Climate Change Vulnerability Assessment for New Juaben South Municipal Assembly

March 2024 | Final Report

Climate Change Vulnerability Assessment for New Juaben South Municipal Assembly

Author: Dr. Adade Williams on behalf of
Foresight Planners and Research Africa Limited

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

Photo credit: EPA

Acknowledgements

The Government of Ghana, represented by the Environmental Protection Agency (EPA), expresses its gratitude to the different experts from the national government, municipal assemblies, civil society organizations, academia, the private sector, and all stakeholders who participated in various workshops to generate the needed information and knowledge to support this work. The EPA extends a special thanks to Dr. Bob Manteaw of Foresight Planners and Research Africa, the lead consultant and process coordinator, for his coordinating and technical leadership roles. A special thanks also goes to Dr. Portia Adade Williams for her role as lead author of this assignment. Finally, a special thanks goes to Dr. Antwi Boasiako Amoah, of the EPA and NAP Project Coordinator, for his insightful supervision and coordination of the project.

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

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

In partnership with Canada

Federal Ministry for Economic Cooperation and Development

Government of Ireland International Development Programme

Secretariat hosted by:
Secrétariat hébergé par :

IISD

Climate Change Vulnerability Assessment for New Juaben South Municipal Assembly

March 2024 | Final Report

Foreword

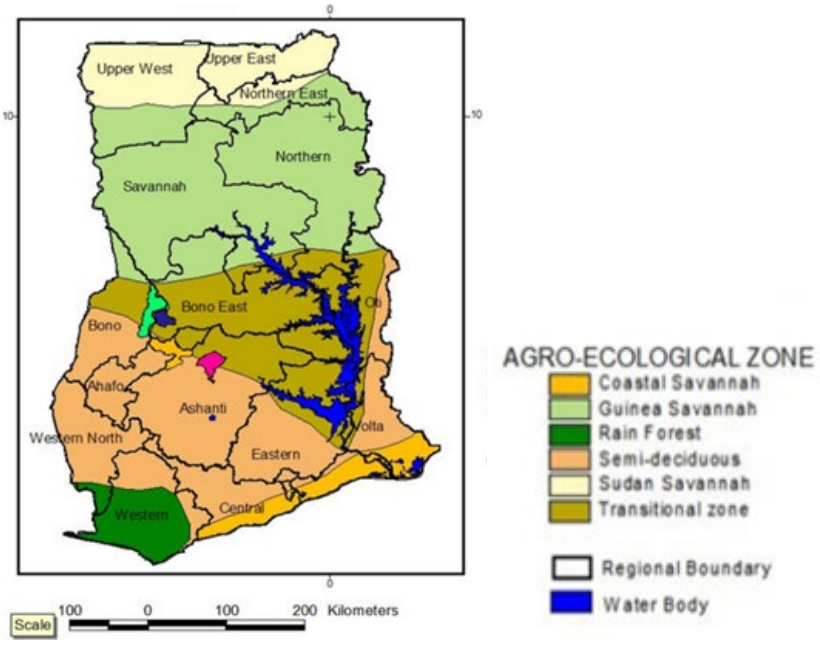
The Government of Ghana prepared six district-level climate vulnerability assessments, each for a municipal assembly located in one of the country's agroecological zones as part of the National Adaptation Planning (NAP) process. These vulnerability assessments aimed to improve the national and subnational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

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

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

This vulnerability assessment was prepared for the New Juaben South Municipal Assembly (NJSM) and is representative of a district located in the Semil-Deciduous Forest (see Figure 1).

Figure 1. Regional and agroecological map of Ghana



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

Table of Contents

List of Tables

List of Figures

Abbreviations

°C	Degree Celsius
AR6	Sixth Assessment Report
CAPI	Computer-assisted personal interviewing
CHPS	Community-based Health Planning and Services
DOVSU	Domestic Violence and Victim Support Unit
EPA	Environmental Protection Agency
FBO	Farmer-Based Organisation
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
km^2	Kilometre squared
LVI	Livelihood Vulnerability Indicator
MCE	Municipal Chief Executive
mm	Millimetre
MP	Member of Parliament
MPCU	Municipal Planning Coordinating Unit
NAP	National Adaptation Plan
NGO	Non-Governmental Organization
NJSMA	New Juaben South Municipal Assembly
PWDs	Persons With Disabilities
R&D	Research and Development
RCP	Representative Concentration Pathway
SLT	Sustainable Livelihood Framework
UNFCCC	United Nations Framework Convention on Climate Change
VA	Vulnerability Assessment

1. Background

1.1 Introduction

Climate change and its impacts pose severe threats to future growth and development and have gained great attention in global and local discussions in recent times. The impacts of climate change continue to rise, with negative effects on key development sectors such as agriculture, water, health, transportation, and energy. Climate change impacts also interact with non-climate drivers and stressors to exacerbate vulnerability of various social and economic systems. Ghana's climatic conditions have changed in the past four decades, including increases in temperature, more erratic rainfall, greater incidence of floods, and more extreme weather events. These impacts are accelerating and worsening, requiring that Ghana strengthen its capacities for responding to climate-related challenges. This means mainstreaming climate change priorities in development planning processes and policies at multiple levels.

Ghana's NAP process is facilitating the promotion and mainstreaming of climate change adaptation issues as well as supporting multi-sectoral medium- to long-term adaptation planning for all districts in the country. To avoid the design and implementation of adaptation actions and strategies that inadvertently result in deepened vulnerability and put local actors at risk, it is critical to understand how communities are vulnerable to climatic and non-climatic stressors. Understanding exposure, sensitivity, and adaptive capacity to climate change can inform vulnerability assessments and provide guidance on "best-fit" adaptation options. These assessments can guide plans and programs to minimize climate effects, enhance resilience, manage any present and future anticipated risks, and improve adaptive capacity, planning, and actions. Conducting a vulnerability assessment (VA) allows the government, community members, and stakeholder groups to identify key climate risks that require a response and a baseline against which to measure successful implementation of adaptation practices.

Ghana's NAP process emphasizes the importance of context-specificity and place-responsive approaches to adaptation planning. It has adopted a district-focused adaptation planning process which uses district-level vulnerability assessments to ground adaptation planning for key climate-sensitive sectors. This report presents a district-level vulnerability assessment for New Juaben South Municipality (NJSM), which is one of the oldest of the 32 Municipal Assemblies in the Eastern Region of Ghana. New Juaben South's economy relies heavily on climate-sensitive sectors, and this vulnerability assessment at the municipal level aims to advance resilience of its communities to improve their adaptive capacity, climate planning, and adaptation actions. The district-level VAs reflect that the vulnerability and exposure to climate-related hazards varies across regions because of differences in economic, social, demographic, cultural, institutional, and governance circumstances. Findings from this vulnerability assessment will guide context specificity in the NJSM's approach to improve adaptive capacity and identify strategies to strengthen resilience and reduce vulnerability.

1.2 Purpose and Objective of the Vulnerability Assessment

The overall purpose of this VA process is to evaluate the exposure, sensitivity, and adaptive capacity of the human, natural, and economic systems in NJSM. This assessment provides context-specific knowledge for enhancing resilience and informing local adaptation planning for climate resilience in a changing environment.

The specific objectives are to:

- Identify district-specific vulnerabilities for prioritization in the district-specific adaptation planning and action under the NAP process.
- Inform the design of projects and programs to be implemented at the district level.
- Develop knowledge products that can be used for awareness creation, advocacy campaigns, and effective adaptation planning.

1.3 Scope of the Vulnerability Assessment

- **Sectors:** The VA identified impacts and vulnerabilities through a cross-sectoral analysis that considered the cascading nature of climate change impacts and a key range of sectors at risk from climate change impacts including agriculture (crop and livestock), health and sanitation, water, transportation and infrastructure, biodiversity (natural resources), and energy as stipulated in the Ghana NAP framework.
- **Geographic scope:** The VA assessment covered the New Juaben South Municipality (NJSM), which is representative of a municipality located in t the semi-deciduous forest agroecological zone. The assessment considers its zonal areas as the minimum unit of analysis. However, the zonal data was obtained through the aggregation of household information from selected communities.
- **Timeframe for analysis:** Given the long-term nature of climate change and its impacts, the VA examined current vulnerabilities as well as projected future expected impacts up until 2100. This provides important information for planning into the future.

1.4 Outputs of the VA

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

- Output 1: Development of Climate Projections and Scenarios for New Juaben South Municipal Assembly (4.2.1)
- Output 2: Description and creation of representative district-level vulnerability narratives (4.1.2)
- Output 3: Projections and description of potential future vulnerabilities (4.2.2)
- Output 4: Analysis of pathways that link current vulnerabilities to the future (4.2.2)
- Output 5: Description of prioritized vulnerabilities in key climate-sensitive sectors (4.1.2)
- Output 6: Creation of a map of vulnerability hotspots in each district (4.1.2.2)
- Output 7: Identifying available options to help people and communities adapt to the effects of climate variability and change (5.1)

1.5 Guiding Principles

The VA process was guided the framework and principles set out in Table 1.

Table 1. Guiding principles of the vulnerability assessment

Guiding Principle	How Applied
District-specific and needs-driven: The assessment should be tailored to identify specific vulnerabilities in specific districts to inform the development of district-specific adaptation responses.	The VA identified climate vulnerability in the NJSM, drawing insights from the relevant location and the socioeconomic context of the municipality. The VA process analyzed the prevailing climate change manifestations, impacts, socioeconomic attributes, and physical and environmental factors, which all contribute to the sensitivity of NJSM to the impacts of climate change (e.g., increasing temperatures, change in seasonal patterns) and other associated hazards such as floods and droughts.
Inclusivity: The VA process should make conscious efforts to identify, engage, and include all or most 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.	Identification of key stakeholders and their interests was an important first step in coordinating their participation in the vulnerability assessment. Stakeholders were identified based on their experience with, role in, knowledge of, and exposure to climate change and its impacts, and their involvement in existing climate adaptation policies within Ghana and the municipality. The VA process engaged different stakeholders comprising nineteen women and thirty-three men, from the public/government sector (which includes regulatory bodies, policy makers, and implementers from the ministries, departments and agencies [MDAs]); research/academia; development partners; non-governmental organizations (NGOs)/ civil society organizations (CSOs); vulnerable groups (women/youth/disabled); private sector; traditional authorities; other relevant groups; and media. (See Stakeholder list in the appendix.)
Relevant to the NAP and national priorities: The VA should aim to align with and feed into Ghana's NAP process, as well as other national development priorities. Thus, the VAs must be relevant both in context and content to the NAP process and national development aspirations.	Following the desired outcome of Ghana's NAP process to facilitate the promotion and mainstreaming of climate change adaptation issues as well as to support multi-sectoral medium- to long-term adaptation planning for all districts in the country, it was critical for the VA process to understand how vulnerable a system is to climate and non-climatic stressors. This understanding helps to avoid the design and implementation of adaptation actions and strategies that inadvertently result in deepened vulnerability and put local actors at risk.

Guiding Principle	How Applied
Gender-sensitive approach: The VA process should seek 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 should be analyzed and disaggregated by sex and age. This focused analysis is in recognition that vulnerable groups (by age, capabilities, gender, economic standing) are affected in different ways by climate change. Both men and women should be consulted separately, for example in focus group discussions, about their perception of climate change, hazard, and livelihoods.	The VA process considered gender sensitivity and, as a result, identified different gender roles in communities within the district and highlighted how different gender roles lead to different exposure levels, capacities, options, and barriers to resilience.

1.6 Definition of Key Terms and Concepts

This VA framework adopts definitions from *Climate Change 2022: Impacts, Adaptation and Vulnerability,* Contribution of Working Group II to the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC, 2022). An insightful understanding and appreciation of the nature and definition of these terms is particularly helpful in the creation of context-responsive approaches. The definitions used in this report and that guided the assessment of climate vulnerability in the NJSM are listed below:

- Adaptation is defined, in human systems, as "the process of adjustment to actual or expected climate impacts, in order to reduce risks 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 "the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected" by climate impacts.

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

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

- Adaptive capacity refers to "the ability of systems, 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.

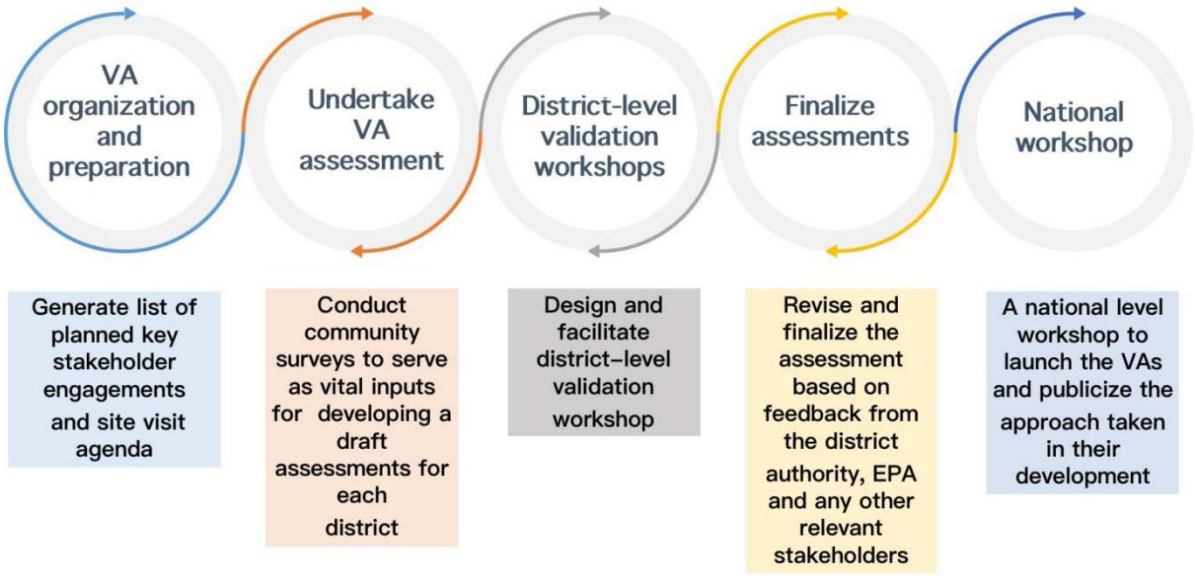
1.7 Methodological Framework for the VA Process

The methodology to the VA was mainly explorative, using both qualitative and quantitative approaches[1]. This approach was consistent with the objective of the VA, its timeframe, and the resources available. The assessment also relied on expert judgment and participatory approaches, reflecting the NAP's guiding principle of participatory decision making that involves relevant stakeholders. The various data collection methods provided inputs that complemented the information from climate models. The VA team used this information to study and quantify the climate exposure, sensitivity, and adaptive capacity of the municipality.

Information and data for the VA was collected, processed, and analyzed at the indicator level. Both primary and secondary sources of data were used for the indicator factors. Primary data was collected through household surveys, Key Informant Surveys, and a workshop. The workshop adopted a participatory approach and discussed municipality-specific exposure, sensitivity, and adaptive capacity indicators to consider in the VA methodology. An initial VA stakeholders' workshop that was conducted at NJSMA brought together diverse stakeholders impacted by climate change within the municipality, including the government or public administration, university/academia, traditional authority and opinion leaders, people with disabilities, vulnerable groups (women's and youth groups), farmers, media, and residents of NJSMA. A national workshop was held to launch this VA and the five others prepared under the oversight of the EPA.

Examples of secondary data sources include Ghana's national and local hydro-meteorological data, grey and published literature, and climate model data. A stakeholders' analysis was also conducted to collate background responses on stakeholder roles and expected contributions to the VA to complement the initial desk exercise to identify stakeholders. Results from the desk study and stakeholders' workshop have been used in this report. Figure 2 below describes the steps followed for the VA process.

Figure 2. District-specific framework for the VA process



[1] See Chapter 4 of this report for detailed data collection approaches.

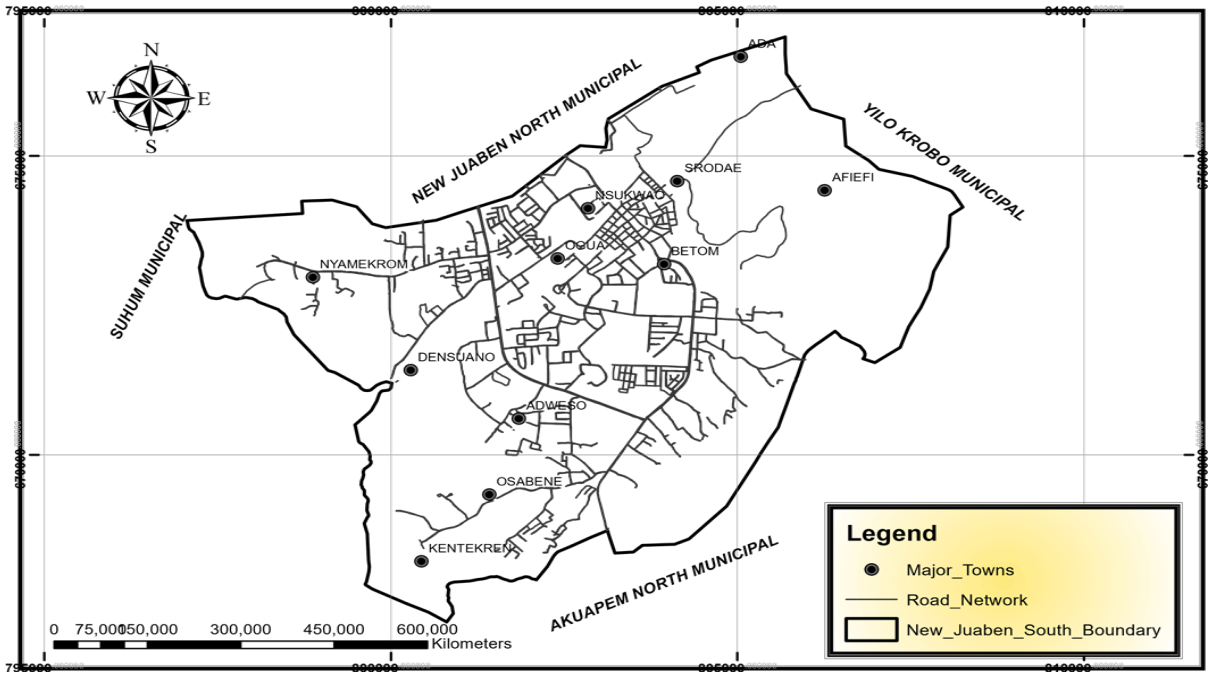
2. District Profile

This chapter presents background information on key issues, which provides context for understanding the climate vulnerability of NJSMA now and in future. This includes physical and environmental features (such as basic geography, local climate and exposure to climate-related hazards, natural resources); a demographic overview (e.g., density of the population, rural/urban ratio, migration trends); an economic overview (major economic sectors vulnerable to climate change); and the administration and governance structure (e.g., description of the governance structure and capacities of the district, and the role of other stakeholders). The information is taken primarily from the NJSMA municipal profile report (NJSMA Municipal Planning and Coordination Unit [MPCU], 2021), and complemented by data from literature review.

2.1 Location and Size

The New Juaben South Municipal Assembly is one of the 33 Municipal Assemblies in the Eastern Region with Koforidua as its capital. It covers a land area of 43 km^2. The municipality shares boundaries in the north with New Juaben North Municipal Assembly, to the southeast with Akwapim North Municipal, and to the east with the Yilo Krobo Municipal Assembly. The land is gently undulating with heights ranging between 152 metres and 198 metres above mean sea level. The highest area is the mountain belt along the eastern boundary of the municipality. The municipality is drained mainly by the Densu River and its tributaries, which include the Bompom, Obopakko, Afena, Nsuokwao, and others. The Densu River is dammed by the Densuagya where the water is treated and distributed to the municipality.

Figure 3. Map of New Juaben South Municipality



Source: Municipal Planning Coordinating Unit.

2.2 Demographic Overview

The 2022 population of the municipality was 125,257, constituting 60,567 (48.4%) males and 64,689 (51.6%) females (Ghana Statistical Service [GSS], 2022). The sex ratio is 93.6 implying that for every 100 females, there are 93 males (NJSMA, 2021).The population is largely urban with 125,004 living in urban localities and 252 in rural localities, with an average household size of 2.7 persons. In terms of locality of residences, less than 1% of the population in the municipality live in rural areas (GSS, 2022). This contributes to the high population density in the district and Koforidua, the district capital in particular. The municipality forms 4.3% of the regional population. The municipality has a youthful population with 30.8% of the population aged less than 15 years, while those aged 20-24 years account for 12% of the population. Residents of the municipality are heterogeneous in terms of ethnicity with a high dominance of Akans and Ga-Adangbes. Ewes and people belonging to other ethnic groups of the north also form significant proportions of the population in the municipality. The Akan tribe constituents are a fair mix of Asantes, Kwahus and Akims with a sizeable number of Akwapims. The municipality is predominantly Christian, followed by Muslims and Traditional believers, respectively.

2.3 Administration and Governance

The General Assembly of the New Juaben South Municipal Assembly comprises 51 members: the Municipal Chief Executive (MCE), 34 elected assembly members (32 men and 2 women), 15 government appointed assembly members (11 men and 4 women), and 1 Member of Parliament representing the New Juaben South constituency. The Assembly has a Presiding Member who is elected by two-thirds of all the members of the assembly. He chairs the Assembly meetings as well as the Complaints Committee. The Assembly has 34 electoral areas.

The Assembly has many mandatory subcommittees in place. The committees comprise the various Assembly Members and the Departmental Heads who play various roles within the subcommittees. The five mandatory sub-committees of the Assembly are Development Planning, Finance and Administration, Social Services, Works, and Justice and Security. In addition, the Assembly has two other sub-committees: Environmental and Agricultural.

In parallel to the formal government, a traditional form of governance also operates along family lines. Under the traditional system, the Omanhene of the municipality is traditionally called “Dasebere” and widely regarded as the epitome of New Juaben culture. He presides over all the other Chiefs within the New Juaben Traditional Council area. Below the Omanhene are the Divisional Chiefs and the “Adikrofos” The line of inheritance or succession among the people, who are mostly Akans and especially Asantes, is matrilineal. Each family unit is headed and controlled by the “Abusupanin” and “Obaapanin” who always ensure that there is peace and harmony in the family. This system operates in every family, and it goes up to the larger community where there are chiefs, queen mothers and elders, who apart from being spiritual heads of the large community, are responsible for the welfare of their subjects.

2.4 Physical and Environmental Features

The New Juaben South Municipality falls within one of Ghana's six agroecological zones, specifically the semi-deciduous rain forest zone with a bi-modal rainy season of between 1,200 mm and 1,700 mm that reaches its maximum during peak periods of May/June and September/October. The dry season is relatively short and occurs between November and February. Humidity and temperatures are generally high, ranging between 20°C and 32°C (GSS, 2014). The mild temperatures have a significant bearing on why the municipality a major tourist destination.

The vegetation of New Juaben South is mainly characterized by tall trees with evergreen undergrowth, although many of the tall trees with economic values have been cut down. Scattered patches of secondary or broken forest are present under most of the larger trees among which are *Triplochiton scleroxylon* (wawa), *Antiaris toxicaria* (kyenkyen), *Milicia excelsa* (odum), and *Ceiba pentandra* (onyina). The few tall trees occur as scattered emergent trees that tower above the canopy. Three soil types are predominant in the municipality, which support the growth of perennial cash crops (such as cocoa, coffee, oil palm, and citrus), and annual and semi-perennial food crops of the area such as vegetables, sweet potatoes, sugar cane, rice, plantain, cocoyam, and bananas.

The forest and evergreen characteristics of the municipality provides ecosystem services, including carbon sequestration for the mitigation of climate change; soil protection, moisture and nutrient retention; a buffer against the spread of pests and diseases; watershed preservation functions (regulation of water flows in terms of both quality and quantity), flood-and-drought reduction regimes, and moderation of climate at the local and regional levels through regulation of rainfall regimes. These services provide food, medicine, timber, and many non-timber forest products which offer livelihoods to people in the municipality. However, chainsaw logging, illegal logging, bushfires, fuel gathering, and weak penalties for offences are identified as contributing to a rapid depletion of the closed canopy forest cover in the municipality. Additional stress from climate perturbations, such as droughts can reduce fuel moisture and lead to fires that render the reserves more vulnerable to further degradation (Dwomoh et al., 2019).

Human activities such as estate development and improper waste disposal have contributed to the near-disappearance of some of the municipality's streams. Encroachments of natural reserves have also impacted negatively on streams, further threatening their existence. This has led to flooding problems that perennially confront most of the towns in the municipality (NJSMA MPCU, 2021).

The Municipality has a total of 596 km of feeder roads, with 260 km being urban roads. The compact size of 110 km^2 gives it a road density of 3.2 km which is relatively adequate and suitable for efficient movement of people, goods, and services. The Urban Road network of 260 km is made up of 60% tarred and 40% untarred roads. 60% of the road network is in good condition, 20% fair, and the remaining 20% in a poor condition.

2.5 Economic Overview (Vulnerability of Major Economic Sectors to Climate Change)

Ghana's National Adaptation Plan (NAP) framework lists agriculture, water resources, biodiversity and forestry, transport, infrastructure, industry, and human health as the main sectors of socioeconomic importance (EPA, 2018). It is necessary to assess how these main socioeconomic sectors are impacted by climate change hazards. The key economic sectors in New Juaben South are the services sector, industrial manufacturing and processing, agriculture, and other socio-economic activities such as business and consumer commerce. The service sector (such as transport, hospitality, business services, finance, and insurance) constitutes 39.9% of the municipality's economy, industrial manufacturing and processing (such as textile and garment manufacturing, wood processing, metal processing) comprise 26.7%, agriculture 26.1%, and other socio-economic activities constitute 7.3%. While most industrial establishments are found in the central business area of the Municipality, agricultural production is carried out in the small settlements and peri-urban localities.

Agriculture in New Juaben consists largely of crop farming of a variety of products including yam, grains, cocoa, oil palm, and kola nut, as well as livestock and timber. The 2010 Population and Housing Census noted that agricultural activities constitute about a fifth of the municipality's activities and employs many in formal and informal settings (GSS, 2014). Asante and Amuakwa-Mensah (2014) report that the variability of rainfall patterns and perennial flooding impose huge risks on agricultural activities. This is because precipitation serves as the main source of irrigation for farmers in the municipality. With increased rainfall variability, farmers find it difficult to plan and schedule planting activities, which in turn adversely impacts farm yields and threatens food security. The increasing variability of rainfall increases the risk associated with farming as prediction of planting and harvesting times becomes almost impossible. This results in low agriculture productivity, food scarcity, and low income for farmers. The livelihoods of households who depend solely on produce or gains from farming are equally impacted (Logah et al., 2013). Perennial flooding and torrential rainfall along the undulating topography in the municipality expose farms and plantations to runoff.

The transportation sector and infrastructure in the municipality also suffer frequent damage from flooding. Runoff water from torrential rainfall interacts with mining activities in the municipality, and in particular illicit waste disposal methods, to increase the pollution of major surface water bodies such as the Densu River and its tributaries. These rivers serve as the main source of water for New Juaben South Municipality and its environs. The Ghana Water Company has noted that contamination of the Densu River and its tributaries poses huge water supply quality and quantity risks (NJSMA, 2022). As a coping mechanism, a study by Asibey et al., (2019) indicated that due to the inadequate water supply and water scarcity issues in New Juaben South, residents resort to reducing their water intake and purchasing sachet water and water from private water tanker drivers who supply water at relatively higher cost than that provided by formal suppliers.

According to the Global Forest Watch (2023), New Juaben had tree cover of 9.44 kha in 2010, estimated to represent over 55% of its land area. However, in 2021, New Juaben had lost an estimated 152 ha of tree cover, equivalent to 108 kt of CO_2 emissions. The impact of climate variability and change on the destruction of forest and ecosystem services further affects the water, energy, and tourism sectors. Loss of forest cover affects water filtration and aquifer recharge, leading to situations where residents demand more energy to access water through increased water pumping and purification. The ability of urban trees to improve thermal comfort and hence improve eco-energy efficiency[2] in their surroundings is also affected by increasing temperature and rainfall variability (Marful, 2013).

Obour Tabiri has been identified for tourism development for those seeking an adventure holiday. A trek to the peak of Obour Tabiri Mountain provides an opportunity to see an aerial view of Koforidua. With looming climate change and variability, tourists could begin seeking other climate-friendly destinations.

The municipality has various market centres for commercial activities, especially for marketing farm produce. There are two major markets located within the Central Business District (Juaben Serwaa and Central Market) and three minor markets (Adweso, Zongo Market and Agartha Market). One of the few beads markets in the country is in the municipality located at Gallaway where bead products are sold to customers across the world. The municipality has numerous health facilities, including a Regional Hospital which serves as a referral centre. Some key challenges confronting New Juaben South as it seeks to promote economic development are the poor road network (the deplorable state affects economic activities), undeveloped tourist sites (none of the tourist sites are appropriately developed), flooding, and insecurity (mainly boundary disputes and high crime rates).

[2] Eco-energy efficiency is a function of seasons, background climate, size of green area, type of surface over which trees are planted and the amount of leaf cover.

3. Vulnerability to Current Climate Change

This chapter describes the level of vulnerability to climate change for New Juaben South Municipal Assembly including its towns/villages and economic sectors. The analysis considers underlying factors such as observed climatic change including hazards, factors of vulnerability to identify vulnerable locations, sectors, and groups, and climate change impacts on vulnerable locations, sectors, and groups.

3.1 Observed Climate Change Manifestations

NJSMA is in the semi-deciduous rain forest zone and is experiencing the impacts of climate variability and change. The change has resulted in temperature rise, increased evaporation, decreased and highly variable rainfall patterns, and more frequent and pronounced flooding and drought spells. New Juaben experiences a bi-modal rainfall pattern, with major and minor rainy seasons. The major rainy season is estimated to occur from April to July/August while the minor season is from September to November. The municipality also experiences a double maxima rainfall period. That is, the recorded rainfall reaches maximum in the two peak periods of May/June and September/October. Mean annual rainfall ranges between 1,200 and 1,700 mm and is normally associated with tropical thunderstorms from southwest monsoon winds (Attua & Fisher, 2011). Annual rainfall decreased by 11.3% and 12.0% in 5- and 10-year intervals (EPA, 2020).

Such rainfall variabilities have huge consequences for agriculture in the municipality. Farmers are negatively affected by heavy rainfall, as these events cause surface runoff and erosion that damage crop and pasture composition. Also, after every heavy-rainfall-induced flood, market centres and school services are disrupted due to the destruction of structures. Due to high topographic wetness indices, mosquito-prone areas are identified as high and very high in 6% and 29% of the municipality, respectively (Kumi-Boateng, 2017). Changing rainfall patterns could threaten to increase the scale of these mosquito-prone areas, potentially increasing the distribution of vector-borne diseases.

Humidity and temperatures are generally high in the district, ranging between 20°C and 32°C. Asare-Nuamah & Botchway (2019) reported that for the semi-deciduous agroecological zone in which New Juaben lies, the average annual temperature of 27^{o}C is highest in February-March and lowest in July-August. An increase in temperature was attributed to the global emission of greenhouse gases like carbon dioxide and nitrogen oxide through human activities (Boateng & Larbi, 2021).

Key literature sources for climate and weather trends for New Juaben South are presented in Table 2.

Table 2. Review of weather trends in New Juaben Municipality

Institution/ author	Data	Data description	Data source
Atuah and Fisher (2010)	Variable rainfall pattern	Rainfall variability in New Juaben Municipality	Attua, E. M., & Fisher, J. B. (2011). Historical and future land-cover change in a municipality of Ghana. Earth Interactions, 15(9), 1-26.
EPA (2020)	Decreasing rainfall pattern	Variability coefficients of rainfall amounts in 10-years intervals	EPA (2020). Climate Vulnerability Assessments for Six (6) Districts in Ghana: Baseline Scoping Report NJSM.
Asare-Nuamah and Botchway (2019)	Decreasing rainfall pattern	Rainfall variability for semi-deciduous agroecological zone	Asare-Nuamah, P., & Botchway, E. (2019). Understanding climate variability and change: analysis of temperature and rainfall across agroecological zones in Ghana. Heliyon, 5(10), e02654.
	Increasing temperature	Temperature and humidity conditions of the semi-deciduous agroecological zone	
Logah et al. (2013)	Decreasing rainfall pattern	Rainfall variability for three decades of the agroecological zones	Logah, F. Y., Obuobie, E., Ofori, D., & Kankam-Yeboah, K. (2013). Analysis of rainfall variability in Ghana.
Boateng and Tete-Larbi (2021)	Increasing temperature	Causes of increasing temperatures	Boateng, K., & Larbi, R. T. (2021). Collaboration between Chiefs and Local Government Actors in Combating Climate Change: Evidence from New Juaben, Ghana. Contemporary Journal of African Studies, 8(1 & 2), 25-41.

3.2 Factors of Vulnerability and Associated Impacts on Vulnerable Locations, Sectors, and Groups

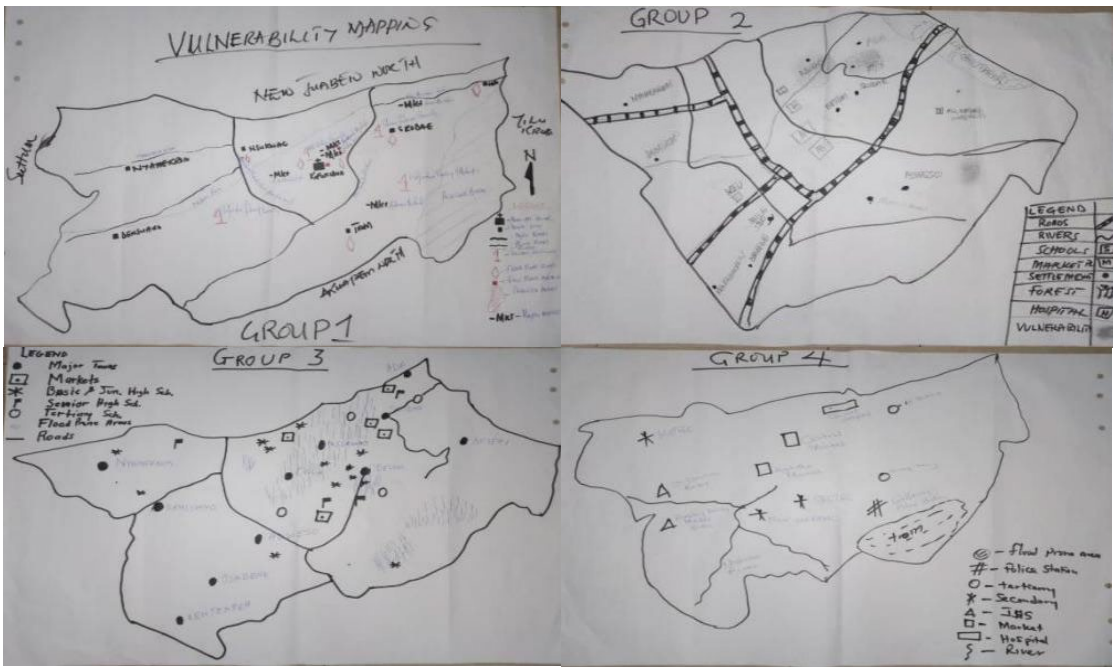
Climate change vulnerability studies specific to the New Juaben South Municipality are rare. The available vulnerability assessment at the district level was conducted as part of Ghana's Fourth National Communication to the United Nations Framework Convention on Climate Change (EPA, 2020). The NJSM's Medium Term Development Plan 2022-2025 identifies potential climate change impacts and vulnerabilities (NJSM MPCU, 2021, p. 13-14). While this analysis is at a general level, it demonstrates that the New Juaben South Municipal Assembly, which was only established in 2017 and was derived from the prior New Juaben Municipality, takes climate change seriously and has begun to consider climate change impacts and vulnerabilities in its planning and programs.

The municipality experiences yearly torrential rainfall which often leads to flooding. Floods are the main climate change hazard in the area. Meanwhile weather extremities such as droughts and floods are noted to occur more frequently and forcefully, causing insecure living conditions, food shortages, and forced migration (Müller-Kuckelberg, 2012). While events and the effects of rainstorms are natural, certain anthropogenic factors affect and create vulnerability to the climate impacts for various sectors and groups in the municipality.

3.2.1 Hazards and Associated Impacts on Vulnerable Locations

In the earlier phase of the VA process, participatory mapping of proposed most vulnerable locations within the municipality was conducted with select stakeholders in a workshop. Participants in the workshop (30 men and 11 women) used their experiences as officers, residents, and workers in the municipality to map out boundary locations in the municipality that are perceived as most vulnerable to climate risks. The exercise generally showed that areas around Nsukwao were particularly vulnerable because they are flood prone areas that have concentrated social amenities like senior high schools, markets, and bus stations. The stakeholders identified other at-risk locations in the municipality (Figure 4).

Figure 4. Maps showing proposed vulnerable locations



3.2.2 Hazards and Associated Impacts on Vulnerable Sectors

The key economic sectors of NJSMA as earlier noted are the service sector (39.9% of the district economy), followed by industrial manufacturing and processing (26.7%), agriculture (26.1%), and other socio-economic activities (7.3%). It has been observed that rainfall variability and torrential rainfall exists as the main climate hazard in the municipality. Other climatic elements, such as temperature and humidity, have not yet recorded significant variation from annual mean records (EPA, 2020). The perennial nature of variation in rainfall and the increased difficulty in predicting rainfall patterns have had significant consequences on agricultural productivity and food security. Negative climate impacts on the water sector (water scarcity) have also been observed and compounded by threats to water quality from pollution.

Table 3 presents climate change hazards and their associated impacts on the district's main economic sectors. For instance, the occurrence of disasters such as floods, rainstorms, wildfires, and strong winds affects infrastructure facilities such as roads, bridges, and housing. The design of these infrastructure facilities did not consider climate risks and they are therefore often unable to withstand the shocks associated with these climate events. Poor relief and drainage in the municipality affects human health and sanitation, transportation systems, and infrastructure. With knowledge of the effects of perennial flooding, measures might be put in place to reduce the effects of poor sanitation on health of residents.

Rainfall variability is a challenge for infrastructure. High precipitation rates cause road destruction by creating new potholes and deepening existing ones, and high temperatures combined with increased solar radiation reduce the quality of asphalt road surfaces (Taylor & Philp, 2010). Relatedly, population growth coupled with increasing economic, housing, and environmental demands have significantly contributed to accelerating land use change. These factors have caused destruction of natural habitat and increased natural hazards such as flooding in the municipality (Nyamekye et al., 2020).

In addition to enhancing easy movement of goods and services to and from the municipality, good roads also play an integral role in tourism. The moderately cold temperature conditions of the area have had a significant impact on the desirability of the municipality as a major tourist destination. This has resulted in the construction of several first-class hotels and hostels in the municipality. However, climate change and variability resulting from global warming could negatively impact the potential of the tourism sector in New Juaben Municipality.

Table 3. Climate hazards and their effects on various economic sectors

Climate element	Hazard	Economic sectors					
		Agriculture	Health and sanitation	Water	Transportation and infrastructure	Natural resources/ biodiversity	Energy
Temperature	Increasing temperature	Longer dry spells leading to decreases in crop productivity	Even small differences from seasonal average temperatures are associated with increased illness and death	Evapo-transpiration of surface water sources, reduction in ground water	High temperatures heat up and compromise roads	Increase in evapotranspiration and forest fires in drier conditions, leading to forest destruction	Decrease in hydro generation due to drier conditions
Rainfall	Drought	Low agriculture productivity (food scarcity)	Exposure to health hazards	Inadequate water supplies have severe consequences on human health	Drought results in dusty roads causing pollution and respiratory diseases	Increasing frequency of droughts reduces biodiversity and exacerbates bush fires	Decreasing total rainfall affects the generation capacity of the hydro-electric dams,
	Floods	Erosion and destruction of farms	Destruction of life and properties Increased prevalence of water- and vector-borne communicable diseases such as malaria	Pollution of water bodies	Floods wash away roads and collapse bridges Destruction of buildings and roofing	Flooding can have a negative effect on wildlife, causing drowning, disease proliferation, and habitat destruction	Impacts on power distribution lines
	Rainfall variability	Increases the risk associated with farming because it is difficult to plan sowing and harvest times	Pollution of rivers with solid and liquid waste Poor environmental and sanitary conditions	Water scarcity	Impacts on roads, dams, power distribution lines, homes, and drainage systems		-

Source: Municipal Planning Coordinating Unit (MPCU), NJSMA 2021.

3.2.3 Hazards and Associated Impacts on Vulnerable Groups

According to Neumayer et al. (2007), natural disasters such as the floods have gendered implications, with women typically more impacted than men. Flooding in New Juaben South Municipality is perennial with annual reports of loss of lives and/or livelihoods. Empowering women and other marginalized groups is beneficial not only as a policy goal, but also as a means of reducing loss of life and further strengthening the effectiveness of climate change adaptation measures (Kangas et al., 2014). Policymakers must not overlook the most important and differentiated challenges of various populations, as doing so may increase vulnerability rather than reduce it (Carr & Thompson, 2014).

The socio-demographic report of the 2010 population and housing census shows that women formed about 57% of the adult population (aged 15 years and above) in New Juaben South Municipality (GSS, 2010). The employment status shows that while there was not a significant difference between economically active men and women, there were gender-dominated fields. The government sector, private formal sector, and technical working sectors were dominated by men; while women dominated the private informal sectors and service sectors and were involved in trading (both wholesale and retail). The report also highlighted that Persons with Disabilities (PWDs) formed about 5% of the residents in New Juaben. In Ghana, PWDs are often regarded as unproductive and incapable of contributing in a positive way to society, and rather seen as constituting an economic burden on the family and the society at large, which leaves them in a vicious cycle of poverty.

Even though the number of economically empowered women is improving, women continue to be largely marginalized through under-representation or no representation in final decision-making processes (Dankleman, 2008). This is despite the role of women in decision making on how to address the impacts of climate change by government administration, traditional authorities, local family, and community bodies increasing in recent years, Exclusion of women's voices means that their extensive knowledge of the environment and resource conservation as adaptive measures to climate change effects remain untapped (Kangas et al., 2014). This limits the adaptive capacity of the district and increases its vulnerability to climate change impacts.

3.2.4 Summary of Observed Climate Changes

A summary of the observed historical climate data (1980 to 2020) in NJSMA, as provided by the Ghana Meteorological Agency, is as follows:

- Rainfall in Koforidua was variable on monthly and annual scales.
- The number of rain days in a year varied but demonstrated a slightly increasing trend.
- The number of heavy rainfall events each year varied and decreased slightly over the time period.
- Wet and dry spells varied in Koforidua with only a slight increasing trend.
- Day and night temperatures increased, and the last 20 years were warmer in Koforidua than the previous 20 years.
- The number of hot days and nights increased with high variability in Koforidua.

4. Vulnerability to Current and Future Climate Change

This chapter first presents the methodology (description of indicators derivation, data sources, data collection, data normalization, etc.) used to assess vulnerability in NJSMA. The results are presented in Section 4.2.1, which provides a description of climate change vulnerability in the municipality. The chapter further assesses future climate change risk (summary of climate change projections and potential impacts and future climate change risks) and explains how projected changes in climate can affect the district in the future under a business-as-usual scenario.

4.1 Assessing Current Climate Change Risks

4.1.1 VA Method, Process, and Tools

4.1.1.1 Research Design

Assessing the vulnerability of a geographic location, population, or human environment should be done by pragmatically comparing with different geographic locations, populations, or human environments within it and identifying the relative factors that influence their vulnerability levels (Williams et al., 2020). The New Juaben South Municipality VA follows the IPCC approach to vulnerability, which covers three concepts (exposure, sensitivity, and adaptive capacity).
The approach included:

i. **Desk review:** The review aimed to understand what information existed and where there were gaps. The initial desk review undertaken in Phase I provided a good baseline for the New Juaben South Municipality.

ii. **Stakeholder and expert consultations:** A combination of Key Informant Interviews and meetings were conducted in Phase II of the VA process. The consultations were participatory, drew on local knowledge, and were a useful source of additional data for this phase of the assessment.

iii. **Stakeholder workshop:** A stakeholder workshop was also held in Phase II of the VA process. It was an excellent way of further understanding local-level climate vulnerabilities and to begin to consider adaptation options. By getting different perspectives in the same room, it helped uncover other dimensions of vulnerability, reviewed identified indicators, and suggested context-relevant additional indicators or modification of the identified ones while filling in gaps in knowledge. The stakeholder workshop was participatory and transparent to ensure results are owned by stakeholders and was an opportunity for capacity building and awareness creation.

iv. **Community-based approaches:** Community-based approaches provide an important source of information that complements outputs from desk review, expert consultation, and other tools. Community-based approaches inform field-based activities such as household/community surveys (in the form of questionnaire administration or focused group discussion), and community mapping of assets and vulnerabilities. A field survey was conducted in various communities at the household level to further provide information about past experiences and potential vulnerabilities of communities in the municipality.

These approaches guided identification of indicators relevant to each of the three components of vulnerability. It also guided appropriate data collection approaches for each indicator.

Climate vulnerability is considered in terms of the relationship between exposure, sensitivity, and adaptive capacity. The concepts were defined in section 1.6 and further described below:

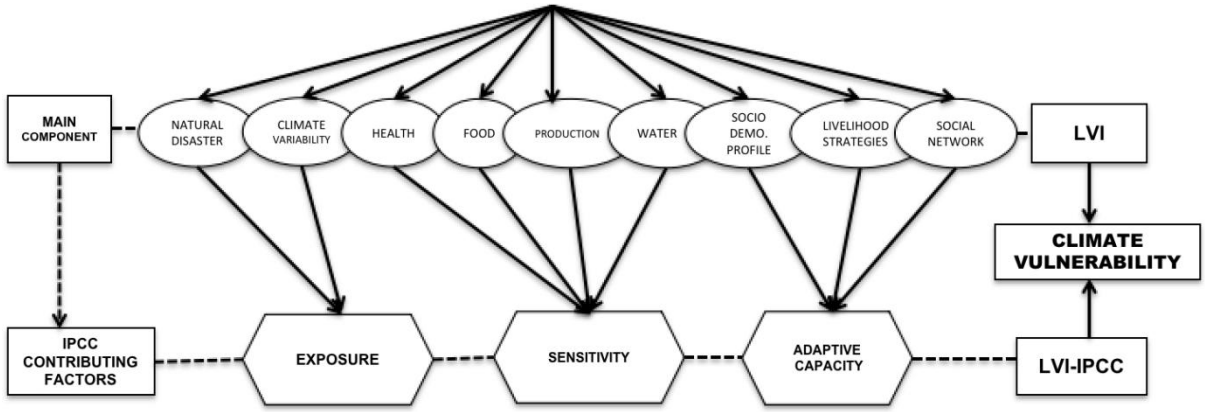
Exposure: To assess exposure, the first step is to identify stressors that may affect the geographic area, sector, or population of concern. Understanding the spatial distribution of climate stressors can help determine what inputs are likely to be exposed. In conformity with the NAP process (selecting the same parameter options for downscaling), exposure indicators considered for New Juaben Municipality under temperature and rainfall variables are presented in Table 11 (Appendix 3).

Sensitivity: The more sensitive a place, population, or sector is to one or more climate stressors, the more vulnerable it tends to be. Highly sensitive places, populations, or sectors can be identified through considerations such as past damage from climate stressors, pressure from both climate and non-climate stressors, and the introduction of new stressors. Sensitivity indicators for New Juaben South Municipality are also presented in Table 11 (Appendix 3).

Adaptive Capacity: The adaptive capacities of individuals, households, and organizations may vary according to one's access to information, ownership of or access to resources, the skills of the people within these systems, and the ability to assess climate issues and make decisions (see also Table 11 for adaptive capacity indicators). Analysis of adaptive capacity can help identify gaps in capacity among different systems. These gaps can then be addressed to reduce vulnerabilities.

In this VA process, the Sustainable Livelihood Framework as used by Williams et al. (2019) was adapted to develop an indicator-based Livelihood Vulnerability Indicator (LVI) approach. This served to provide understanding of the contributions social, demographic, and physical factors, as a practical tool to identify areas for possible interventions. The LVI approach used household-level data combined with secondary data on climate exposures to capture differences in community/ district-level vulnerability. The LVI comprised eight major components, namely social networks, livelihood strategies, access to food, water, production and health, socio-demographic profile, climate variability, and natural disaster risks. Further connected to the LVI is the LVI-IPCC method developed by (Hahn et al., 2009) which was also used for calculating climate vulnerability based on categorization of the main components of LVI framework into IPCC vulnerability framework: exposure, sensitivity, and adaptive capacity as illustrated in Figure 5.

Figure 5. Grouping of major and subcomponents/indicators into LVI and LVI–IPCC

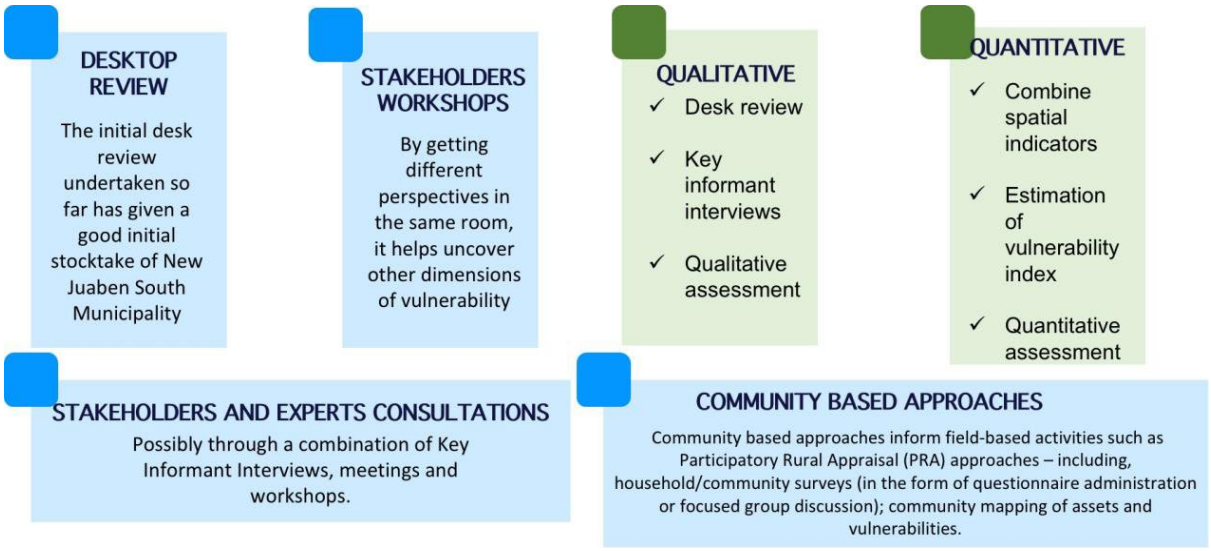


The same subcomponents used in the calculation of LVI are employed in the calculation of the LVI–IPCC. For the LVI-IPCC calculation, rather than computing the LVI by combining the major components in the initial step, they were merged according to the three main IPCC categorizations: exposure, sensitivity, and adaptive capacity. In this VA process, IPCC contributing factors and the major components of the LVI are compared rather than the overall score. Through the series of consultative expert meetings, the research team reached consensus and selected the final set of vulnerability indicators. The participatory and consultative approach ensured the selection of context-appropriate indicators. Table 10 in Appendix 3 summarises the finalized major LVI components and sources assessed for the study.

4.1.1.2 Data Collection for the Community-Based Field Survey

The approaches that guided identification of indicators relevant to each of the three components of vulnerability, and the data collection approaches are presented in Figure 6 below.

Figure 6. Approach for indicator selection



As noted earlier, the qualitative approaches (desktop review, stakeholder and expert consultations, and stakeholders' workshop) for the VA were all completed during Phase II of the VA process.[3] The quantitative/community-based approach was conducted in Phase III. As an approach to data collection of the community-based field survey, a cross-sectional design was employed to obtain both qualitative and quantitative data. A multistage sampling method was adopted with cluster and systematic sampling methods. Sixteen electoral assemblies from eight zonal councils within the NJSMA were considered. The zonal councils included Old Estate, Nsukwao, Adweso, Oguaa, Betomu, Anlo Town, New Town and Srodae. Applied disproportional sampling was done to ensure that there existed adequate data for comparison by selecting a minimum number of 15 respondents in each of the 16 electoral areas. In the next stage, a household was systematically selected by selecting any other two households from the starting point. Finally, an enumerator enters a compound and interviews an adult or household head who is willing to participate in the study.

A total number of 264 face-to-face questionnaires were administered (see Appendix 4). The instrument used for the survey was a well-structured questionnaire with both open- and close-ended questions and administered using the computer-assisted personal interviews method through a digital data collection cloud system, KoboCollect. The data was collected by four trained enumerators in November to December 2022. To ensure a smooth data collection exercise vis-a-vis commutation in the communities, the assembly person(s) of each community was consulted ahead of time to facilitate community entry and to create awareness of the exercise in the various communities. In most instances the assembly person(s) also served as the interpreter for the respondents. The survey was conducted in English and paraphrased into local languages for respondents based on respondents' preference. The respondents were informed about the purpose and objectives of the study and assured of the confidentiality of their participation and any information given in the interviews. The respondents thus demonstrated their consent to participate in the survey.

Figure 7. Images of enumerators with respondents during data collection

[3] The detailed description of the method used for the review, consultations, and stakeholder workshop (qualitative approaches) can be obtained in the Phase II report, which is available from the EPA.




4.1.1.2 Data Analysis for the IPCC-LVI

Information received from the assessment process was consolidated to determine overall vulnerability of the municipality. Specifically for the quantitative assessment (survey), the data was analysed using STATA 15 software. The data analysis involved descriptive statistics comprising demographic characteristics of the respondents interviewed, their livelihood strategies and credit avenues, assets, social networks, access to social basic amenities, and their prevailing exposure to climatic threats. The process provided a descriptive insight into the context by applying exploratory statistical analysis. Additional analysis of the livelihood vulnerability of the municipality was done by analysing the balanced-weighted average of the LVI based on the IPCC framework.

As highlighted by Basiru et al. (2022), the LVI uses a balanced weighted approach. This is because each indicator subcomponent is measured differently using different units. The LVI formula thus applies equal weights to all the components. This is significant because this method standardizes each subcomponent into comparable units or indices. The standard balanced weighting approach applies equation 1.

$$Index_C = \frac{C - C_{min}}{C_{max} - C_{min}} \quad \ldots 1$$

Where Index represents the subcomponent, C, being weighted and min and max represent the minimum and maximum values of subcomponent, C, respectively. After standardization of all indicators, the major components are generated by averaging the standardized scores of related subcomponents using equation 2.

$$H_c = \frac{\sum_{i=1}^{n} Index_C}{n} \quad \ldots 2$$

Where H_c represents one of the major components, the average of a summation of all subcomponents $Index_c$, of number, n. Finally, after calculating all the major components, a combination of the weighted averages for all major components was applied (equation 3). This ensures equal contribution of the main components to the overall LVI (Sullivan, 2002).

$$LVI = \frac{W_{SDP}SDP + W_{ls}LS + W_{SN}SN + W_H H + W_F F + W_P P + W_W W + W_{ND}ND + W_{CV}CV}{W_{SDP} + W_{LS} + W_{SN} + W_H + W_F + W_P + W_W + W_{ND} + W_{CV}CV} \ldots 3$$

Where LVI is the Livelihood Vulnerability Index for NJSMA. This equals the average of the nine major components: (socio-demographic profile [*SDP*], livelihood strategies [*LS*], social networks [*SN*], health [*H*], food [*F*], production [*P*], water [*W*], natural disasters [*ND*], and climate variability [*CV*]), each weighted by their number of subcomponents.

The LVI-IPCC indices were estimated from the weighted LVI main components and the standardized indicators (equation 4). Changing events under climate variability and natural disaster occurrences were used in the estimation of exposure. Sensitivity was estimated by the municipality's current state of health, food, production, and water status. Adaptive capacity was also estimated by the socio-demographic profile, types of livelihood strategies employed, and the strength of social network of surveyed households. The result of the LVI-IPCC falls into the range of -1 and +1, with -1 representing the least vulnerable score and +1 representing the most vulnerable score.

$$LVI - IPCC = (Exposure - Adaptive\ Capacity) * Sensitivity \quad \ldots 4$$

4.1.2.1 Socio-Demographic Characteristics

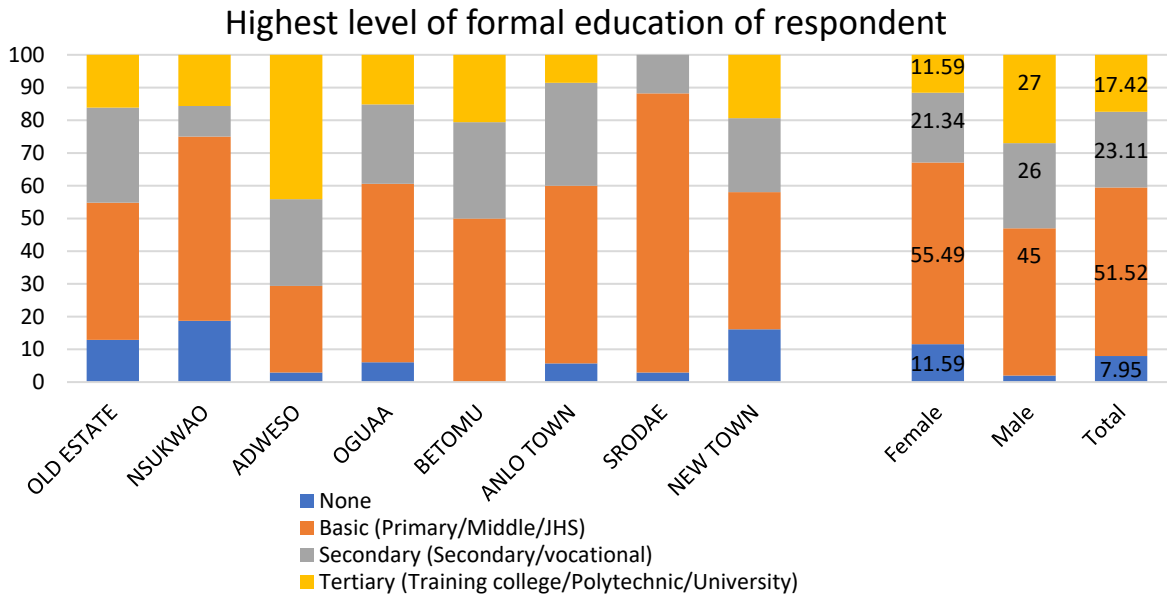
The survey was conducted in two electoral areas in each in the eight zonal councils of the municipality. Out of the total 264 respondents interviewed, 62% were women (Table 4). The average age of the respondents interviewed was 46. The study also found that more than half of the respondents were married (53%). For respondents that have had some level of formal education, more than half of adults in the municipality had attained basic or junior secondary education. Almost a quarter had attained secondary or vocational education, while the remaining seventeen percent had attained tertiary level of education. Eight percent of the representative sample interviewed had received no formal education. Education increases households' willingness to adopt new strategies to better cope with negative climatic changes and has a positive impact on productivity overall (Lin, 1991; O'Brien & Leichenko, 2003). With higher literacy rate, adaptive capacity increases and households are more likely to positively cope/adapt to changes.

Table 4. Gender of the respondents

Zonal council	Gender of respondent	
	Female	Male
Old Estate	17 (54.84)	14 (45.16)
Nsukwao	20 (62.50)	12 (37.50)
Adweso	17 (50.00)	17 (50.00)
Oguaa	20 (60.61)	13 (39.39)
Betomu	19 (55.88)	15 (44.12)
Anlo Town	29 (82.86)	6 (17.14)
Srodae	21 (61.76)	13 (38.24)
New Town	21 (67.74)	10 (32.26)
Total	164 (62.12)	100 (37.88)

Comparatively, the survey showed that there are more women with no formal education and basic level of education than men. Similarly, the percentage of male respondents with high formal education, secondary or vocational and tertiary education, was greater than the female proportion. This highlights the literacy gaps that exist between men and women in the district, but also across Ghana (Ghana Statistical Service, 2021). The study also showed that the level of illiteracy was highest in Nsukwao, New Town, and Old Estate, while the Betomu zonal council had no uneducated respondents (Figure 8). The survey revealed that the level of literacy in New Juaben South was above the regional average of 75.7% and national average of 69.8% as reported by the Ghana Population and Housing Census, Literacy and Education report of 2021 (Ghana Statistical Service, 2021). The survey also found that in the various zonal councils, more than half (59%) of the respondents were migrants or settlers who had stayed in their respective communities for an average of 18 years.

Figure 8. Level of education



For most respondents, their primary occupation was in the private sector (business/commerce). Respondents noted that they were largely self-employed persons engaging in trade and handcrafts such as sewing, masonry, etc. Less than 10% of the respondents engaged in agriculture. These were respondents particularly from the Old Estate and Densuano electoral areas. Even though respondents who were employed as civil service staff were 11% of the total sample, almost half of this proportion were located in Adweso, a peri-developed residential area near the NJSMA office. Ten percent of the respondents were unemployed. More than half (52%) of the respondents answered that no member of their household worked outside the community they live in, which implied a relatively lower diversification of income sources. Similarly, less than 5% obtained income from mining activities or tourism.

The study also showed that although almost two-thirds (62%) of the respondents relied on ecosystem services, less than 10% obtained income from ecosystem services. Respondents explained that their general interaction with the ecosystems largely was for household use and services including harvesting fuelwood and herbs for medicine. Among the assets largely owned by respondents were mobile phones, which nearly all respondents (95%) owned, television sets (91%), radio (75%), bicycles (14%), and cars (13%). A third of the respondents who owned cars were from Adweso, while only one of the 35 respondents interviewed in Anlo Town owned a car. Other assets owned by the respondents included refrigerators, fans, and air conditioners.

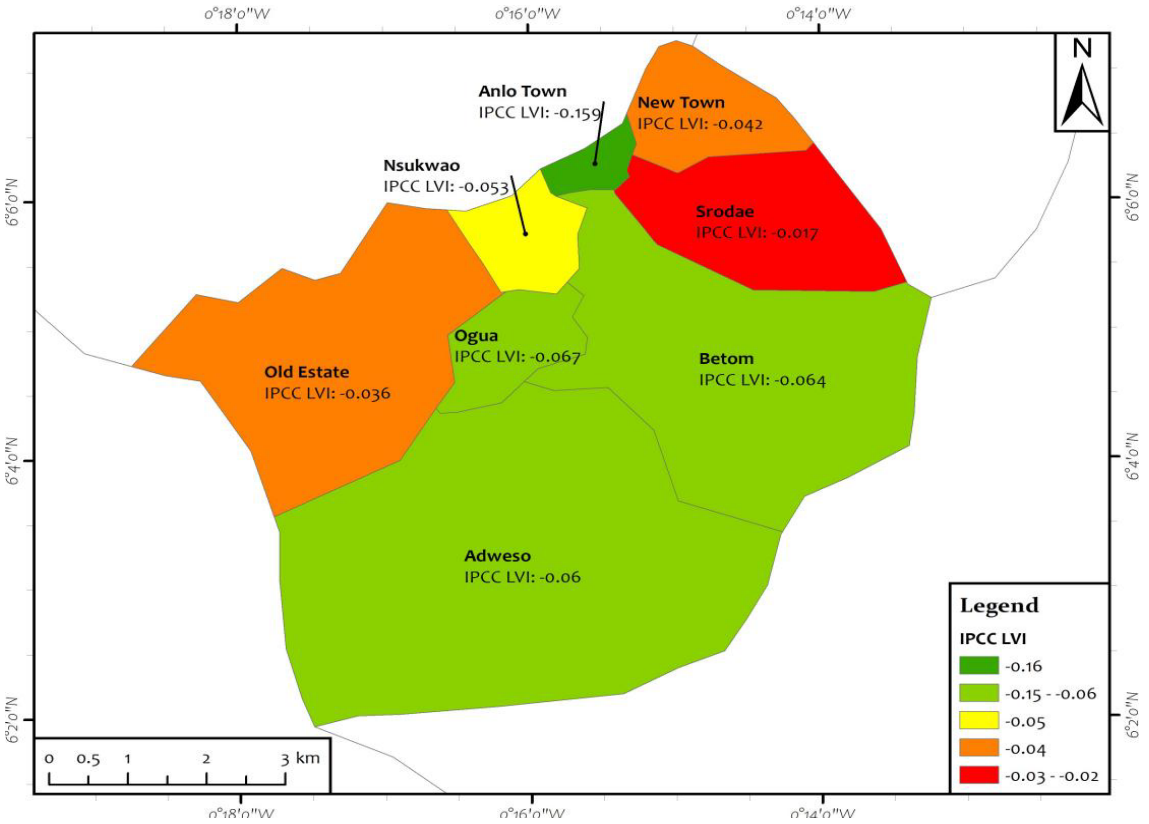
The housing of most of the respondents was observed to be built with cement. A small percentage, particularly in Nsukwao Zonal Council and Densuano in Old Estate Zonal Council, were built with mud and coated with cement. Also, a quarter of the total respondents had houses built with brick. Assessing the quality of road network, 62% of the respondents noted that they do not have access to good road network. Most respondents in Old Estate, Nsukwao, and Anlo Town did not have access to good roads, while the opposite was observed in Oguaa.

4.1.2 VA Results and Discussions

4.1.2.2 IPCC-LVI Results

Results for the overall LVI-IPCC scores (using groupings of the subcomponents as shown in Table 5 suggests that on a scale of -1 to +1, zonal councils within NJSMA shared a broadly similar degree of vulnerability, though Srodae, Old Estate, New Town, and Nsukwao households are marginally more vulnerable than Adweso, Betomu, Oguaa, and Anlo Town households (Figure 9).

Figure 9. IPCC-LVI map for NJSMA



In comparing the level of contribution from the three vulnerability-contributing factors, as depicted in Table 5, Srodae, Adweso, and Anlo Town are the most exposed to climate impacts. Residents in Srodae live on the foot of a hill and the zone includes a major tributary of the Nsukwao River. Drainage systems were observed to be very poor for this area, making the area geographically highly exposed to climate stressors. This was similar for Anlo Town and for some sections of Adweso and Nsukwaoso in Nsukwao.

The most sensitive zonal areas were recorded to include Anlo Town, Srodae, Oguaa, and Nsukwao, which had areas that recorded relatively frequent past damage from climate stressors and exhibited pressure from both climate and non-climate stressors. This resulted from high exposure to natural disasters and high sensitivity to health, natural disasters, and available factors for economic (Table 5).

Generally, the residents living on hilly areas, close to a tributary of the Nsukwao River with poor drainage and poor road access were highly exposed to climate impacts. Similarly, residents who lived in areas near constructed or demarcated drain access for the Nsukwao River often were flooding. Nonetheless, adaptive capacity was high for zones with quick access to major hospitals; better socioeconomic profiles, livelihood strategies and opportunities; closeness to a major market; and better safety nets in social networks.

In terms of adaptive capacity, Anlo Town, Betomu, Adweso, and Oguaa have less adaptive capacity (0.434) to climate vulnerability compared to Srodae, Nsukwao, Old Estate, and New Town. This is mainly due to weak social networks (such as households not belonging to any organization or social group and limited communication devices) and livelihood strategies (such as households with only agriculture as source of income or not rearing livestock in addition to crops and households without a member working outside the community) existing in the municipality (Table 5).

Table 5. IPCC-LVI results for NJSMA

Zonal council	Exposure	Sensitvity	Adaptive capacity	IPCC-LVI
Srodae	0.621	0.434	0.660	-0.017
Old Estate	0.503	0.376	0.601	-0.036
Oguaa	0.547	0.425	0.705	-0.067
Nsukwao	0.488	0.410	0.616	-0.053
New Town	0.517	0.358	0.635	-0.042
Betomu	0.547	0.377	0.716	-0.064
Anlo Town	0.555	0.823	0.748	-0.159
Adweso	0.568	0.371	0.730	-0.060

The negative sign of the IPCC-LVI index indicates that the adaptive capacity of all zonal councils is higher than the sum of the exposure and sensitivity elements. This suggests that the zonal councils have some capacity to adapt to climate change, with the lower the index (up to -1) indicating a moderate vulnerability of the people. Detailed results for corresponding indicators for the IPCC-LVI are given in Appendix 1.

Table 6. LVI by components

Zonal council	Sociodemo-graphic profile	Livelihood strategies	Social network	Health	Water	Production	Food	Natural disaster	Climate change
Srodae	0.061	0.698	0.725	0.384	0.321	0.679	0.11	0.813	0.467
Oguaa	0.083	0.587	0.883	0.316	0.284	0.654	0.293	0.646	0.467
Betomu	0.059	0.674	0.895	0.296	0.257	0.768	0.103	0.646	0.467
Adweso	0.103	0.685	0.905	0.234	0.400	0.711	0.086	0.694	0.467
Nsukwao	0.124	0.559	0.732	0.436	0.247	0.650	0.013	0.514	0.467
Anlo Town	0.409	0.738	0.832	0.981	0.534	0.928	0.667	0.665	0.467
New Town	0.186	0.608	0.757	0.253	0.222	0.764	0.168	0.579	0.467
Old Estate	0.08	0.613	0.672	0.304	0.236	0.645	0.068	0.548	0.467

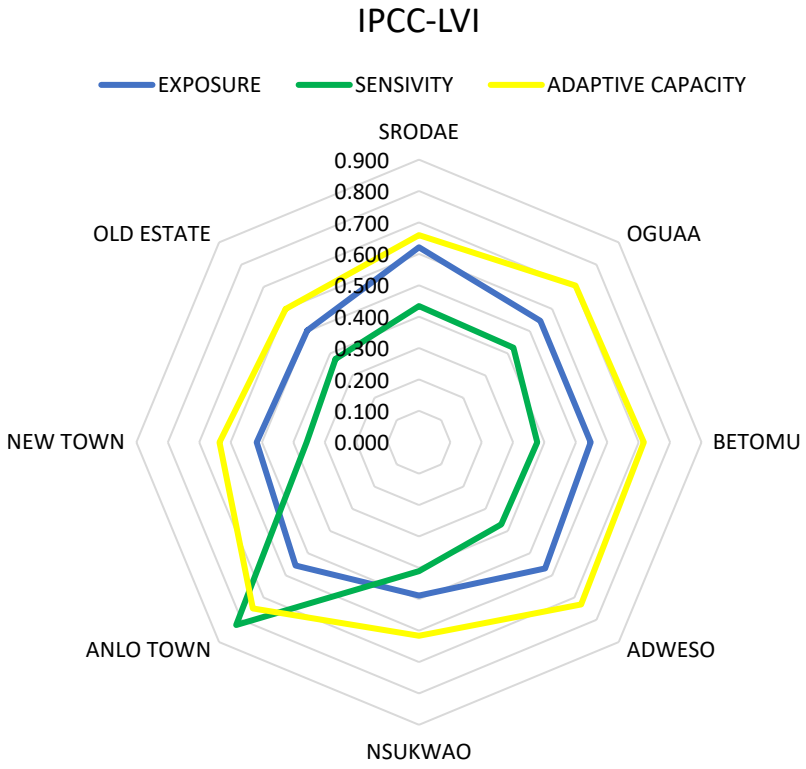
4.1.2.3 Vulnerable Locations

Overall, all the zonal councils in the municipality showed relatively high vulnerability to climate change. The main observations about vulnerable locations are summarized below:

- Srodae is the most vulnerable zonal council. This zone has the highest exposure to climate change, primarily via flooding. Peoples' adaptive capacity in this zone is, however, relatively high. Srodae, due to the presence of the Chief's palace in Ahenbronom, has access to good road networks, close proximity to health facilities, and other basic social amenities. Access to economic production facilities is, however, limited and this component runs through all the zonal areas (Table 6).
- Nsukwao recorded the lowest exposure to climate (Figure 10).
- Zonal councils like Oguaa recorded high adaptive capacity ratings because of the relatively developed nature of the Residential Area and Sempoamiensa electoral areas, which house many government-sector and medium- to large-scale private sector workers.
- Anlo Town could be considered as one of the most vulnerable zonal areas. The results shows that this zonal council had the highest sensitivity rating (Figure 10). Respondents' perceptions of climatic parameters in the past ten years show that there is an observed significant increase in floods, windstorms, and temperature. It is the only area which showed high vulnerability across all the sensitivity components with a high exposure index as well. This is due to the lack of assessable roads, a poor drainage system, and lack of access to safe sanitation services and health facilities.

Per the mapping of vulnerable areas exercise by identified stakeholders within the municipality, certain factors caused some areas in the municipality to be relatively more vulnerable to the impacts of torrential rainfall and flooding. It was noted that the siting of Densuano, a town with residences at the foot of a hill, for instance, exposed residents in that area to regular flooding during prolonged torrential rainfall. Overflow of the Nsukwao River similarly, has caused flooding in surrounding communities because Nsukwao has built defensive structures to protect its immediate communities, which moves the flood hazard elsewhere. This could explain the reduced exposure index obtained from the VA results. The sections below further describe the analysis of the IPCC-LVI components.

Figure 10. IPCC-LVI radar representation on exposure, sensitivity, and adaptive capacity for NJSMA



4.1.2.4 Climate Exposure

The study on exposure revealed that the municipality experienced at least one extreme flood in each zonal council every four years. Srodae, the most vulnerable zonal area, experienced almost one extreme flood every year (Table 7). However, only 6% of all respondents noted that they received a warning about a flood or drought before it occurred.

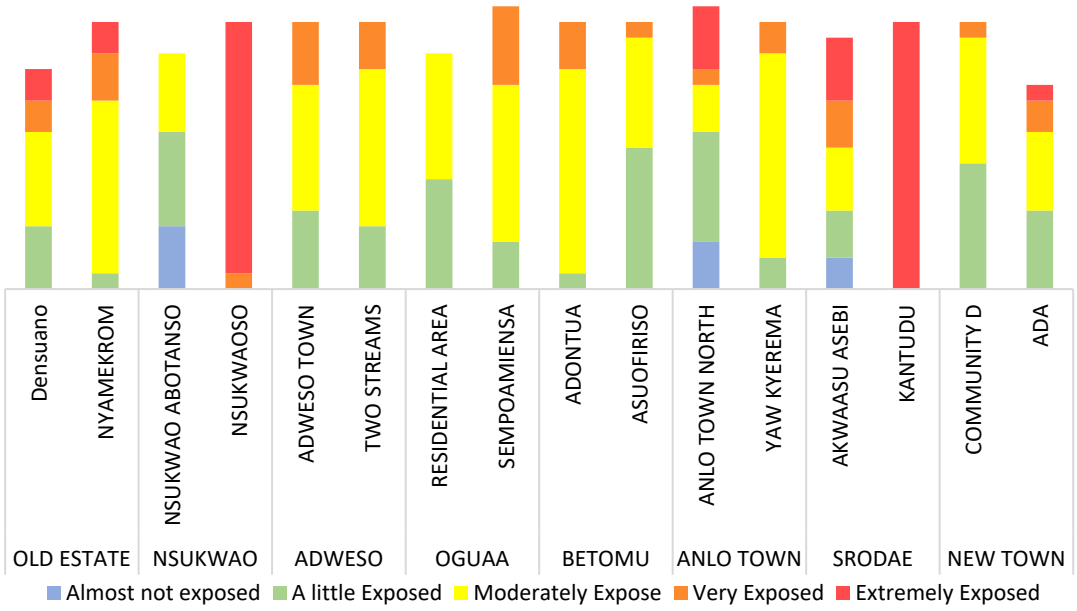
Table 7. Summary statistics: Extreme flood occurrences since 2010

Zonal Council	Number of respondents	mean	sd	min	max
Adweso	34	8.029	3.996	0	20
Anlo Town	35	5.086	4.09	0	15
Betomu	34	4.765	6.796	0	30
New Town	31	6.71	5.43	0	22
Nsukwao	31	5.645	5.407	0	20
Oguaa	33	3.03	4.426	0	20
Old Estate	31	4.613	3.148	0	10
Srodae	34	10.235	6.809	0	30

Source: Field survey, 2022.

With regards to changes in climatic parameters over the last decade, increases in rainfall quality and quantity, and windstorm frequency and force (violence) have been observed. Figure 11 illustrates the extent of exposure to floods. Most respondents, 79%, observed a change in the seasonal calendar for the municipality. Similarly, the respondents largely observed an increase in temperature and flood volume. In Nsukwao, especially Nsukwaosu, 95% of the respondents expressed they are extremely affected by floods in their community. This was also the situation in Srodae, where all the respondents in an electoral area (Kantudu), noted they are extremely exposed to floods. Also, some respondents in Densuano in Old Estate and Akwaasu Asebi in Srodae expressed extreme exposure to flood because of the locations of households (near a main community drainage outlet into the Densu or Nsukwa river, etc.). Even though damage to infrastructure from floods had increased moderately, respondents explained that damage to infrastructure more than a decade ago was worse due to lack of drainage facilities. This implies that in recent times efforts had been put in place to build the resilience of some communities against flooding.

Figure 11. Extent of exposure of floods in zonal councils



Source: Field survey, 2022.

Figure 12. Images of the Densu River (a climate exposure source)

4.1.2.5 Climate Sensitivity

Accounting for health, water, food, and production components in the municipality, it was observed that at least one health facility, either a hospital, clinic or Community-based Health Planning and Services (CHPS) compound, existed in each zonal area. The results showed that on average, it takes households 20 minutes to get to the nearest health facility. About 92% of the respondents been registered on the National Health Insurance Scheme. Further, 65% of the respondents noted that they have access to safe sanitation services. Additionally, due to the high topographic wetness indices observed in certain areas in the Municipality, the malaria risk is reported to be relatively low (Kumi-Boateng, 2017). This could explain how most of the zonal areas had relatively low vulnerability in the health component. Meanwhile, only a quarter of respondents had received any training or sensitisation on climate-related diseases. With regards to water, most households (63%) indicated 2 minutes to reach a source of water from their household (the water sources are located mainly inside their own compound). Only 15% highlighted they had experienced water conflicts in the past.

In terms of food and production factors for economic activities, only 10% of the respondents were dependent on the agricultural sector with the remaining 90% from the services sector. For respondents that own farms or work on one, the minimum recorded farm size was 0.5 acres and the maximum of 30 acres. Additionally, 44% of the farmers kept livestock, mostly poultry or goats. For the crop producers, the majority did not have irrigation for their farm; hence, the majority of farmers in the municipality depend on rains for irrigation (Mintah Ampaw et al., 2013). Almost half of the farmers voiced that their farms were located in flood-prone areas. particularly in Nsukwao, Old Estate (Densuano), and Anlo Town. Farming households mostly saved a proportion of their produce for consumption. The majority were not aware or subscribed to agricultural insurance and only one farm had subscribed to agricultural insurance. Farmers mostly walked (46%), took public transportation (35%), used a bicycle (8%), or used a tricycle (8%) to reach their farms.

For the non-agricultural sector respondents, they mainly indicated that their services do not depend on agricultural raw materials, but some business sites were located in flood-prone areas. Almost all (94%) service sector respondents had not insured any part of their business, were not a member of any business cooperative, and were not aware of any government intervention for businesses. Most industrial establishments are found in the central business area of the Municipality, while agricultural production is carried out in the small settlements and the peri-urban localities.

Figure 13. Sanitation services in Nsukwao, Abotansu

4.1.2.6 Adaptive Capacity

A community is considered more vulnerable if there exist too few options in terms of livelihood diversification (Antwi-Agyei et al., 2013). Engagement in non-farm livelihoods can help farming households to spread the risks from climate threats, although it can have effects on food availability within the municipality. Most households possess basic communication devices (e.g., radio, television, and mobile phone). This has a direct positive impact on social network scores as these devices strongly enhance access to weather-related information and increase the ability of households to plan for any impending climate risk.

Social groups observed to be prominent in the surveyed areas include church groups, community groups, settler/migrant groups, employee or worker groups, and farming groups. Forty-three percent of the respondents were noted to belong to such groups. Households not actively associating with social groups at the local level further limited access to weather- related information. Social capital is reported to improve financial support, access to markets, information accessibility, technical support, and access to formal government structures (Eakin & Bojórquez-Tapia, 2008). Furthermore, built trust among such associations is important in positively influencing the adoption rate of adaptation strategies through information dissemination within groups (Masson-Delmotte et al., 2021). The main reason reported by respondents for joining social groups was for credit. Other reasons included the joint voice for advocacy and the provision of a community to prevent minority marginalization.

The study further observed that less than 10% of the total respondents had received support from either a research and development (R&D) organization, government organization or non-governmental organization (NGO). This depicts the low level of government and external support for individuals and groups in the municipality. For personal support, 27% of the respondents noted that they had access to credit. Of this percentage, a third noted that their credit sources were from contributing to susu (informal collective savings system) or savings ventures.

Figure 14. Images of resilient adaptation strategies adopted by (a) the municipality and households viz-a-vis (b) direct climate impacts

4.1.2.7 Gender Dimensions of Vulnerability

Sixty-two percent of the survey respondents were female. As with male respondents, the primary occupation of female respondents was largely in the private sector. However, the type of work was different for men and women. Most female private sector workers were engaged in petty trading, sewing, and catering, while male private sector workers mostly included artisans and tradespersons (electricians, masons, tailors, etc.). More women than men noted that their households depend on ecosystem services from the forest. The results also showed that more female respondents noted that their houses were in flood-prone areas. This indicates that women respondents and their households were more vulnerable to floods than male respondents.

Also, while two-thirds of female respondents noted that they did not belong to any social group or organization (Table 8), whereas over half of men did. The study further observed that men had much higher levels of access to and information about support system organizations, either from the government or NGOs, while women had lesser access to information and support. Male respondents were more likely than female respondents to have benefited from support from the government or have access to subsidies.

Encouragingly, more women were registered on the National Health Insurance Scheme than men. The percentage of respondents with access to credit was equal for both men and women. While most female respondents depended on susu collectors, male respondents owned more bank accounts, increasing the magnitude of their credit options. The study found more male respondents used sachet water for as their main source of drinking water while women mostly used pipe-borne water as their main source of drinking water. Sachet water is comparably more expensive to use than pipe-borne water.

Relating to agricultural production, the mean farm size of the female farmers was estimated at 2.9 acres (Table 8) and the mean farm size of male farmers was 6.6 acres, a sizable difference. Also, the maximum farm sizes for female and male farmers differed significantly; one male farmer had a farm size of 30 acres, while the maximum farm size for a female was 6 acres. With regards to land ownership, relatively similar proportions of both female and male farmers inherited their lands and more men than women engaged in sharecropping. Moreover, more male farmers had access to support groups, with a third of male farmers belonged to farm-based organizations compared to a fifth of female farmers.

Private sector production workers were a group comprising mainly self-employed entrepreneurs. One-third of the female entrepreneurs reported that their business structures were located in flood prone areas, compared to 19% of male entrepreneurs (Table 8). However, more of the female entrepreneurs than male respondents considered their infrastructure disaster resilient. Also, significantly more female private sector operators depended on agricultural products as raw materials for their business than males, implying that climate impacts could affect the productivity of women within the municipality. Although the proportion of private sector respondents who had insured their businesses was low (<5%), the proportion of male private sector respondents who had insured their businesses was almost three times that of female private sector respondents.

Table 8. Gender-disaggregated descriptive summary

Variables	Gender of respondent		
	Female (%)	Male (%)	Total (%)
Is your house in a flood prone area?			
Yes	64.63	42.42	56.27
No	35.37	57.58	43.73
Are you a member of any social organization?			
Yes	33.54	57.00	42.42
No	66.46	43.00	57.58
Do you have access to credit,			
Yes	27.44	28.0	27.65
No	72.56	72.00	72.35
If yes from which source?			
Bank Loan	13.33	35.71	12.32 (n=9)
Family / Friend Support	17.78	10.71	17.81 (n=13)
Susu	42.22	10.71	36.99 (n=27)
Trade Credit	6.67	17.86	9.59 (n=7)
Church / Social Group / NGOs	2.22	0	4.11(n=3)
Personal Savings	17.78	25	19.18 (n=14)
What is the total size of your farm - in acres?			
Mean	2.9	6.582	
Standard Deviation	1.792	7.674	
Minimum	1	0.5	
Maximum	6	30	
Is your business in a flood prone area?			
Yes	32.24	19.28	27.66
No	67.76	80.72	72.34

Source: Field survey, 2022.

4.2 Assessing Future Climate Change Risks

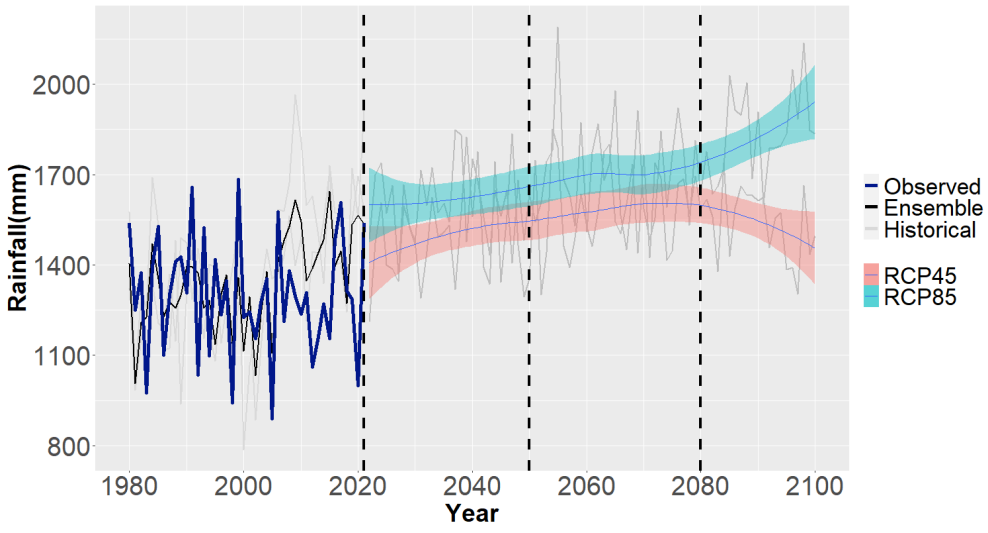
4.2.1 Summary of Climate Change Projections

Climate change projections to the year 2100 were made based on observed meteorological data (1980-2020) provided by the Ghana Metrological Agency. A research consultant (climatologist) modelled climate projections from the present to the end of the century for rainfall (Figure 15), and minimum (Figure 16) and maximum (Figure 17) temperatures for the Representative Concentration Pathways (RCP) 4.5 and 8.5. The projections were made for the Koforidua, a city located in NJSMA and considered representative of expected climatic changes in the municipality.

An increasing annual rainfall trend is projected, with high variability. The projections expect annual rainfall to increase steadily from a current mean of 1,250 mm to reach a mean of 1,550 mm by mid-century (2050). Another increase is expected after 2050 and then a dip after 2080, reaching an annual mean of 1,470 mm by the end of the century. The annual mean is expected to be much higher in an RCP 8.5 scenario. The projections show a large spatial variability for the two scenarios, an indication that rainfall is difficult to predict. The conspicuous inter-annual variability is a likely indicator of long wet and dry spells in wet and dry seasons respectively. This would possibly translate into more frequent floods in wet seasons and droughts in dry seasons. This makes Koforidua prone to climate extreme events in the future. Future projections of rainfall amount are likely to be high if carbon usage and the emissions of greenhouse gases go unchecked (see RCP 8.5 in Figure 15).

Koforidua is expected to experience a steady increase in rainfall amounts and variability. Annual rainfall variability will likely become intermittent alongside prolonged dry and wet spells. Koforidua will be increasingly prone to floods and droughts in the future. The variation in rainfall will likely reveal itself at the start of the wet seasons with either an early or late onset of rainfall events. Some years may have an early onset of the dry season, while others may experience delay. This is likely to displace agricultural and other economic activities. Variability of heavy rainfall events makes planning difficult, as the municipality is vulnerable to flash floods.

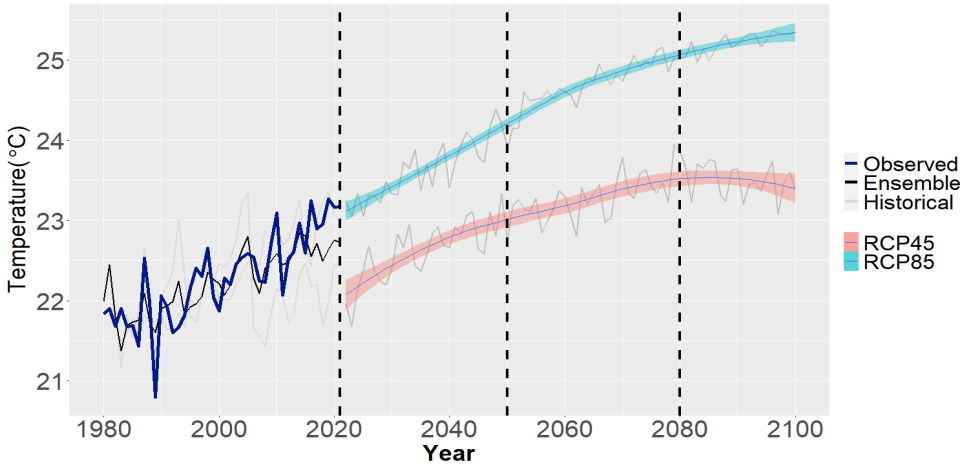
Figure 15. Projected annual rainfall over Koforidua



Source: Ghana Meteorological Agency.

Projections under RCP 4.5 when the use of greenhouse emissions is checked (Figure 16) anticipate a colder night-time temperature with a mean of 23°C by 2050. If greenhouse emissions go unchecked under the business-as-usual RCP 8.5, a night-time temperature of 24.3°C is expected by 2050. Both scenarios project relatively more warmer nights which increase in number by the end of the century. This translates directly into fewer cold nights and increases in the frequency of warm nights.

Figure 16. Projected mean annual minimum temperature over Koforidua

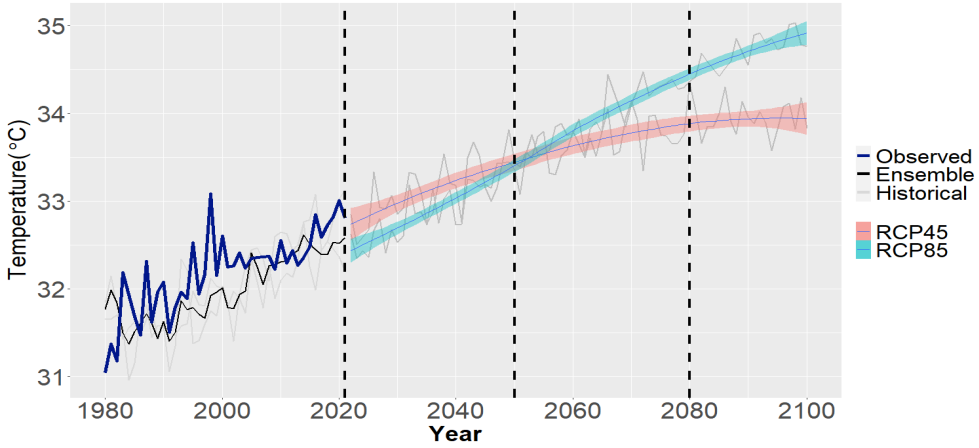


Source: Ghana Meteorological Agency.

By mid-century, mean temperature is expected to reach a value of 33.4°C, an increase from the current average of 32.3°C. Both projection pathways anticipate a daytime temperature profile similar to the night-time temperature profile, i.e., daytime temperature is expected to increase until the end of the century (Figure 17). The continuous warming during the day indicates that cold days will continue to decline while warm days will rise. Koforidua would most likely be prone to heat stress in the future.

Both daytime and night-time temperatures over Koforidua are projected to get warmer in the future. The frequency of cold days and nights are projected to decline, while the number of warm nights and days will continue to rise over Koforidua.

Figure 17. Projected mean annual maximum temperature over Koforidua



Source: Ghana Meteorological Agency

4.2.2 Potential Impacts and Future Climate Change Risks

The impacts of climate change can be exacerbated by other problems such as uncertain land tenure, gender disparities, lack of access to financing, lack of access to modern energy supplies, soil degradation, competing demands for water resources, and deforestation. Emerging threats include increased droughts, floods, increased temperatures, and the spread of diseases into areas previously not exposed. Under a business-as-usual scenario, NJSMA is at risk of the climate hazards of heavy precipitation and its impacts, such as crop damage, soil erosion, and an increase in flash floods due to variability of heavy rains (Hayhoe et al., 2018). A nexus between the increases in climate variability and increasing food insecurity in the future has been established (Thornton et al., 2014). Additionally, the rapid expansion of urban settlements of NJSMA has resulted in the clearing of biodiversity and forestry to construct infrastructure and also deforestation for other purposes. Further depletion of the Municipality's biodiversity and forestry can impact livelihoods and may impact the increasing trend of annual temperature.

Climate vulnerability impacts in NJSMA are largely unequal across zonal councils, communities, and genders, which have varied capacity to adapt. Some of the expected risks include:

- Frequency of floods are expected to significantly increase with the expected increase in annual rainfall totals.
- The erratic annual rainfall event is expected to increase the frequency of droughts in dry seasons.
- Increasing temperature will impact the livelihoods of the people.
- Water scarcity is eminent in both wet and dry years due to the low water storage and high evapotranspiration because of increasing temperatures.
- Increasing temperature compounded by high levels of humidity will impact the health of the people.
- An increase in heat stress is expected, which will significantly affect the health and well-being of residents of Koforidua.
- The outbreak of tropical diseases is expected to rise under increasing temperature.

Perennial flooding has numerous effects on the various sectors of the municipality. For instance, inaccurate prediction of planting dates could have adverse effects on crop productivity and subsequent food insecurity if crops are planted too early or too late; changing planting days due to rainfall season prediction has been reported as a main cause of crop failure among farmers (Owusu et al., 2015). Mensah and Ahadzie, (2020) note that the most applied adaptation measures include protection of properties, relocation, and construction of drains. Table 9 shows the effect of climate on different economic sectors in the municipality.

Table 9. Summary of climate hazards, climate vulnerability, and climate risks in the NJSMA

Climate hazards	Key factors of vulnerability
Acute • Increasing rainfall variability and likelihood of heavy rainfall events Increased frequency and severity of: • Floods • Landslides • Extreme weather events • High temperatures / heat waves • Longer dry spells **Chronic/slow onset** • Changes in precipitation patterns • Increased intensity of drought	• High dependence on small-scale agriculture with most farms on less than 5 acres of land. • High reliance on natural rainfall and insufficient irrigation systems. • Reliance on groundwater resources for domestic and commercial activity; low water storage. • Frequent water shortages in communities, with long queues at water supply points. • High levels of deforestation, exacerbated by unsustainable human activities such as construction. • Inadequate, but improving, governance structures. • Poor sanitation infrastructure. • High levels of illiteracy. • Limited ability to uptake and act on science and improved technologies. • Inadequate evidence and knowledge base. • Low levels of gender equality, with women having limited access to financial resources. **Particularly vulnerable areas** • **Climate vulnerable – Flooding –** Communities along tributaries of the Nsukwao River with poor drainage systems: Kantudu, Nsukwaoso, Nyamekrom, Adontua, and Ada **Particularly vulnerable groups** • Communities or households closest to the main tributaries or pathways of the Nsukwao River. • Women, youth, children, senior citizens, persons with all forms of disability, pregnant women, incapacitated and disadvantaged persons or groups • Farmers with small landholdings dependent on rainfed agriculture **Particularly vulnerable assets** • Households • Transport infrastructure (e.g., roads, bridges) • Farms • Schools • Hospitals
Priority sectors	**Climate impacts / Risks**
Health and sanitation **Vulnerable communities:** Nsukwao, Old Estate, and Srodae	• The municipality has numerous health facilities including a Regional Hospital which serves as a referral centre. • On average, it takes residents an estimated maximum of 35 minutes to reach a health facility. The bad nature of access roads could however increase this time. • Generally, there is good sanitation in the municipality. Nonetheless, in zones like Nsukwao, Old Estate, and Srodae, more than half of the respondents noted that they do not have access to safe sanitation services. In Abotanso in Nsukwao in particular, there exist only one community toilet facility and a single refuse dump container. • Training and sensitisation on the impacts of climate change and climate-related diseases is very low.

Agriculture and food security **Vulnerable communities:** Communities along the Nsukwao River, Densu Kantudu, Nsukwaoso, Nyamekrom, Adontua, Ada, Densuano	• Higher weather uncertainties. • Increase in flooding, with destruction of crops and infrastructure. • Uncertainties in timing of rains and increasing rainfall variability, impacting farmers' ability to plan/time the planting and harvesting of crops. • Extreme rainstorms, windstorms and dust storms rarely occur; however, they damage and uproot crops and cause soil erosion and declines in soil quality. • Increase in disease and pests, including increase in fall armyworm. • Declining crop production due to reliance on rainfed agriculture contributes to deterioration in food availability and nutrition/food security, and potentially a decrease in incomes.
Water	• Water availability is very good in the municipality. • Due to the presence of the water processing facility in Densuano and the availability of groundwater, almost every compound has pipe-borne water or a well.
Transportation and infrastructure	• All zones of the municipality are accessible by land vehicles. • Areas with relatively poor drainage in the municipality have relatively poor road networks. • The poor road networks are often exacerbated by perennial torrential rainfall and –floods. • Impacts of extreme events on buildings, especially school buildings, markets, and other public infrastructure

5. Adaptation Policy and Planning Implications of Vulnerability Assessment Results

This chapter provides a vision of the future for NJSMA based on the VA results and scenarios, and highlights actions needed to build climate resilience and reduce vulnerability.

5.1 Future Adaptation Planning

Table 10 presents expected impacts and an assessment of actions to reduce future climate vulnerability for NJSMA. This analysis serves to guide adaptation planning in the municipality in the short, medium, and long term to address anticipated climate impacts.

Table 10. Impact and responses on selected climate occurrences

Scenario	Impact	Response		Predominant geographical location within municipality
		What can be done to reduce vulnerability in the short to medium term (4-year time frame)?	What could be done to reduce vulnerability in the medium to long term (5-to-15-year time frame)?	
Business-as-usual	Food insecurity (not enough food and insufficient nutrients) - all year round	Build capacity of farmers on climate-smart agriculture Provide opportunities for unemployed youth to get jobs in the agriculture sector Promote irrigated farming Build and strengthen capacities of local farmers to increase productivity and create awareness on climate change issues (food insecurity, flooding, etc.)	Enhance the use of science and technology to improve production activities (such as use of aquaponics and advanced genetic engineering) Provide market and road facilities for deprived communities	Obourtabire, Srodae, Railways, Betom, Bonya, Trom
	Flooding	Provide proper drainage systems (expansion of small drains and gutters)	Sensitize, enforce, and strengthen all environmental bylaws	Nsukwao, Zongo, Tanoso, Oguaa, Adweso, Kenkey Factory

		Undertake regular monitoring and technical supervision to regulate standard usage of quality building materials Ensure developers obtain permits for all developmental projects in the municipality Ensure monthly clean up exercise is strictly followed Construct additional drains by the end of December 2025	Use early warning and detection systems including use of localized weather forecasting technologies	
	Landslides	Monitor regularly to ensure erosion is reduced	Ensure trees are planted to reduce erosion and to reduce the likelihood of landslides Protect the environment through the promotion of agriculture biodiversity and planting of trees in the form of afforestation programs	Obourtabire, Kantudu, Betom,Srodae, Bonya,Agavenya
	Heat waves	Ensure developers comply with building regulations	Organize community forums on the effect of heat wave on the environment	Obourtabire, Central Market, Raiways, Betom, Anglican
	Gender disparities	Support the Domestic Violence and Victim Support Unit and the Social Development Department address abuse cases Organise capacity building for the youth Engage financial institutions on their services to ensure there is flexibility in access to loans. Organise sensitization programs on the radio and in communities for parents to know the importance of education, and to understand the impacts of climate change	Organise sensitization programs for religious organisations, womens' groups, and the youth on climate change and the negative effect of gender-based violence Organise skills development programs for unemployed youth	Kru Town, Zongo, Ogua, Old Estate, Srodae, Betom, Anlo-Town, Klu Town, Yaw Kyerema, Ada, Nsukwao

Scenario	Impact	Expected impact of short-, medium-, and long-term interventions on vulnerability	Predominant geographical location within municipality
Ideal scenario for 2050 - resilience is built	Food Insecurity (not enough food and insufficient nutrients) - all year round	Reduction in number of people living in poverty Reduction in numbers of malnourished people Reduction in infant mortality	Obourtabire, Srodae, Railways, Betom, Bonya, Trom
	Flooding	Clean environment Improved drainage systems Reduction in level and impacts of flooding	Nsukwao, Zongo, Tanoso, Oguaa, Adweso, Kenkey Factory
	Landslides	Reduction in area of eroded land	Obourtabire, Kantudu, Betom,Srodae, Bonya,Agavenya
	Heat waves	Reduction in outbreak of climate-related diseases and illnesses	Obourtabire, Central Market, Railways, Betom, Anglican
	Gender disparities	Reduction in number of instances of gender-based violence Reduction in illiteracy rate, and levels among women are equal to those among men Access to and levels of education are the same for women and men	Kru Town, Zongo, Ogua, Old Estate, Srodae, Betom, Anlo-Town, Klu Town, Yaw Kyerema, Ada, Nsukwao

Source: Adapted from the NJSMA Vulnerability Plan (2022-2025) and MTDP (2022-2025).

5.2 Implications of VA Results

Each region's response adaptation strategy needs to match its individual circumstances to be effective. Vulnerability scores for the various components provide direction for the selection and implementation of both collective and area-specific strategies that could improve the people's ability to cope with and adapt to climate change and to reduce their vulnerability to it. For instance,

- Srodae could benefit from strategies targeted at reducing their exposure to natural disasters (such as flood management structures).
- Anlo Town's access to health, water, food, and efficient production facilities ought to be critically reviewed to reduce its sensitivity to climate impacts.
- Nsukwao and Old Estate require enhanced adaptive capacity for climate impacts in their localities, such as enhancing access to financial support and increasing membership in social groups.

Overall, the municipality needs district-level planning to improve flood management practices such as providing flood resilient infrastructure (e.g., creation of drainage facilities and improving the climate resilience of some amenities such as roads, schools, and hospitals). In addition, the government could provide and encourage institutional support in relation to inputs assistance and subsidies for enhanced economic productivity. Furthermore, individual-level encouragement to actively interact and participate in social groups is important across the municipality to improve people's ability to adapt to climate change and address crises.

Inadequate production factors, lack of insurance, lack of government support/subsidies for economic activities, regular occurrence of natural disasters, and a lack of disaster-resilient infrastructure translated into the high vulnerability scores. Also, lack of secondary occupations across diverse sectors and weak social networks resulted in low adaptive capacity. The VA results therefore provides adequate information and practical guidance to support decision-making on adaptation. For example, given the broadly positive socioeconomic conditions in NJSMA, sensitization and education of households on climate risks and impacts would further build adaptive capacity to cope with and adapt to the future changing climate.

Given that flooding is the most significant expected climate hazard in NJSMA, the specific strategies to address flood-related vulnerability in NJSMA include:

- Improve drainage systems in the municipality, including construction of additional drains.
- Provide a wastewater treatment plant.
- Devise a flood early warning system.
- Desilt of gutters in the municipality.
- Provide education and sensitization on water resource management in the municipality (e.g., capacity building on rainwater harvesting).

At an institutional level, options to diversify livelihoods for both agricultural and non-agricultural workers are important. The municipality would benefit from climate disaster early warning systems and education programs to enhance adaptation planning. This includes improved dissemination and accessibility to reliable climate information such as down-scaled seasonal forecasts to enhance preparedness against extreme weather events.

While a range of options that could reduce sensitivity and increase adaptive capacity exist, identifying the most suitable adaption actions for the municipality requires a dedicated assessment of adaptation strategies that accounts for limited financial resources. Regardless, adaptation should be mainstreamed in NJSMA's development planning to ensure suggested measures are integrated in the implementation of the municipality's activities and projects. NJSMA has taken steps to integrate adaptation in its MTDP, identifying actions to promote climate smart agriculture and to prevent disasters via education. Many other actions in the MTDP support adaptation, such as planting trees and improving drainage systems (NJSMA MPCU, 2021).

Further investigation into the identification of adaptation options suited to NJSMA is recommended. This will direct the limited resources toward investment and development initiatives that respond to a changing climate and guide policy recommendations to promote climate adaptation.

Gender-responsive climate change programming is an obvious gap. As earlier noted, the VA process acknowledges the disproportionate impact of climate change on women. It is therefore recommended that all adaptation planning and related programs at the district level should be gender-sensitive and ensure that the monitoring of results includes the collection of gender-disaggregated data. Efforts need to address equity and inclusiveness for women, children, and other marginalized groups.

The learning from the VA process – for example, how to combine a literature review with participatory stakeholder approaches to identify and analyze indicators – presents a rigorous and replicable approach that can be used in other geographical and sectoral settings. It also contributes to a better understanding of district-level vulnerability that reflects the realities at the district level.

References

Antwi-Agyei, P., Dougill, A. J., Fraser, E. D. G., & Stringer, L. C. (2013). Characterising the nature of household vulnerability to climate variability: Empirical evidence from two regions of Ghana. *Environment, Development and Sustainability*, *15*(4), 903–926. https://doi.org/10.1007/S10668-012-9418-9

Asante, F. A., & Amuakwa-Mensah, F. (2014). Climate Change and Variability in Ghana: Stocktaking. *Climate 2015, 3*(1), 78–99. https://doi.org/10.3390/CLI3010078

Asare-Nuamah, P., & Botchway, E. (2019). Understanding climate variability and change: analysis of temperature and rainfall across agroecological zones in Ghana. *Heliyon*, *5*(10), e02654. https://doi.org/10.1016/J.HELIYON.2019.E02654

Asibey, M. O., Dosu, B., & Yeboah, V. (2019). The roles and attitudes of urbanites towards urban water insecurity. Case of the New Juaben Municipality, Ghana. *Sustainable Water Resources Management*, *5*(4), 2023–2036. https://doi.org/10.1007/S40899-019-00349-8/METRICS

Attua, E. M., & Fisher, J. B. (2011). Historical and Future Land-Cover Change in a Municipality of Ghana. *Earth Interactions*, *15*(9), 1–26. https://doi.org/10.1175/2010EI304.1

Basiru, A. O. ;, Oladoye, A. O. ;, Okanlawon Basiru, A., Oladoye, A. O., Omotola Adekoya, O., Akomolede, L. A., Oeba, V. O., Awodutire, O. O., Charity, F., & Abodunrin, E. K. (2022). Livelihood Vulnerability Index: Gender Dimension to Climate Change and Variability in REDD+ Piloted Sites, Cross River State, Nigeria. *Mdpi.Com*, *2022*, 1240. https://doi.org/10.3390/land11081240

Boateng, K., & Larbi, R. T. (2021). Collaboration between Chiefs and Local Government Actors in Combating Climate Change: Evidence from New Juaben, Ghana. *Contemporary Journal of African Studies (CJAS)*, *8*(1 & 2), 25–41. https://doi.org/10.4314/contjas.v8i2.3

Carr, E. R., & Thompson, M. C. (2014). Gender and Climate Change Adaptation in Agrarian Settings: Current Thinking, New Directions, and Research Frontiers. *Geography Compass*, *8*(3), 182–197. https://doi.org/10.1111/GEC3.12121

Dankleman, I. (2008). *Gender, Climate Change and Human Security Lessons from Bangladesh, Ghana and Senegal Prepared for ELIAMEP This report has been prepared by The Women's Environment and Development Organization (WEDO) with ABANTU for Development in Ghana, ActionAid Bangladesh and ENDA in Senegal*.

Dwomoh, F. K., Wimberly, M. C., Cochrane, M. A., & Numata, I. (2019). *Forest Degradation Promotes Fire during Drought in Moist Tropical Forests of Ghana 2*.

Eakin, H., & Bojórquez-Tapia, L. A. (2008). Insights into the composition of household vulnerability from multicriteria decision analysis. *Global Environmental Change*, *18*(1), 112–127. https://www.sciencedirect.com/science/article/pii/S0959378007000660

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

Environmental Protection Agency. (2020). *Ghana's Fourth National Communication to the United Nations Framework Convention on Climate Change*. https://unfccc.int/sites/default/files/resource/Gh_NC4.pdf

Ghana Statistical Service. (2014). *Ghana 2010 Population and Housing Census.*

Ghana Statistical Service. (2014). GLSS 6 Poverty Profile—Ghana Statistical Service. http://www.statsghana.gov.gh/docfiles/glss6/GLSS6_Poverty%20Profile%20%20ghana.pdf

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

Ghana Statistical Service. (2021). *Ghana 2021 Population and Housing Census: Literacy and Education*.

Global Forest Watch. (2023). *Ghana: New Juaben, Eastern, Ghana Deforestation Rates and Statistics.* https://www.globalforestwatch.org/dashboards/country/GHA/

Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change—a case study in Mozambique. *Glob. Environ. Chang.*, *19*(1), 74–88. https://doi.org/10.1016/j.gloenvcha.2008.11.002

Hayhoe, K., Wuebbles, D. J., Easterling, D. R., Fahey, D. W., Doherty, S., Kossin, J. P., Sweet, W. V., Vose, R. S., & Wehner, M. F. (2018). *Chapter 2 : Our Changing Climate. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II*. https://doi.org/10.7930/NCA4.2018.CH2

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

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

Kangas, A., Haider, H., & Fraser, E. (2014). *Gender: Topic Guide.* Revised Edition with E. Browne. Birmingham: GSDRC, University of Birmingham, UK. www.gsdrc.org

Kumi-Boateng, B. (2017). *Mapping Malaria Risk in the New Juaben Municipality of Ghana Using GIS and Remote Sensing Techniques*.

Lin, J. Y. (1991). Education and Innovation Adoption in Agriculture: Evidence from Hybrid Rice in China. *American Journal of Agricultural Economics*, *73*(3), 713–723. https://doi.org/10.2307/1242823

Logah, F. Y., Obuobie, E., Ofori, D., & Kankam-Yeboah, K. (2013). Analysis of rainfall variability in Ghana. *International Journal of Latest Research In Engineering and Computing (IJLREC)*, *1*(8). http://csirspace.csirgh.com/handle/123456789/2087

Marful, A. B. (2013). *Greening communities in tropical sub-saharan Africa : a research on the dynamics of developing new Juaben Municipal Area in Ghana into an energy-efficient and ecologically-responsive community*. https://doi.org/10.18419/OPUS-95

Masson-Delmotte, V., Zhai, P., Chen, Y., Goldfarb, L., Gomis, M. I., Matthews, J. B. R., Berger, S., Huang, M., Yelekçi, O., Yu, R., Zhou, B., Lonnoy, E., Maycock, T. K., Waterfield, T., Leitzell, K., & Caud, N. (2021). *Climate Change 2021: The Physical Science Basis.* Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Mensah, H., & Ahadzie, D. K. (2020). Causes, impacts and coping strategies of floods in Ghana: a systematic review. *SN Applied Sciences*, *2*(5), 1–13. https://doi.org/10.1007/S42452-020-2548-Z/TABLES/5

Mintah Ampaw, E., Akuffo, B., Opoku Larbi, S., & Lartey, S. (2013). Time Series Modelling of Rainfall in New Juaben Municipality of the Eastern Region of Ghana Waste Management in Ghana View project Healthcare and service quality View project Time Series Modelling of Rainfall in New Juaben Municipality of the Eastern Regi. *International Journal of Business and Social Science*, *4*(8). https://www.researchgate.net/publication/341254605

Müller-Kuckelberg, K. (2012). Climate Change and its Impact on the Livelihood of Farmers and Agricultural Workers in Ghana. *Friedrich-Ebert-Stiftung Agricultural Workers, General of GTUC, Union*.

Neumayer, E., American, T. P.-A. of the association of, & 2007, undefined. (2007). The gendered nature of natural disasters: The impact of catastrophic events on the gender gap in life expectancy, 1981–2002. *97*(3), 551–566. Taylor & Francis, https://doi.org/10.1111/j.1467-8306.2007.00563.x

New Juaben South Municipal Assembly. (2021). *New Juaben South Municipal Assembly - Municipal Profile*. 1–10. https://en.m.wikipedia.org/wiki/New_Juaben_South_Municipal_Assembly

New Juaben South Municipal Assembly. (2022), Medium Term Development Plan (2022-2025). Prepared by the Municipal Planning and Coordination Unit. https://njsma.gov.gh/documents/MEDIUM%20TERM%20DEVELOPMENT%20PLAN%20[MTDP%202022-2025].pdf

New Juaben South Municipal Assembly. (2022). N*ew Juaben South Municipal Assembly - Climate Vulnerability Assessment Phase II Report.*

Nyamekye, C., Kwofie, S., Ghansah, B., Agyapong, E., & Boamah, L. A. (2020). Assessing urban growth in Ghana using machine learning and intensity analysis: A case study of the New Juaben Municipality. *Land Use Policy*, *99*, 105057. https://doi.org/10.1016/J.LANDUSEPOL.2020.105057

O'Brien, K. L., & Leichenko, R. M. (2003). Winners and losers in the context of global change. *Annals of the Association of American Geographers*, *93*(1), 89–103. https://doi.org/10.1111/1467-8306.93107

Owusu, K., Obour, P., change, S. A.-B.-H. of climate, & 2015, undefined. (2015). Climate variability and climate change impacts on smallholder farmers in the Akuapem North District, Ghana. *Springer*, 1791–1806. https://doi.org/10.1007/978-3-642-38670-1_111

Sullivan, C. (2002). Calculating a Water Poverty Index. *World Development*, *30*(7), 1195–1210. https://doi.org/10.1016/S0305-750X(02)00035-9

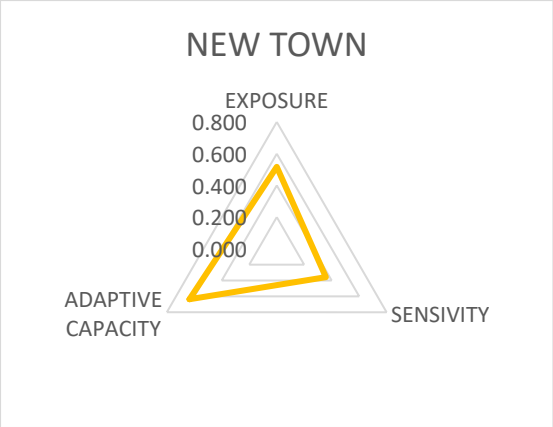
Taylor, M., & Philp, M. (2010). Adapting to climate change-implications for transport infrastructure, transport systems and travel behaviour. *Road & Transport Research: A Journalsearch.Informit.Org*. https://search.informit.org/doi/abs/10.3316/INFORMIT.673322031000336

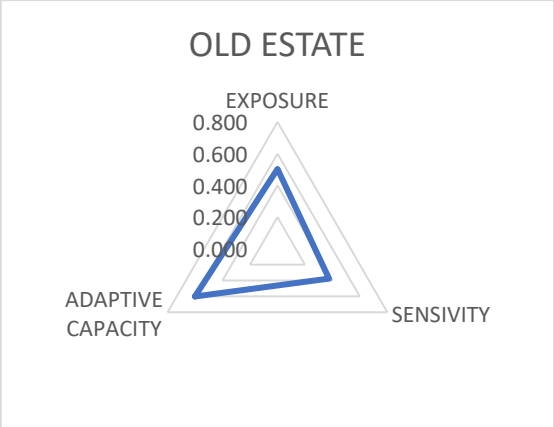
Thornton, P. K., Ericksen, P. J., Herrero, M., & Challinor, A. J. (2014). Climate variability and vulnerability to climate change: A review. *Global Change Biology*, *20*(11), 3313–3328. https://doi.org/10.1111/GCB.12581

Williams, P. A., Crespo, O., & Abu, M. (2020). Assessing vulnerability of horticultural smallholders' to climate variability in Ghana: applying the livelihood vulnerability approach. *Environment, Development and Sustainability*, *22*(3), 2321–2342. https://doi.org/10.1007/s10668-018-0292-y

Appendix 1. IPCC-LVI Results in the Various Zonal Areas

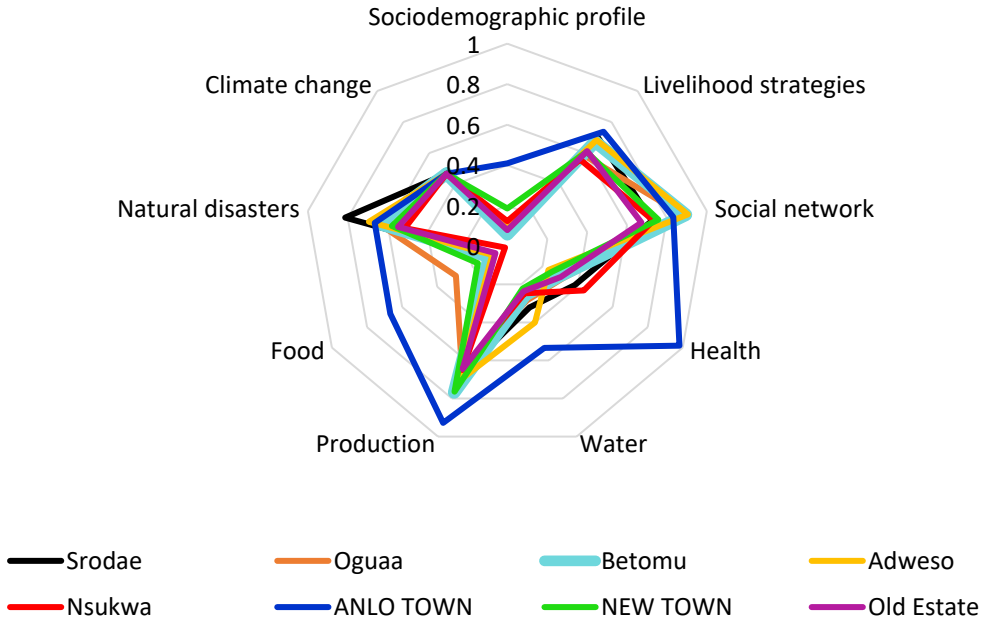
Figure 18. IPCC-LVI results in the various zonal areas


NEW TOWN
EXPOSURE
0.800
0.600
0.400
0.200
0.000
ADAPTIVE CAPACITY
SENSIVITY


OLD ESTATE
EXPOSURE
0.800
0.600
0.400
0.200
0.000
ADAPTIVE CAPACITY
SENSIVITY

Appendix 2. Indices for the Main Vulnerability Components in Each Zonal Area

Figure 19. Indices for the main vulnerability components in each zonal area



Appendix 3. LVI Components and Data Sources

Table 11. LVI components and data sources

SN	Indicator	Main component	IPCC component	Data source
1.	% Respondents with no education	Sociodemographic characteristics	Adaptive capacity	Survey, review, stakeholders workshop and interviews
2.	% Unemployed			Survey, review, stakeholders workshop and interviews
3.	% Not engaged in any secondary occupation	Livelihood strategies		Survey, review, stakeholders workshop and interviews
4.	%Households without member working outside community			Survey, review, stakeholders workshop and interviews
5.	% Not dependent on ecosystem services			Survey, review, stakeholders workshop and interviews
6.	% Not obtaining income from the forestry sector			Survey, review, stakeholders workshop and interviews
7.	% Not obtaining income from the mining sector			Survey, review, stakeholders workshop and interviews
8.	% Not obtaining income from the tourism sector			Survey, review, stakeholders workshop and interviews
9.	% Households with agriculture as only source of income			Survey, review, stakeholders workshop and interviews
10.	% Farmers not growing 1 more crop			Survey, review, stakeholders workshop and interviews
11.	% Farmers not rearing livestock			Survey, review, stakeholders workshop and interviews
12.	% Respondents not part of any social group	Social network		Survey, review, stakeholders workshop and interviews
13.	% Not aware of any gender association or organisation in their community			Survey, review, stakeholders workshop and interviews
14.	% of communities without tany gender-related government social interventions (e.g., LEAP)			Survey, review, stakeholders workshop and interviews
15.	% who have never received support from any Research and Development Institution			Survey, review, stakeholders workshop and interviews

16.	% who have never received support from any NGO or CSO			Survey, review, stakeholders workshop and interviews
17.	% who have never received support from any government organisation			Survey, review, stakeholders workshop and interviews
18.	% without access to credit			Survey, review, stakeholders workshop and interviews
19.	% Without access to remittances from family or friends			Survey, review, stakeholders workshop and interviews
20.	% Without access to subsidies			Survey, review, stakeholders workshop and interviews
21.	% Farmers not associated with any Farmer Based Organization (FBO)			Survey, review, stakeholders workshop and interviews
22.	% Farmers not associated with any Agriculture Extension Agent (AEA)			Survey, review, stakeholders workshop and interviews
23.	% Farmers without access to information on production methods and systems			Survey, review, stakeholders workshop and interviews
24.	% Without knowledge about agricultural insurance			Survey, review, stakeholders workshop and interviews
25.	Size of farm (acres)			Survey, review, stakeholders workshop and interviews
26.	% Without a health facility in their communities	Health	Sensitivity	Survey, review, stakeholders workshop and interviews
27.	Minutes of travel to the nearest health facilities			Survey, review, stakeholders workshop and interviews
28.	Number of health facilities in the community			Survey, review, stakeholders workshop and interviews
29.	% Without the NHIS			Survey, review, stakeholders workshop and interviews
30.	% Households with a member with chronic illness			Survey, review, stakeholders workshop and interviews
31.	% Households where a member missed work/school due to illness			Survey, review, stakeholders workshop and interviews
32.	Number of mosquito nets owned in a household			Survey, review, stakeholders workshop and interviews
33.	% Without access to safe sanitation services			Survey, review, stakeholders workshop and interviews
34.	Number of public toilet facilities in the community			Survey, review, stakeholders workshop and interviews

35.	% Without training/sensitization on climate related diseases			Survey, review, stakeholders workshop and interviews
36.	% With dealing with persistent water source unavailability	Water		Survey, review, stakeholders workshop and interviews
37.	% Without access to potable water			Survey, review, stakeholders workshop and interviews
38.	Average cost of water per month			Survey, review, stakeholders workshop and interviews
39.	% Households without water source being available everyday			Survey, review, stakeholders workshop and interviews
40.	Average minutes to get to a water source not inside the household			Survey, review, stakeholders workshop and interviews
41.	% Conflicts about water sources in the community			Survey, review, stakeholders workshop and interviews
42.	Proportion of farm under irrigation			Survey, review, stakeholders workshop and interviews
43.	Average of Total output lost as post-harvest loses	Production		Survey, review, stakeholders workshop and interviews
44.	% Farming households which save output to eat in a different year			Survey, review, stakeholders workshop and interviews
45.	% Farming households which save seeds to grow the next year			Survey, review, stakeholders workshop and interviews
46.	% Not subscribed to agricultural insurance			Survey, review, stakeholders workshop and interviews
47.	% Agricultural respondents dependent on household farms for most of its food			Survey, review, stakeholders workshop and interviews
48.	% Without access to farm implements			Survey, review, stakeholders workshop and interviews
49.	% Dependent on agricultural raw products for their activity			Survey, review, stakeholders workshop and interviews
	% Respondents' businesses without insurance			Survey, review, stakeholders workshop and interviews
51.	% Respondents' businesses not associated with a cooperative union			Survey, review, stakeholders workshop and interviews

52.	% Business persons not aware government support for their business			Survey, review, stakeholders workshop and interviews
53.	% Respondents without any properties (cars, buildings) insured			Survey, review, stakeholders workshop and interviews
54.	% Without disaster resilient buildings			Survey, review, stakeholders workshop and interviews
55.	% Agricultural respondents' Households without adequate food for the year	Food		Survey, review, stakeholders workshop and interviews
56.	Number of months in a year, farmers' households struggle to get food			Survey, review, stakeholders workshop and interviews
57.	% Service worker respondents mostly dependent on household farms for food			Survey, review, stakeholders workshop and interviews
58.	% Service respondents without adequate food for the year			Survey, review, stakeholders workshop and interviews
59.	Number of months in a year, service respondents' households struggle to get food			Survey, review, stakeholders workshop and interviews
60.	% that does not receive information of weather information for your communication devices	Natural disaster	Exposure	Survey, review, stakeholders workshop and interviews
61.	Extreme Droughts in respective communities			Survey, review, stakeholders workshop and interviews
62.	Extreme Floods in respective communities			Survey, review, stakeholders workshop and interviews
63.	% Respondents who received no warnings to extreme weather			Survey, review, stakeholders workshop and interviews
64.	Mean annual rainfall	Climate change		Model data
65.	Annual minimum temperature			Model data
66.	Annual maximum temperature			Model data
67.	Average number of Consecutive Dry Days (CDD)			Model data
68.	Average number of Consecutive Wet Days (CWD)			Model data

Appendix 4. Questionnaire

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 organisations 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 organisation(s)? [ ]
1 = Yes 2 = No

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

D7. If you have received support from any of the organisations/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					

	Large increase	Moderate increase	Constant	Moderate decrease	Large decrease
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

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 5. Organizations and Entities Represented in the Stakeholder Workshops

1. Koforidua Technical University
2. Edu Media
3. Feed Farm Forum
4. New Juaben South Municipal Assembly (NJSM)
5. Adweso Newtown
6. Betom Community
7. Department of Parks and Gardens
8. Environmental Protection Organization
9. University of Ghana
10. Center for Scientific and Industrial Research
11. Farmers Group
12. Traders Association
13. Ghana Federation of Disability
14. Ghana Health Service
15. Ghana Education Service
16. Ministry of Food and Agriculture
17. Ghana Meteorological Agency
18. Forestry Commission
19. National Youth Authority
20. Ghana National Fire Service
21. Statistical Service Department


NEW JUABEN SOUTH
MUNICIPAL ASSEMBLY


FREEDOM AND JUSTICE