive support in coping with climate-related issues? [ ] 1 = Yes 2 = No

D8. Do you receive information on weather forecasts for your livelihood activities or in the community? [ ] 1 = Yes 2 = No

D9. 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*) _____

E. Availability and access to credit

E1. Do you have access to credit for your economic activities? [ ] 1 = Yes 2 = No

E2. If yes, from which source? [ ]/ [ ]/ [ ]/ [ ]/ [ ]/ [ ]/ [ ]/ [ ]]/ [ ]
1 = Family/friend support 2 = Trade credit 3 = Susu 4 = Local money lenders
5 = Reinvestment 6 = Personal savings 7 = Bank loan 8= NGOs/Church
9=Other (specify) _____

E3. Has your household received remittances/assistance from family or friends within the past 12 months? [ ] 1 = Yes 2 = No.

E4. Do you have access to any subsidies ? [ ] 1 = Yes 2 = No

F. CLIMATE EXPOSURE

F1. How many extreme drought/dry spells have occurred in this community since 2012 (10 years ago)

F2. How many extreme flood(s) have occurred in this community since 2012 (10 years ago)

F3. Did you receive any warning about a flood or drought event before it happened? [ ]
1 = Yes 2 = No

F4. Comparing your experiences now with about ten (10) years ago, what kinds of changes have you observed about the following parameters in this community?

	Large increase	Moderate increase	Constant	Moderate decrease	Large decrease
a. Rainfall Quantity Duration					
b. Wind storm Frequency Force (violent)					
c. Water Sources Number Abundance Quality					
d. Temperature					
e. Drought					
f. Flood Volume Damage to infrastructure					
g. Seasonal calendar					
h. Bush fires					

F5. To what extent are you exposed to the changes above? [ ]
Rate from 1 (low) to 5 (high)

F6. How many forest fires have occurred in this community since 2012 (10 years ago) _____

G. Health

G1. Do you have a health facility in this community? [ ] 1 = Yes 2 = No

G2. How long (minutes) does it take to get to a health facility? _____ minutes

G3. Are you on the National Health Insurance Scheme? [ ] 1 = Yes 2 = No

G4. Does any of your household get sick very often? [ ] 1 = Yes 2 = No

G5. Has any household member been so sick in the past two weeks that they had to miss work/school? [ ] 1 = Yes 2 = No

G6. How many mosquito nets do you have as a household? [ ]

G7. Do you have access to safe sanitation facilities? [ ] 1 = Yes 2 = No

G8. How many health facilities do you have in this community/town?_____

G9. How many public toilet facilities do you have in this community/town _____

G10. Have you had any training/sensitization on climate related diseases like malnutrition and diarrhea, respiratory diseases, waterborne diseases etc. [ ] 1 = Yes 2 = No

H. Water

H1. Has water availability been a problem? [ ] 1 = Yes 2 = No

H2. What is the average cost of water per month? _____ (GHS)

H3. What is your main source of drinking water? [ ]
1=Stand pipe 2= Bore hole 3=Tube well 4=River/lake/lagoon/spring 5 = dam
6 = Traditional well 7 = Sachet water 8 =Bottled water 9= Other (specify) _____

H4. What is the main source of water for household chores? [ ]
1=Stand pipe 2= Bore hole 3=Tube well 4=River/lake/lagoon 5 = dam
6 = traditional well 7 = Sachet water 8 =Bottled water 9= Other (specify) _____

H5. Is this water source available every day? [ ] 1 = Yes 2 = No

H6. How long does it take to get to this water source? _____ minutes

H7. In the past, have you heard about any conflicts over water in this community? [ ]
1 = Yes 2 = No

H8. What is the level of NGOs and CSOs activity (Collective action - e.g., NGOs and CSOs investing in water) in the community (very low = 1; low = 2; somewhat low = 3; high = 4; very high = 5)

H9. Do you have access to potable water? [ ] 1 = Yes 2 = No

Select the sector most applicable to you : [ ] 1 = Food 2 = Services

I. FOOD/AGRICULTURE DEPENDENT SECTOR

I1. What is the total size of your farm? (Average since 5 years ago): _____ acres

I2. How did you acquire land for farming? [ ] 1 = Inherited 2 = Bought 3 = Lease
4 = Sharecropping 5 =Hiring 6= Other (specify) _____

I3. What is the major crop you cultivate? _____

I4. Do you grow other crops?.[ ] 1 = Yes 2 = No

I5. Do you have livestock/poultry? [ ] 1 = Yes 2 = No

I6. Do you have irrigation system on your farm? [ ] 1 = Yes 2 = No

I7. If yes, what type of irrigation system? [ ] 1= Manual 2 = Mechanised

I8. If yes, what percentage of your farm land is under irrigation? _____

I9. Do you have access to water for dry season farming? [ ]
1 = Yes, every year 2 = Yes, some years 3 = No

I10. Are you a member of a Farmer Based Association (FBO)? [ ] 1 = Yes 2 = No

I11. Do you have access to/contact with Agricultural Extension Agents (AEA) [ ]
1 = Yes 2 = No

I12. If yes how often? [ ]
a) Weekly b) Monthly c) Quarterly d) Every six months e) Annually

I13. Do you get information on improved production methods and systems? [ ]
1 = Yes 2 = No

I14. Is your farm in a flood prone area? [ ] 1 = Yes 2 = No

I15. What percentage of your total output do you lose as a result of post harvest losses? ____

I16. How often do you get access to labor for your agricultural activities throughout the farming season [ ] 1 = Very often 2 = Not often 3 = Sometimes 4 = Not at all

I17. Does your household save some of the crops you harvest to eat in a different year? [ ]
1 = Yes 2 = No

I18. Does your household save seeds to grow the next year? [ ] 1 = Yes 2 = No

I19. Do you know about agricultural insurance? [ ] 1 = Yes 2 = No

I20. If yes, have you subscribed to any insurance product? [ ]
1 = Yes 2 = No 3 = Interested but no money

I21. Where does your household get most of its food? [ ] 1= Household farms 2= Bought from market 3= Assistance programs 4= other (specify) _____

I22. Do you have access to farm inputs/equipment? [ ] 1 = Yes 2 = No

123. Does your household have adequate food for the whole year? [ ] 1 =Yes 2= No

I24. Between January to December, how many months does your household struggle to get enough food? _____

I25. What is the major form of transportation to your farm? [ ] 1 = Walking 2 = Bicycle
3 = Motorcycle 4 = Tricycle 5 = Car 6 = Other(specify) _____

J. NON-AGRIC DEPENDENT SECTOR

J1. Is your business in a flood prone area? [ ] 1 = Yes 2 = No

J2. Do you depend on agriculture for raw materials in your business activities? [ ]
1 = Yes 2 = No

J3. Have you insured your business? [ ] 1 = Yes 2 = No

J4. Are you a member of any business cooperative? [ ] 1 = Yes 2 = No

J5. Are you aware of any government intervention, strict enforcement of regulations and laws (e.g., education policy, credit)for businesses) [ ] 1 = Yes 2 = No

J6. 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

J7. Have you insured any of your properties (buildings, cars, etc)? [ ] 1 = Yes 2 = No

J8. Do you have disaster resilient infrastructures? [ ] 1 = Yes 2 = No

J9. Are you aware of any climate driven risk based on past threats? [ ] 1 = Yes 2 = No

J10. Where does your household get most of its food? [ ] 1= Household farms
2= Bought from market 3= Assistance programs 4= other (specify) _____

J11. Does your household have adequate food for the whole year? [ ] 1 =Yes 2= No

J12. Between January to December, how many months does your household struggle to get enough food? _____

J13. What is the major form of transportation to your business? [ ] 1 = Walking 2 = Bicycle
3 = Motorcycle 4 = Tricycle 5 = Car 6 = Other(specify) _____

The end: Thank you for your cooperation.

Appendix 8. Organizations and Entities Represented at the Stakeholder Workshops

1. Ministry of Food and Agriculture
2. Bibiani-Awhiaso Bekwai Municipal Assembly
3. Environmental Protection Agency
4. National Youth Authority
5. Ghana Federation of Disability
6. Ghana Health Services
7. Ghana Education Service
8. BibIan Youth Group
9. Kwame Nkrumah University of Science and Technology
10. Ghana National Fire Service
11. National Commission of Civic Education
12. National Disaster Management Organization
13. Forestry Commission
14. Asempa Youth
15. Department of Social Welfare
16. Community Development
17. Rice Farmers Association
18. Traders Association
19. Assembly Men/Women
20. Statistical Services
21. Ghana Meteorological Agency
22. Department of Parks and Gardens


BIBIANI - ANHWIASO - BEKWAI MUNICIPAL ASSEMBLY
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KYEA BIE TI


FREEDOM
AND
JUSTICE