CLIMATE CHANGE RISK AND VULNERABILITY ASSESSMENT REPORT

for

NZEMA EAST MUNICIPAL ASSEMBLY, WESTERN REGION-GHANA

Prepared under the

UNCDF Local Climate Adaptive Living Facility (LoCAL) – Boosting Green Employment and Enterprise Opportunities in Ghana (GrEEn) & Promoting Green and Climate-Resilient Local Economies in Ghana – Applying circular economy and Climate-smart Agriculture Principles and Solutions (LoCAL-ACE) Projects.

by

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TO:

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ACRONYMS

Acronym	Full Meaning
CRVA	Climate Risk and Vulnerability Assessment
NEMA	Nzema East Municipal Assembly
MTDP	Medium-Term Development Plan
NAP	National Adaptation Plan
NDPC	National Development Planning Commission
NADMO	National Disaster Management Organisation
GSS	Ghana Statistical Service
GMet	Ghana Meteorological Agency
MoFA	Ministry of Food and Agriculture
PFJ	Planting for Food and Jobs
LVI	Livelihood Vulnerability Index
EBA	Ecosystem-Based Adaptation
NbS	Nature-based Solutions
WASH	Water, Sanitation and Hygiene
SDGs	Sustainable Development Goals
UNFCCC	United Nations Framework Convention on Climate Change
IPCC	Intergovernmental Panel on Climate Change
GFDRR	Global Facility for Disaster Reduction and Recovery
SSP	Shared Socioeconomic Pathways
AR5	IPCC Fifth Assessment Report
AR6	IPCC Sixth Assessment Report
Rx1	Maximum 1-day precipitation (climate extreme index)
Rx5	Maximum 5-day precipitation (climate extreme index)
CWD	Consecutive Wet Days (climate extreme index)
TN90p	Percentage of hot nights (climate extreme index)
PWDs	Persons with Disabilities
GESI	Gender Equality and Social Inclusion

EXECUTIVE SUMMARY

Background: Nzema East Municipality, located along Ghana's Western coastline, is among the most climate-exposed districts in the Western Region. The local economy is anchored in rain-fed smallholder farming, artisanal fisheries, petty trade, and natural resource use — all highly sensitive to climate variability and environmental change. Communities already face recurrent flooding, shoreline erosion, sea-level rise, and prolonged dry spells, which intersect with poverty, fragile infrastructure, and entrenched gender inequalities. This Climate Risk and Vulnerability Assessment (CRVA) was undertaken to generate evidence that will inform the integration of climate resilience into municipal development planning and align with Ghana's National Adaptation Plan (NAP).

Methodology: The CRVA combined climate data analysis with community-based participatory methods and institutional reviews:

- **Household Surveys** across selected communities captured demographic, livelihood, water, health, and adaptation information.
- **Participatory Consultations** (FGDs, community mapping, key informant interviews) engaged farmers, fishers, women, youth, and vulnerable groups to document lived experiences and coping strategies.
- **Livelihood Vulnerability Index (LVI)** applied indicators of exposure, sensitivity, and adaptive capacity to measure composite vulnerability.
- **Climate Data & Projections** drew on ERA5, CHIRPS, GMet, and downscaled CMIP6 models under SSP2-4.5 (moderate) and SSP5-8.5 (high) scenarios.
- **Zonal Council and Community Analysis** disaggregated findings by location to reflect intra-municipal differences in exposure and adaptive capacity.

Key Findings

1. **Spatial & Demographic Vulnerabilities**
    - High-risk hotspots include Apewosika, Domunli, Adelekazo, and Ahunyame, where recurrent flooding, erosion, and tidal surges displace households and damage infrastructure.
    - Vulnerability is unevenly distributed: women face greater caregiving and livelihood burdens; youth confront limited livelihood opportunities and often migrate; elderly persons and people with disabilities are disproportionately exposed during floods and lack adaptive support.
2. **Sectoral Vulnerabilities**
    - **Agriculture & Food Security:** Farming is dominated by rain-fed smallholders with limited irrigation. Irregular rainfall, flooding, and heat stress reduce crop yields, increase post-harvest losses, and deepen food insecurity.
    - **Fisheries & Coastal Livelihoods:** Coastal communities such as Axim, Domunli, and Brewire are at severe risk from flooding, erosion, and storm surges. Fish landing sites and processing facilities are regularly damaged, undermining women processors' incomes and food security.
    - **Water Resources & Sanitation:** Communities depend on streams, wells, and sachet water. Floods contaminate water sources, while dry-season shortages

fuel conflict and health risks. Saline intrusion exacerbates water insecurity in coastal zones.

- **Health:** Rising malaria, cholera, and diarrhoeal outbreaks follow floods, while heat stress worsens respiratory and skin diseases. Health infrastructure itself is vulnerable, with clinics in flood-prone areas repeatedly disrupted.
- **Infrastructure & Human Settlements:** Poorly built housing, weak drainage, and exposure to sea-level rise place settlements at constant risk. Road inaccessibility and periodic relocation pressures increase vulnerability.
- **Gender & Social Inclusion:** Women lack equal access to land, credit, and extension services. Youth face high unemployment and exclusion from decision-making. PWDs are often left out of evacuation and recovery processes.
- **Natural Resources & Ecosystems:** Mangrove cutting, sand mining, and wetland farming degrade ecosystems, reducing their protective role against floods, erosion, and saltwater intrusion. Biodiversity loss threatens both cultural and economic assets.

3. **Climate Projections (Future Risks)**
   - **Temperature:** Annual mean temperatures have already risen by ~2°C since 1979 and are projected to increase by +2.0–2.5°C (SSP2-4.5) to +3.0–3.5°C (SSP5-8.5) by 2100.
   - **Rainfall:** Seasonal rainfall is projected to become more erratic, with heavier downpours during the wet season increasing flood risks, and declining dry-season rainfall intensifying water stress.
   - **Extremes:** More frequent storm surges, hot nights, and wet spells are expected, compounding risks to fisheries, health, and infrastructure.
4. **Cascading Risks**
   - Agricultural losses drive food insecurity, migration, and rising poverty.
   - Coastal erosion and flooding disrupt fisheries, trade, and tourism, while damaging infrastructure.
   - Water scarcity and contamination heighten disease burdens and undermine productivity.
   - Gender inequalities and exclusion reduce community resilience and adaptive capacity.
   - Ecosystem degradation diminishes natural flood defenses and accelerates vulnerability.

Recommendations

- **Agriculture:** Expand irrigation, promote climate-smart agriculture (CSA), and strengthen extension services.
- **Fisheries:** Support mangrove restoration, improve fish landing and processing infrastructure, and diversify coastal livelihoods.
- **Water & Sanitation:** Invest in rainwater harvesting, small dams, and WASH infrastructure, while enforcing by-laws on water use.
- **Health:** Upgrade clinics, integrate climate resilience into health planning, and expand early warning and disease surveillance systems.

- **Infrastructure & Settlements:** Enforce building codes, improve drainage, and integrate climate risk into spatial planning.
- **Gender & Social Inclusion:** Empower women, youth, and PWDs through equitable access to resources, decision-making, and targeted training.
- **Natural Resources & Ecosystems:** Scale up ecosystem-based adaptation (EbA), enforce resource by-laws, and promote alternative livelihoods.
- **Governance & Finance:** Strengthen municipal coordination, establish a climate adaptation taskforce, and mobilize finance from national and international sources.

Conclusion

The Nzema East CRVA confirms that climate change is already disrupting agriculture, fisheries, water systems, health, and infrastructure, while deepening existing social inequalities. Without decisive action, these risks will intensify under future climate scenarios, undermining development gains and threatening livelihoods. Embedding climate resilience into the Municipal Medium-Term Development Plan (MTDP), prioritizing high-risk sectors and communities, and ensuring inclusive, cross-sectoral planning are critical for safeguarding Nzema East's people, ecosystems, and economy in the face of growing climate uncertainty.

CHAPTER ONE: BACKGROUND

1.0 Introduction

Climate change presents a difficult challenge to global, national, and local development, particularly for vulnerable populations and ecosystems. In Sub-Saharan Africa, including Ghana, the impacts are already evident in rising temperatures, erratic rainfall, prolonged dry spells, intensifying floods, and coastal hazards (Intergovernmental Panel on Climate Change (IPCC), 2022). These changes threaten natural ecosystems and undermine the socio-economic foundations of communities that depend heavily on climate-sensitive sectors such as agriculture, fisheries, and water resources.

The Western Region of Ghana, and specifically Nzema East Municipality, exemplifies how climate change is reshaping local development realities (Adams et., 2016). The Municipality is largely rural, with livelihoods centered on smallholder farming, artisanal fisheries, and trade. These sectors are highly sensitive to climatic variability, leaving communities exposed to recurrent flooding, sea-level rise, coastal erosion, and drought. Low-lying coastal and riverine settlements face compounding risks from tidal surges, saltwater intrusion, and windstorms, resulting in damage to homes, infrastructure, and livelihoods while intensifying poverty and food insecurity (Cudjoe et., 2023).

Socio-economic inequalities further heighten vulnerability. Women carry disproportionate responsibilities in farming, fish processing, and household water management, yet face barriers in accessing finance, land, and decision-making spaces. Youth confront declining opportunities in farming and fisheries, while elderly persons and people with disabilities often remain excluded from adaptation initiatives and disproportionately affected during disasters. These differentiated vulnerabilities underscore the need for inclusive and equity-oriented responses.

At the institutional level, weak enforcement of land-use regulations, inadequate early-warning systems, and limited financial and technical resources constrain effective climate response. While efforts to integrate climate considerations into local planning have begun, they remain fragmented and heavily donor dependent (MTDP, 2025).

This CRVA for Nzema East responds to the urgent need for evidence-based, locally grounded analysis of how climate hazards are evolving, who and what is at risk, and what opportunities exist to strengthen resilience. It combines participatory consultations with scientific data to ensure that local voices, particularly those of vulnerable groups, inform the adaptation agenda.

The report provides a foundation for mainstreaming climate adaptation into the Municipality's development planning. It is structured around three dimensions of vulnerability—exposure, sensitivity, and adaptive capacity—leading to sectoral and social analyses and, ultimately, to recommendations for building a climate-resilient future aligned with the Municipal Medium-Term Development Plan (MTDP) and Ghana's NAP.

1.1 Purpose and Objective of this VA

The purpose of the CRVA for Nzema East Municipality is to establish a structured, evidence-based understanding of how climate change hazards are affecting local populations, livelihoods, ecosystems, and critical infrastructure. Given Nzema East's coastal and resource-dependent context, this assessment functions as both a diagnostic and strategic tool: it informs municipal adaptation planning, strengthens climate resilience, and supports the mainstreaming of climate considerations into development strategies. The assessment is intended not only to guide immediate risk reduction and emergency response but also to underpin long-term, inclusive, and sustainable development in the face of climate uncertainty.

The CRVA for Nzema East Municipality specifically seeks to:

1. **Identify and prioritize vulnerabilities** across sectors, population groups, and ecosystems by analysing the drivers of risk, exposure, and adaptive capacity within Nzema East. The analysis highlights differences across zones and communities, ensuring that interventions are spatially and socially targeted.
2. **Generate actionable evidence** to support the integration of climate adaptation into municipal planning instruments such as the Medium-Term Development Plan (MTDP). This alignment ensures coherence with Ghana's NAP, the Nationally Determined Contributions (NDCs), and the Paris Agreement's global goal on adaptation.
3. **Inform programme and project design** under initiatives such as the GrEEn and LoCAL-ACE projects by identifying no-regret measures and resilience-building interventions suitable for the municipality's socio-ecological context.
4. **Produce knowledge products** (e.g., vulnerability maps, sectoral risk profiles, policy briefs, and communication tools) that raise public awareness, improve decision-making processes, and facilitate resource mobilization for climate adaptation finance at both local and national levels.
5. **Strengthen local ownership and capacity** through participatory processes that actively engage stakeholders—including women, youth, fisherfolk, migrants, and

persons with disabilities (PWDs). These processes help validate findings, co-create adaptation strategies, and ensure equitable representation of vulnerable groups.

6. **Contribute to national adaptation efforts** by providing Nzema East-specific insights that feed into regional and national synthesis reports. This supports Ghana's reporting under the UNFCCC, the NDCs, and the Sustainable Development Goals (SDGs), while enhancing the overall national knowledge base on climate resilience.

1.2. Scope of this VA

The Nzema East Climate Risk and Vulnerability Assessment (CRVA), aligned with Ghana's NAP and the UNCDF LoCAL mandate, provides localized, evidence-based insights on climate hazards, exposures, and vulnerabilities to guide municipal adaptation planning. It applies a context-specific, district-focused approach covering the following:

1. District Profiling: A brief baseline of Nzema East's demographics, socio-economic conditions, settlement patterns, and climate-sensitive sectors—agriculture, fisheries, forestry, tourism, and water resources—alongside key ecosystems such as coastal zones, wetlands, and river systems.

2. Climate Hazard & Risk Analysis: Assessment of historical and seasonal climate hazards (floods, droughts, coastal erosion, storm surges, heat) using quantitative datasets and community narratives, supported by hazard maps and seasonal risk calendars, and identification of the most at-risk population groups.

3. Vulnerability Causality Chains: Linkages between climate stressors (e.g., saline intrusion, flooding, heat) and underlying socio-economic drivers—poverty, weak infrastructure, gender inequality, and resource access gaps—across priority NAP sectors.

4. Current & Future Climate Risks: Evaluation of present vulnerabilities and future risks using downscaled climate projections (CMIP6/CORDEX/ERA5) to determine impacts on key sectors, assets, ecosystems, and social groups.

5. Differentiated Social Impacts: Gender-, age-, and disability-responsive analysis of how women, youth, the elderly, and PWDs experience and cope with climate risks, and what tailored adaptation options they require.

6. Good Practices & Recommendations: Documentation of existing coping mechanisms and development interventions, with practical, financially viable, and socially inclusive adaptation recommendations.

7. Stakeholder Validation & Knowledge Co-production: Engagement with communities, traditional authorities, municipal departments, and national institutions through participatory validation workshops to ensure ownership and strengthen local governance capacity.

8. Regional & National Integration:Synthesis of Nzema East findings for Western Region reporting and alignment with national frameworks (NAP, NDCs, sector policies) to support Ghana's broader adaptation agenda.

1.3. Outputs of this VA

The CRVA for Nzema East Municipality is designed to deliver tangible, actionable outputs that move beyond academic analysis to provide practical tools for planning, decision-making, advocacy, and implementation. The outputs will directly support municipal-level adaptation action, while aligning with Ghana's NAP framework and the LoCAL mechanism to strengthen access to adaptation finance.

The key outputs include:

1. Comprehensive CRVA Report for Nzema East

- A detailed report documenting Nzema East's current and projected climate risks, sectoral vulnerabilities, and adaptive capacities.
- Analysis of differentiated vulnerabilities by gender, age, and socio-economic groups, including fisherfolk, farmers, youth, migrants, women traders, and persons with disabilities.
- A clear set of municipality-specific adaptation priorities to guide planning, investment, and resource mobilization.

2. Geospatial Hazard and Vulnerability Maps

- Municipal-level maps highlighting climate hazard hotspots (e.g., flood-prone settlements, erosion-prone coastal communities, and drought-stressed agricultural areas).
- Spatial representation of exposed assets and vulnerable populations, enabling evidence-based targeting of adaptation investments.

3. Vulnerability Profiles and Causality Chains

- Sectoral vulnerability profiles for agriculture, fisheries, health, water resources, infrastructure, gender, and natural resources/ecosystems.
- Causality chains illustrating linkages between climate stressors (e.g., sea-level rise, rainfall variability, extreme heat) and socio-economic drivers of vulnerability (e.g., poverty, weak infrastructure, gender inequality, and land tenure insecurity).

4. Knowledge Products for Awareness and Advocacy

- Simplified communication materials, such as infographics, policy briefs, and community posters, tailored for non-technical audiences.
- Awareness-raising content to support public campaigns on climate risks and adaptation measures in Nzema East.

5. CRVA Methodological Toolkit

- A toolkit outlining the step-by-step methodological framework applied in the assessment, including indicators, participatory tools, and data sources.
- An accompanying CRVA database (Excel/compatible formats) containing climate, socio-economic, and vulnerability datasets for future use by the Assembly and stakeholders.

6. Regional and National Synthesis Report Contribution

- Input into a Western Region synthesis report to highlight cross-district lessons, common risks, and shared adaptation priorities.
- Contribution to Ghana's national climate adaptation reporting systems and the Local Information System for Adaptation (LISA) platform.

7. Capacity-Building and Action Roadmaps

- Guidelines and roadmaps for mainstreaming climate adaptation into Nzema East's Medium-Term Development Plan (MTDP) and annual action plans.
- Capacity-strengthening materials for district officials, traditional leaders, and community representatives to sustain local adaptation planning and implementation.

8. Feedback and Validation Mechanisms

- A framework for returning findings to communities through validation workshops and participatory dialogues, ensuring local ownership of results.
- Documentation of community-driven adaptation recommendations, reflecting indigenous knowledge, cultural practices, and lived experiences.

1.4 Guiding Principles

The Nzema East Municipality CRVA is underpinned by a set of guiding principles that reflect global best practice, Ghana's national adaptation priorities, and the municipality's local development agenda. These principles ensure that the process is technically sound, inclusive, participatory, and responsive to the unique realities of Nzema East.

1. Alignment with National and Global Frameworks: The assessment is anchored in Ghana's NAP and contributes to national commitments under the Paris Agreement and the Sustainable Development Goals (SDGs). It aligns with the broader vision of building adaptive capacity, strengthening resilience, and reducing vulnerability, as articulated in Article 7 of the Paris Agreement (UNFCCC, 2015).
2. District-Specific and Place-Responsive: Recognizing that climate impacts are not homogeneous, the CRVA adopts a place-based approach tailored to Nzema East's coastal, rural, and socio-economic realities. The municipality's dependence on fisheries, farming, mangrove ecosystems, and coastal infrastructure makes it especially vulnerable to sea-level rise, coastal erosion, flooding, and rainfall variability. Adaptation options are therefore designed to reflect Nzema East's geography, ecosystems, and livelihoods, ensuring locally relevant solutions.
3. Inclusivity and Participation: The assessment process prioritizes active engagement of stakeholders at every stage, ensuring that community voices shape the identification of vulnerabilities and the design of adaptation strategies. Particular attention is given to marginalized and vulnerable groups—including women, youth, migrants, persons with disabilities, and the elderly—whose experiences and coping strategies are often overlooked in traditional planning processes.
4. Gender Sensitivity and Equity: Climate change impacts are differentiated by gender and social categories. The CRVA therefore applies a gender-sensitive and intersectional lens, ensuring that the specific vulnerabilities and adaptive capacities of both women and men are acknowledged and addressed. In Nzema East, women play central roles in fish processing, trading, farming, and household care, yet they face persistent barriers

to finance, land, technology, and decision-making platforms. Promoting equity and empowerment is integral to building climate-resilient communities.

5. Integration of Local and Indigenous Knowledge: While scientific data and projections provide essential insights, the CRVA also recognizes the value of local knowledge and indigenous practices. Communities in Nzema East have long histories of adapting to coastal and climatic variability through strategies such as mangrove restoration, diversified farming systems, traditional fishing practices, and community risk-sharing mechanisms. Documenting and integrating these practices ensures culturally grounded and contextually appropriate adaptation pathways.
6. Multi-Sectoral and Systems Approach: Climate risks in Nzema East cut across agriculture, fisheries, water resources, health, infrastructure, gender, and ecosystems. The CRVA adopts a systems approach, examining how risks interact across sectors, and how interventions in one domain (e.g., flood control) may create synergies or trade-offs in others (e.g., water quality, farming, or fisheries). This approach ensures that adaptation strategies are comprehensive and well-coordinated.
7. Knowledge Development and Capacity Building: A core principle of the CRVA is learning-by-doing. The process is designed not only to generate evidence but also to strengthen the capacities of municipal officials, traditional authorities, civil society groups, and community representatives. This ensures that the outputs of the CRVA remain usable, replicable, and sustainable beyond the life of the project.
8. Transparency, Openness, and Accountability: The assessment is carried out in a transparent and participatory manner, with findings openly shared for validation and critique. Workshops, stakeholder dialogues, and feedback mechanisms provide spaces for inclusive engagement and accountability, ensuring that the CRVA is rooted in trust and legitimacy.
9. Quality Assurance and Scientific Rigor: The CRVA adheres to international best practices in climate risk analysis, drawing on IPCC methodologies, peer-reviewed evidence, and triangulation of data sources. Quality assurance is ensured through robust data validation, peer review, and benchmarking against global standards, while maintaining contextual relevance for Nzema East.

1.5 Definition of Key Terms and Concepts

To guide the CRVA for Nzema East, this glossary consolidates key terms, concepts, and analytical frameworks widely used in climate change adaptation and resilience research (Table 1). It draws primarily from authoritative sources such as the IPCC (AR5 and AR6 reports), UNFCCC frameworks, Ghana's NAP (NAP, 2020), and complementary scientific and policy references.

Table 1: Definition of key terms and concepts

Term	Definition	Reference
Climate Change	A change in the state of the climate that can be identified by changes in the mean and/or variability of its properties, persisting for decades or longer, due to natural processes or human activity.	IPCC, 2014 (AR5)
Climate Hazard	A potentially damaging physical event, trend, or impact related to climate, such as flooding, drought, coastal erosion, sea-level rise, extreme heat, or storm surges.	IPCC, 2014
Exposure	The presence of people, livelihoods, infrastructure, ecosystems, or assets in places that could be adversely affected by climate hazards.	IPCC, 2014
Vulnerability	The propensity or predisposition of people, systems, or assets to be adversely affected by climate hazards, determined by sensitivity and adaptive capacity.	IPCC, 2014; UNFCCC, 2021
Sensitivity	The degree to which a system or population is affected, either adversely or beneficially, by climate variability or change (e.g., dependence on rain-fed agriculture).	IPCC, 2014
Adaptive Capacity	The ability of households, communities, institutions, or ecosystems to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.	IPCC, 2014; Ghana NAP, 2020
Risk	The potential for adverse consequences when a climate hazard interacts with exposure and vulnerability. In this assessment, risk is conceptualized following the IPCC AR5 framework: Risk = Hazard × Exposure × Vulnerability.	IPCC, 2014
Resilience	The capacity of social, economic, and environmental systems to cope with hazardous events or climate trends, while maintaining essential functions, adapting, and transforming when necessary.	IPCC, 2014; IPCC, 2022 (AR6)
Adaptation	The process of adjustment to actual or expected climate change and its effects, in order to moderate harm or exploit beneficial opportunities.	UNFCCC, 2021; IPCC, 2014
Maladaptation	Adaptation measures that inadvertently increase vulnerability to climate change instead of reducing it, often by creating long-term negative impacts.	IPCC, 2022 (AR6)
Mitigation (of Climate Change)	Human interventions aimed at reducing the sources or enhancing the sinks of greenhouse gases. While the focus of this report is adaptation, mitigation is acknowledged as complementary.	UNFCCC, 2015 (Paris Agreement)
Climate Projection	A simulated future climate scenario, based on assumptions about greenhouse gas emissions and socio-	IPCC, 2014; WMO, 2019

	economic development pathways, used to estimate future changes in rainfall, temperature, and sea level.	
Slow-Onset Event	A climate impact that occurs gradually over time, such as sea-level rise, salinization, or desertification.	UNFCCC, 2021
Rapid-Onset Event	A climate hazard that occurs suddenly, such as flash floods, cyclones, or storm surges.	UNFCCC, 2021
Ecosystem Services	The benefits that people derive from ecosystems, including provisioning (food, water), regulating (flood control, carbon sequestration), cultural (heritage, tourism), and supporting services (soil fertility, biodiversity).	Millennium Ecosystem Assessment, 2005
Gender and Social Inclusion (GESI)	An approach that ensures the differentiated vulnerabilities and capacities of women, youth, persons with disabilities, and marginalized groups are addressed in adaptation planning.	Ghana NAP, 2020; UN Women, 2019
Mainstreaming	The integration of climate change considerations into policies, strategies, and plans at all levels of governance to ensure sustainable development outcomes.	UNDP, 2011; Ghana Climate Change Policy, 2013
Livelihood Vulnerability Index (LVI)	A composite index that quantifies household or community vulnerability to climate change based on indicators of exposure, sensitivity, and adaptive capacity.	Hahn et al., 2009; Sullivan et al., 2002
Ecosystem-based Adaptation (EbA)	The use of biodiversity and ecosystem services as part of an overall adaptation strategy, helping people adapt to the adverse effects of climate change through conservation, restoration, and sustainable management of ecosystems.	CBD, 2009; UNEP, 2010
Nature-based Solutions (NbS)	Actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges (e.g., climate change, food security, water security) effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.	IUCN, 2016; IPCC, 2022 (AR6)

1.6 Methodological Framework

The CRVA in Nzema Municipal applied a mixed method, layered framework that brought together qualitative community insights, quantitative household data, and climate science. This approach was designed to ensure scientific robustness while remaining firmly rooted in local realities, thereby producing findings that are credible, relevant, and actionable for planning and policy (**Figure 1).**

1.6.1. Desk Review

A comprehensive desk review was undertaken to establish the baseline context for Nzema. Secondary data sources included the Municipal Medium-Term Development Plans (MTDPs), Annual Progress Reports (APRs), Ghana Statistical Service (GSS) publications, poverty mapping, and environmental statistics. Sector-specific policy documents and reports on

previous climate-related studies were also reviewed. This stage provided critical background on population trends, socio-economic conditions, livelihood systems, and environmental pressures, which served as a foundation for indicator selection and vulnerability analysis.

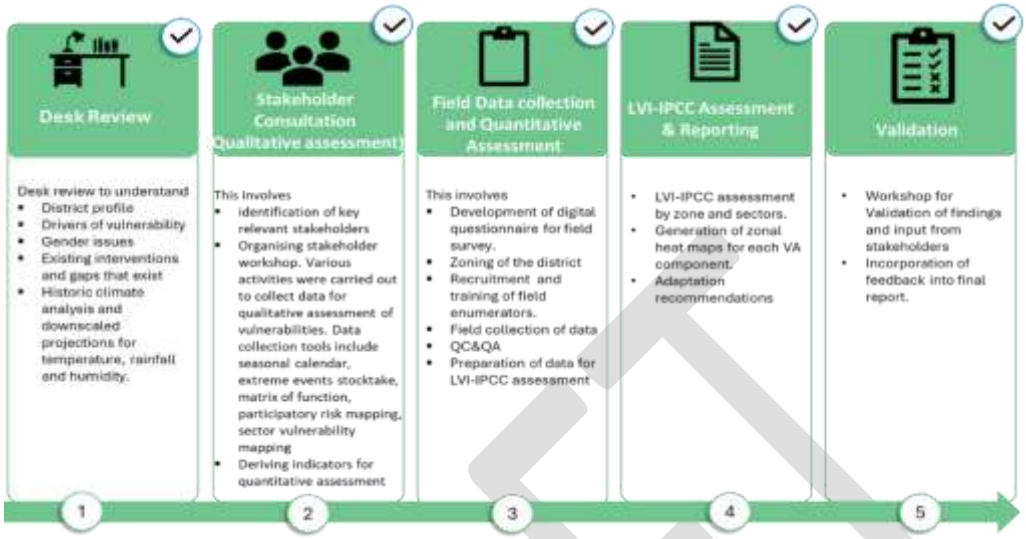

Figure 1. Vulnerability Assessment Methodology for Nzema Municipal Assembly

1.6.2. Participatory Assessments

Participatory approaches were central to this CRVA. A variety of tools were employed — including seasonal calendars, stakeholder workshops, and participatory risk mapping — to capture lived experiences of climate change and community adaptation strategies.

The process deliberately engaged a wide and diverse group of stakeholders:

- **Municipal-level actors** such as staff of the Agriculture, Health, Education, Gender, Water, Works, and NADMO departments.
- **Regional and national representatives**, including the Regional Coordinating Council and the Environmental Protection Authority.
- **Community voices**, including traditional and religious leaders, women's associations, youth groups, and fisherfolk unions.

This diversity ensured that the findings reflected multiple perspectives and knowledge systems, and that proposed adaptation measures were co-created rather than externally imposed.

1.6.3. Household Survey

A structured household survey was conducted across selected communities in the municipality. The survey collected data on:

- Socio-demographic characteristics (age, gender, household size, dependency ratios).
- Livelihoods and income diversification strategies.
- Access to services such as water, health, education, and markets.
- Coping mechanisms and adaptive strategies employed by households.

The sampling framework was designed to ensure representation of vulnerable groups, including women-headed households, youth-led households, elderly persons, persons with disabilities, and migrants. This inclusivity guaranteed that the quantitative dataset reflected the full spectrum of vulnerabilities and adaptive capacities present in the municipality.

The survey results formed the basis for calculating the Livelihood Vulnerability Index (LVI), which was reformulated in line with the IPCC framework into exposure, sensitivity, and adaptive capacity dimensions.

1.6.4. Quantitative Analysis

The LVI framework was applied to the household data, producing composite vulnerability scores that were further disaggregated to highlight differences across:

- Sectors (food production (agriculture), water, health, fisheries, infrastructure).
- Geographic settings (coastal, inland, and peri-urban communities).
- Social groups (women, men, youth, elderly, and persons with disabilities).

This quantitative analysis provided a robust statistical base to complement qualitative insights and allowed for comparisons across space, sectors, and demographics.

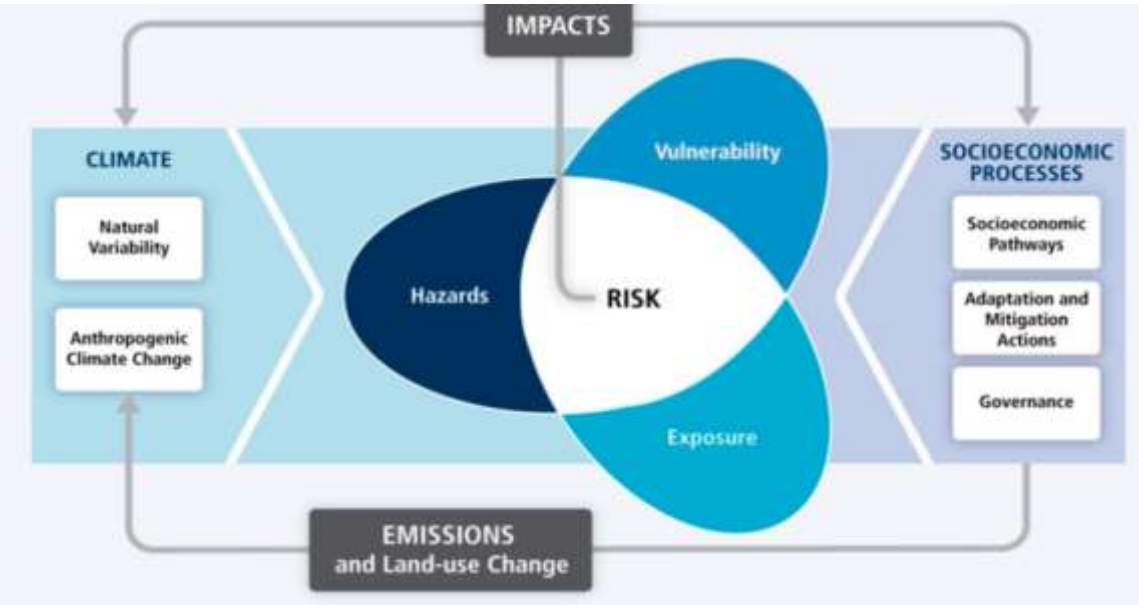

Figure 2: IPCC Risk Framework applied in the Nzema CRVA here (adapted from IPCC, 2022).

1.6.5. Climate Data Analysis

Observed climate data were analyzed to understand historical and present-day variability:

- **Sources**: Ghana Meteorological Agency (GMet), CHIRPS, and ERA5 datasets.
- **Variables**: total rainfall, rainfall intensity, number of dry days, minimum and maximum temperature, and the frequency of extreme events.

This analysis provided empirical evidence of climate trends and anomalies in Nzema, grounding the community narratives in scientific observations.

1.6.6. Future Climate Projections

Future climate risks were assessed using downscaled climate projections from the CMIP6 datasets under two scenarios:

- SSP2-4.5 (medium stabilization pathway).
- SSP5-8.5 (high-emission pathway).

Projected changes in rainfall and temperature were analyzed across relevant time horizons. Sectoral implications were drawn for agriculture, fisheries, health, water resources, and infrastructure, providing foresight into how Nzema's vulnerabilities may evolve in coming decades.

1.6.7. Integration and Triangulation

Insights from the desk review, participatory assessments, household survey, climate data analysis, and projections were integrated into a holistic vulnerability profile. Triangulation ensured that findings were not based on a single data source but reflected both quantitative rigor and qualitative depth.

1.6.8. Validation

Draft findings were presented to municipal stakeholders, including the Assembly, sector departments, traditional leaders, and NGOs, for validation. Feedback sessions served both to verify accuracy and to promote ownership of results. Community voices were again incorporated to refine adaptation recommendations.

The assessment was guided by the IPCC risk framework (**Figure 2**), which defines climate risk as a function of hazards, exposure, and vulnerability. In addition, the process was aligned with Ghana's NAP risk assessment framework (**Figure 3).** The NAP framework provides a structured sequence of steps — from establishing context and identifying risks to assessment, prioritization, and treatment — ensuring that district-level findings remain consistent with national planning priorities.

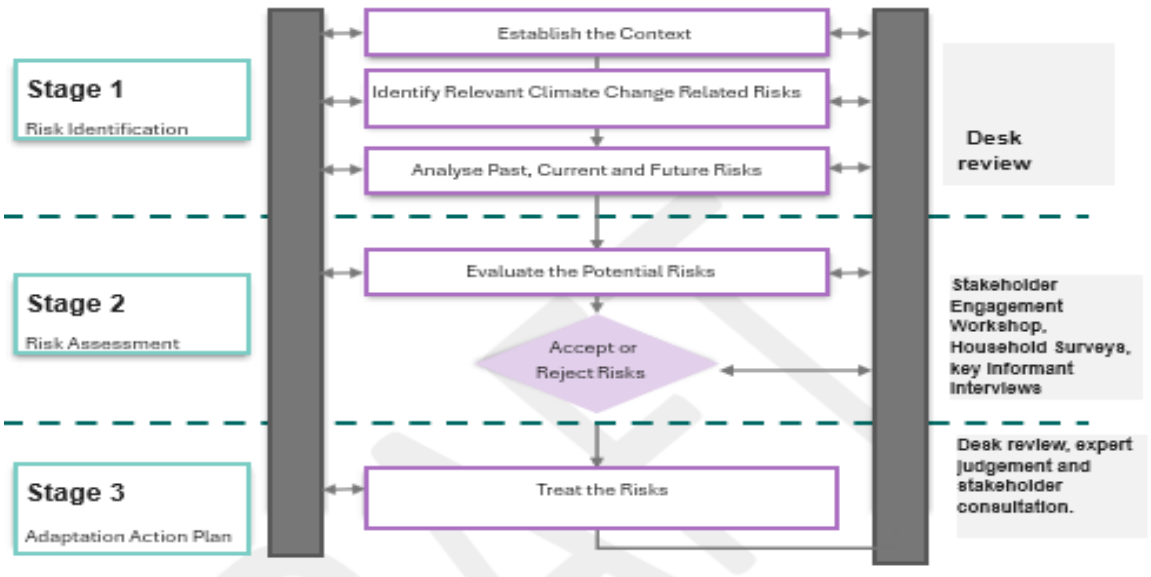

Figure 3: The Ghana NAP framework of risk assessment (Adapted from Norman, et al., 2014

CHAPTER TWO: PROFILE OF NZEMA MUNICIPAL ASSEMBLY

2.0. Introduction

This chapter provides a general profile of Nzema East Municipality (Hereafter, "Nzema East" refers to the Nzema East Municipal Assembly), offering the contextual background for understanding climate risk and vulnerability. It presents the municipality's geographic location, physical and ecological features, demographic characteristics, and socio-economic structure, including livelihood systems, poverty levels, and access to infrastructure and services. These baseline conditions frame the underlying development challenges that influence exposure and sensitivity to climate hazards.

2.1 Geography and Climate-Related Profiles

2.1.1 Location and Size

The Nzema East Municipal Assembly (NEMA) is one of 22 MMDAs in Ghana's Western Region (Fig. 4). Established in 1988 under LI 1446, it was carved from the former Nzema District, with Axim serving as the administrative and economic capital. The municipality covers about 1,200 km²—approximately 4.9% of the region's land area—and is strategically positioned along the Gulf of Guinea. Located between latitudes 4°40′–5°20′ N and longitudes 2°05′–2°35′ W, Nzema East is bordered by the Gulf of Guinea to the south, Ellembelle District to the north, Ahanta West to the east, and Nzema West to the west. Its coastal setting underpins key economic activities such as fishing, tourism, and trade, making the municipality an important hub within the southwestern corridor of the Western Region.

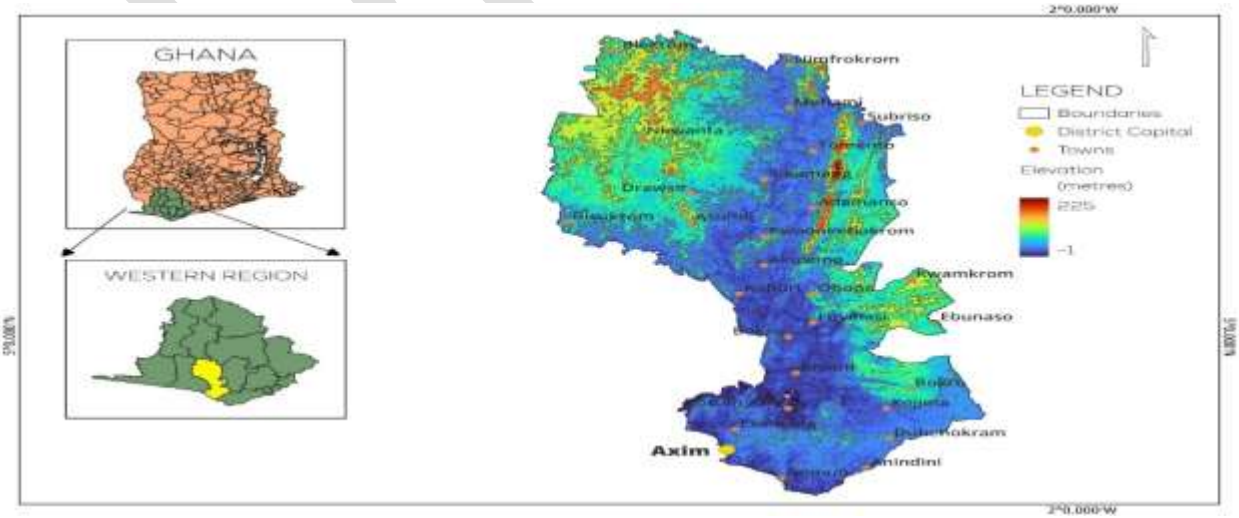

Figure 4 Map of Nzema East Municipality showing the major towns

2.1.2 Topography and Climate

Nzema East lies in the tropical rainforest zone, transitioning into coastal savannah and mangrove ecosystems. The terrain is largely flat, with low-lying coastal plains rising gently to about 60 m inland, making the area fertile but highly exposed to coastal hazards from the Gulf of Guinea. Geologically, the municipality is underlain by Birimian and Tarkwaian formations rich in kaolin, silica, gold, and sandstone. Soils are dominated by ferric acrisols and dysric fluvisols, which support cocoa, oil palm, plantain, and cassava, though high rainfall causes nutrient leaching that favours tree crops. This leaching also exposes mineral-rich rocks, contributing to widespread small-scale and illegal mining, which provides income but drives environmental degradation and health risks.

2.1.3 Average temperatures and precipitation

Nzema East experiences a mean annual temperature of approximately 27°C, with minimal seasonal variations. The municipality receives an average annual rainfall of 1,600 to 2,000 millimeters, distributed across two main wet seasons: April to July and September to November. A short dry spell occurs in August, while a longer dry period extends from December to March. This climatic pattern supports agriculture and vegetation growth, particularly for crops like oil palm, rubber, and coconut (Ministry of Food and Agriculture, 2021).

2.1.4 Relief and Vegetation

Nzema East is dominated by low-lying coastal plains that rise gradually inland to about 60 m above sea level. This flat, exposed terrain makes coastal communities highly vulnerable to tidal flooding and erosion. Vegetation reflects the area's transition from coastal savannah to tropical forest, with inland zones supporting secondary forests and tree crops such as cocoa, oil palm, and rubber, while coastal areas contain important mangrove belts that protect shorelines and support fisheries. However, vegetation cover is declining due to agricultural expansion, galamsey, and urbanization, leading to land degradation, biodiversity loss, and weakened natural buffers around rivers and coastal wetlands.

2.2 Demographics and Gender Characteristics

2.2.1 Key Demographic Characteristics

2.2.1.1 Population Size and Growth

Nzema East Municipality has a population of 94,621 (2021 PHC), up from 60,828 in 2010—an annual growth rate of 4.2%. With a land area of 1,025 km², population density stands at about 92 persons/km². This rapid growth, alongside slow infrastructure expansion, has increased pressure on housing, water, sanitation, and other basic services. It has also intensified demand on already stressed natural resources—fisheries, farmland, and forests—exacerbating vulnerability to climate hazards such as flooding, coastal erosion, and drought.

2.2.1.2 Gender Distribution

The Nzema East Municipality has a near-balanced gender composition, with 51.4% (48,590) males and 48.6% (46,031) females, giving a sex ratio of 97 females to every 100 males. Although gender distribution is relatively even, climate change impacts are not experienced equally across sexes. Women in Nzema East are particularly vulnerable due to their concentration in climate-sensitive sectors such as farming, fishing, and trading, and their roles in household water collection and caregiving. These responsibilities expose them disproportionately to the effects of erratic rainfall, flooding, and resource scarcity. Ensuring that climate adaptation strategies are gender-responsive is therefore essential for building resilience in Nzema East (MTDP, 2022; PHC, 2021).

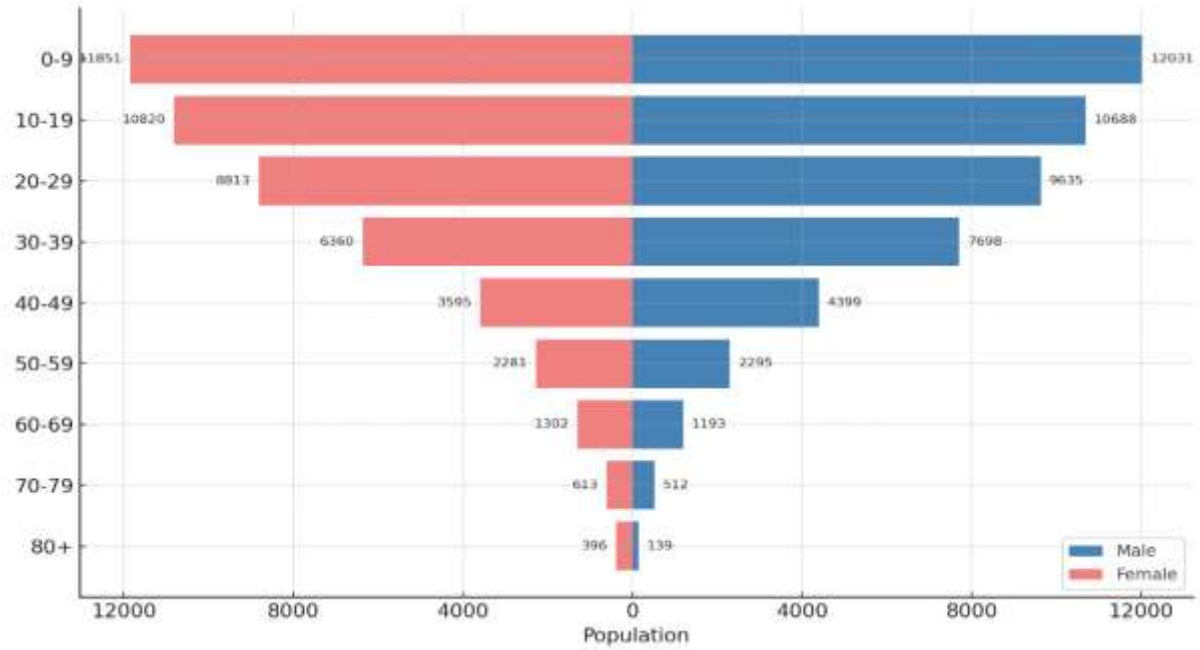

Figure 5: Nema's Rural-Urban distribution by Gender

2.2.1.3 Age Structure

Nzema East has a youthful population, with nearly half under 20 years and a high dependency ratio (MTDP, 2025). Children face heightened vulnerability to heat stress and climate-related diseases such as malaria and cholera, while the elderly—though a small share of the population—are at increased risk from extreme heat and limited healthcare access. The working-age group (20–49 years), which forms the backbone of the local economy, is also exposed to climate-related losses in farming, fisheries, and small-scale trade. These patterns highlight the need for age-responsive climate adaptation measures.

2.2.1.4 Rural–Urban Distribution

Nzema East remains predominantly rural, with 75.4% of the population residing in rural areas and 24.6% living in urban centers (**Figure 5).** The municipal capital, Axim, serves as the main urban hub, while the majority of smaller communities depend heavily on agriculture and fishing. Rural areas are particularly vulnerable to erratic rainfall, flooding, and coastal erosion, given their dependence on climate-sensitive livelihoods and weaker infrastructure.

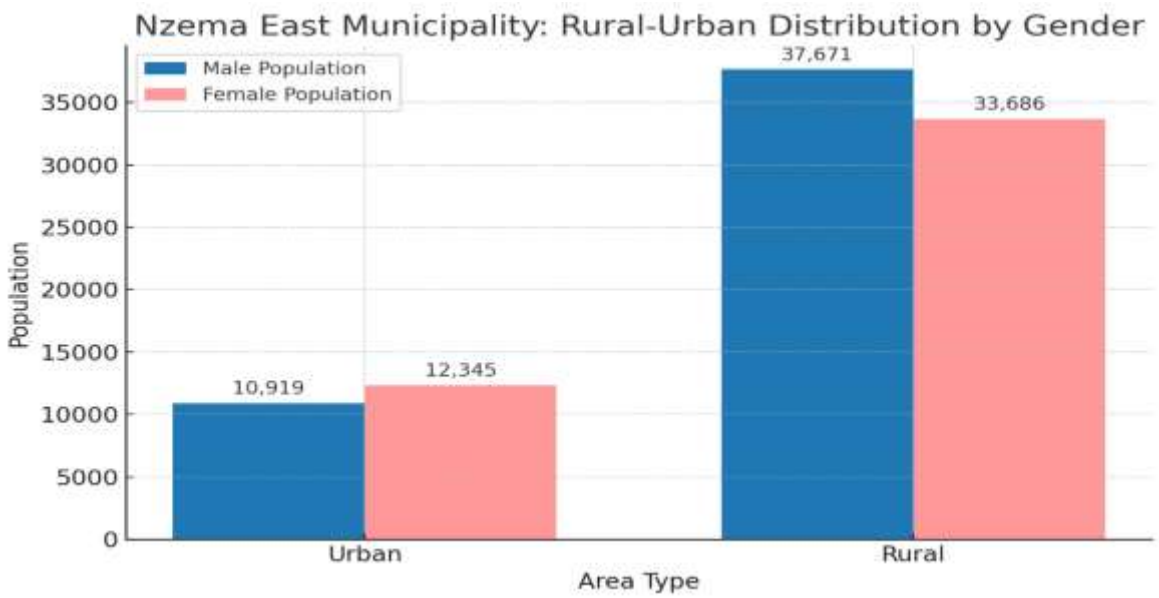

Figure 5: Rural-urban distribution by gender

Urban centers, although better served by services, also face climate risks, including flooding, water scarcity, and heat stress, especially in informal settlements with limited access to resources. Notably, the gender balance differs between settlement types: urban areas have a female majority (53.1%), while rural areas are male dominated (52.8%). This distribution reflects patterns of rural–urban migration and has implications for how climate change impacts are distributed across genders and settlement types (MTDP, 2022; PHC, 2021).

2.3 Administration and Governance Structure

Nzema East operates under Ghana's decentralized local government system (Act 936), with the Municipal Assembly as the main authority responsible for development and climate-related planning. The Assembly consists of elected members, government appointees, the MCE, and an administrative team led by the MCD, supported by zonal councils and unit committees—though these sub-structures often lack resources. Decentralized departments (Agriculture, Health, Education, Social Welfare, NADMO) implement national programmes at the local level, while traditional authorities play major roles in land management and community mobilization. Civil society groups, including women's and youth organizations, also support governance and resilience efforts. However, challenges such as limited technical capacity, weak inter-departmental coordination, poor enforcement of by-laws, and inadequate funding continue to constrain effective climate adaptation planning.

2.4 Physical and Environmental Features

2.4.1 River Systems and Wetlands

TThe Ankobra River is Nzema East's key water source but also a major flood risk. Heavy rains frequently cause overflow that floods low-lying communities, a problem worsened by wetland loss from farming, settlement expansion, and sand mining (Photo 2). In Sanwoma and Axim, river flooding often combines with coastal floods, creating compound hazards. Pollution from artisanal mining (galamsey) further degrades water quality. Without wetland protection and stricter mining control, flood risks will continue to escalate.

Photo 1: A dominant hydrological feature of Nzema East - River Ankobra
Source: George Mireku Duker, Ministry of Lands and Natural Resources (2023).

Photo 2. Ankobra River entering the sea at Ankobra community with seasonal flooding
Source: Boafo, YA (2025)

2.4.2 Forests and Vegetation Cover

Nzema East's original moist evergreen forests are now largely cleared, leaving scattered secondary patches and fast-declining mangroves. Deforestation for farming, fuelwood, salt production, and sand winning has increased soil erosion, reduced water retention, and weakened natural flood and coastal defenses. The loss of mangroves has made communities more exposed to tidal surges and erosion. With intensifying rainfall and rising seas, restoring forests and mangroves is essential for resilience.

2.4.3 Geology and Mineral Resources

Nzema East sits on mineral-rich Birimian and Tarkwaian formations, making mining—especially artisanal mining—a major livelihood but also a major source of risk. Unregulated galamsey has caused severe land degradation, deforestation, and Ankobra River pollution, reducing water quality and harming ecosystems. Exposed pits collect stagnant water that increases mosquito breeding, while degraded soils reduce farm productivity and blocked drainage worsens flooding during heavy rains. Without stronger regulation and reclamation, mining will continue to undermine the municipality's resilience.

2.4.4 Coastal and Marine Ecosystems

Nzema East's 72 km coastline is central to fishing, tourism, and cultural heritage, but it is also the municipality's most climate-exposed zone. Communities like Axim and Brawire face accelerating coastal erosion, tidal surges, and sea-level rise, which are destroying homes, landing sites, and key infrastructure (Adade, 2024). Sand mining and mangrove loss further weaken natural coastal defenses. With beaches shrinking and cultural sites at risk, the coastline remains Nzema East's most critical climate-risk frontier.

Photo 3: Canoes docked at the Axim Fishing Harbour in Nzema East District.
Source: Field Survey, 2025

2.4.5 Soils and Land Use

Nzema East's ferric acrisols and dysric fluvisols support cocoa, oil palm, rubber, and cassava, but these soils are increasingly degraded. Continuous farming, rainfall variability, and erosion have reduced fertility, while small-scale mining has left many areas infertile or contaminated. Intense rains and longer dry spells further worsen soil loss, forcing farmers to clear new lands and deepening environmental decline. If not addressed, soil degradation will weaken the municipality's agricultural base and increase food insecurity.

2.4.6 Key Environmental Risks and Stressors

Nzema East is exposed to several acute and chronic environmental risks, exacerbated by climate change and human-induced degradation. These include:

i. Coastal Erosion

- Shoreline retreat has displaced households, damaged roads and buildings, and reduced land available for development and livelihoods.
- Protective structures are limited, and natural buffers like mangroves are being lost.

ii. Saltwater Intrusion

- Encroachment of seawater into freshwater aquifers affects coastal wells and boreholes.
- Leads to poor water quality for drinking and irrigation, especially in low-lying areas.

iii. Flooding (Riverine and Flash Floods)

- Occurs during peak rainy seasons due to blocked drainage, impervious surfaces, and poor urban planning.

- Floods damage property, crops, schools, and health facilities, particularly in settlements near rivers.

iv. Bushfires and Deforestation

- Common during the dry Harmattan period, especially in farming zones.
- Leads to habitat loss, soil infertility, and reduced carbon sequestration capacity.

v. Environmental Pollution

- Artisanal mining, waste dumping, and agrochemical use are key sources of land and water pollution.
- Degradation of rivers and soils threatens biodiversity and public health.

vi. Biodiversity Loss

- Encroachment on forest reserves, mangrove stands, and wetlands is diminishing critical ecosystems.
- This undermines nature-based livelihoods and weakens ecosystem resilience.

vii. Land Degradation and Soil Erosion

- Driven by intensive farming, sand winning, and poor land-use practices.
- Erosion reduces farm yields, increases siltation of water bodies, and exacerbates flood risks.

2.5 Key Economic Activities

Nzema East Municipality is a dynamic and evolving area with a diverse economic structure. Its economy is primarily driven by agriculture, fishing, small-scale mining, trade, and tourism, with agriculture and fishing being the most significant sources of livelihood for the population. This chapter provides an in-depth analysis of the economic sectors in Nzema East, highlighting their interconnections, challenges, and the opportunities for growth that could transform the region's economic landscape.

Photo 4: Women fish traders at Axim Fishing Harbour in Nzema East District.

Source: Field photograph by enumerators (2025).

2.5.1 Agriculture: The Backbone of the Economy

Agriculture remains the backbone of Nzema East's economy, engaging over 65% of the active population, mainly through cocoa, food crops, fishing, and agro-processing. However, the sector has faced major setbacks—including the Cape St. Paul Wilt Disease, limited extension services, land degradation, and youth shifting into galamsey, sand winning, or out-migration—contributing to rising poverty. Cocoa (about 35,000 ha) is still central, supported by programs like PFJ, while crops such as oil palm and cassava offer diversification potential. Agriculture and fishing are closely linked, with income from one sustaining the other. Meanwhile, new sectors—mining, tourism, and services—are expanding, offering economic opportunities if backed by proper planning and skills development. Ongoing investments such as a new cocoa storage facility aim to strengthen value addition and improve farmers' income.

2.5.2 Fishing: A Vital Livelihood Sector

Photo 5: Women fish processors and traders at Axim Landing Site
Source: Field photograph by enumerators (2025).

Fishing is a major livelihood in Nzema East, with 13 landing sites and over 650 canoes, but the sector is increasingly threatened. Fish catches have declined due to illegal practices (light

fishing, dynamite, monofilament nets), leading to stock depletion and poor-quality fish. Coastal erosion, sea-level rise, and algae blooms further disrupt fishing activities. Strengthening regulation, promoting sustainable methods, and providing alternative livelihoods are essential. The new Axim fishing harbour is a key investment expected to improve storage, processing, and market access, boosting sector productivity.

Photo 6: Women and men engaged in fish trading at Axim Landing Site
Source: Field photograph by enumerators (2025).

2.5.3 Mining: Balancing Economic Benefits and Environmental Costs

Artisanal and small-scale mining (ASM) is a growing livelihood source in Nzema East, especially in communities like Akango, where many households depend on it for income. However, ASM also poses serious environmental risks, including deforestation, soil erosion, and water pollution, which threaten long-term sustainability. The Municipal Assembly is advocating stronger regulation to reduce these impacts while maintaining mining as a viable economic option. Moving toward sustainable mining practices—such as cleaner technologies, improved oversight, and training for miners—is essential to balance the economic gains of ASM with environmental protection.

2.5.4. Tourism: A Promising Sector with Untapped Potential

Nzema East is home to numerous scenic landscapes, historical sites, and cultural landmarks, which position the region as a promising destination for tourism. Notable attractions include

the UNESCO World Heritage Site of Nzulezu Stilt Village, Fort Anthonio (**Photo79**), and Axim Beach, which draw both local and international tourists. The tourism sector, if properly developed, has the potential to become a major source of revenue for the municipality. However, the growth of tourism in Nzema East is hindered by inadequate infrastructure, lack of effective marketing, and minimal private sector investment. To unlock the full potential of tourism, the municipality's development strategy emphasizes improvements in road networks, hospitality facilities, and promotional efforts. Strengthening public-private partnerships is seen as a key strategy to boost tourism and generate employment within the sector.

Photo 7: Fort St. Antonio, Axim (Nzema East District).

Built by the Portuguese in the 16th century and later occupied by the Dutch, the fort is one of Ghana's historic coastal castles with significant heritage and tourism potential. Its strategic coastal location offers opportunities for cultural tourism, education, and local economic development, while also serving as a reminder of the trans-Atlantic slave trade and the resilience of coastal communities.

2.5.5. Trade and Commercial Activities: Growth and Challenges

Trade in Nzema East is growing, with the Axim market serving as a major hub for cocoa, fish, and farm produce. However, poor roads, limited credit, and inadequate facilities hinder business expansion. Improving market infrastructure and financial access remains key.

Overall, the municipality's economy—driven by agriculture, fishing, and mining—has strong potential but is constrained by weak infrastructure and environmental pressures. Targeted investments in agro-processing, tourism, and sustainable mining can help diversify livelihoods and support long-term development.

2.6 Poverty and Inequality

Poverty and inequality remain critical challenges in Nzema East Municipality, shaping the district's vulnerability and adaptive capacity in the face of climate change. The 2021 Population and Housing Census (PHC) Multidimensional Poverty Fact Sheet provides a nuanced picture of poverty beyond income, by measuring deprivations across 13 indicators of human wellbeing, including education, health, housing, water, sanitation, and energy access. The findings reveal that poverty in Nzema East is widespread, intense, and structurally embedded, leaving large sections of the population ill-equipped to cope with and recover from climate-related shocks such as flooding, coastal erosion, and drought.

2.6.1 Incidence and Intensity of Poverty

The analysis shows that 38.2% of the population in Nzema East lives in multidimensional poverty, significantly higher than the national average of 29.9% and the Western Region's average of 27.8%. The average intensity of poverty — reflecting the proportion of deprivations experienced by poor households — is 43.0% in Nzema East. This means that nearly four in ten residents are poor, and when poor, they are deprived in almost half of the measured indicators.

The resulting Multidimensional Poverty Index (MPI) score of 0.165 places Nzema East among the most deprived districts in the country. The data highlight a poverty profile that is not only about income but also about deficits in basic services and social protection. Nzema East ranks 204th out of 261 districts in Ghana for the percentage of population living in multidimensionally poor households. Within the Western Region, it is placed 14th out of 14 districts, making it the poorest district in the region according to the MPI measure.

2.6.2 District Ranking

This ranking reflects a deep structural disadvantage. It indicates that Nzema East faces more acute and widespread deprivation than its regional counterparts, reducing its competitiveness for investment and limiting its social and economic resilience (Fig. 6). The district's weak performance underscores the urgent need for targeted poverty reduction and resilience-building programs.

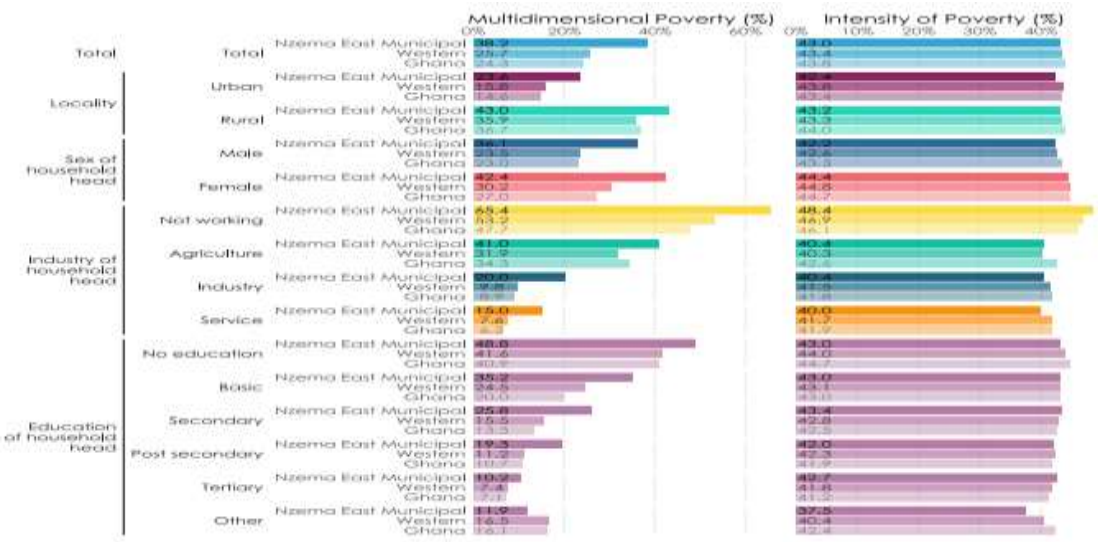

Figure 6: Nzema East District Ranking in Ghana and the Western Region (MPI, 2021)

2.6.3 Indicator Deprivations and Inequality Dimensions

A deeper look at the 13 indicators of multidimensional poverty (**Fig. 7)** shows where the most critical deprivations are concentrated:

- Sanitation: An alarming 91.8% of households lack improved toilet facilities, exposing residents to sanitation-related diseases that worsen during flooding and heavy rains.
- Housing: 69.9% of the population lives in deprived housing conditions, leaving them vulnerable to storm damage, flooding, and poor health outcomes.
- Health Insurance Coverage: 67.7% of households lack health insurance, limiting access to healthcare and constraining recovery from climate-induced illnesses such as malaria, cholera, and respiratory infections.
- Education and Information: While school enrolment has improved, deprivation in school attendance and access to ICT services remain high, limiting opportunities for youth and undermining long-term resilience.
- Water and Energy: Although some progress has been made in water access, many rural households still rely on unsafe sources. Dependence on firewood and charcoal for energy contributes to deforestation and exposes women and children to health risks.

For 11 out of the 13 MPI indicators, Nzema East records higher deprivation than the national averages, underlining the severity of its poverty profile. Gender and locality disparities are also evident:

- Rural communities bear the highest burden of poverty, with limited access to infrastructure, schools, and health services.
- Women and female-headed households are disproportionately affected, particularly due to gender roles in water collection, farming, and caregiving, which are highly sensitive to climate stressors.

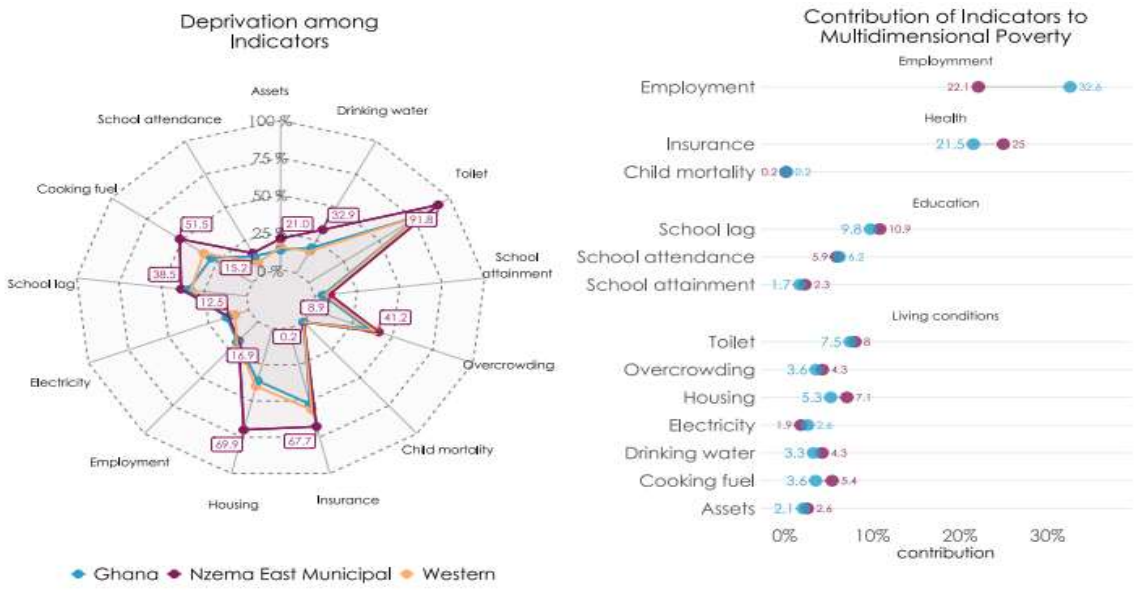

Figure 7*: Deprivation Levels across 13 Poverty Indicators in Nzema East, Regional, and National Comparisons (MPI, 2021)*

2.6.4 Poverty Hotspots and Spatial Inequality

The spatial poverty map (Fig. 8) reveals clear hotspots of multidimensional poverty, where both the incidence (percentage poor) and the absolute number of poor households are highest. These areas are typically rural, inland, and with poor road access, creating a cycle of deprivation and exclusion. Communities in these hotspots often overlap with climate-vulnerable zones, including flood-prone river valleys, erosion-affected coastal areas, and drought-sensitive inland farming communities. This spatial overlap of poverty and climate hazards significantly magnifies risks to lives and livelihoods.

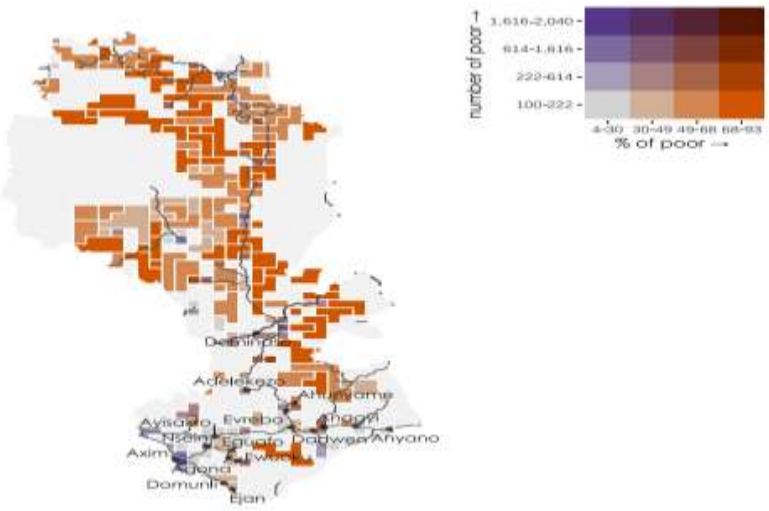

Figure 8 Spatial Distribution of Multidimensional Poverty in Nzema East (MPI, 2021)

The evidence clearly demonstrates that poverty and inequality are central drivers of vulnerability in Nzema East. High poverty incidence, severe deprivations in housing, sanitation, and health insurance, and wide gender and rural–urban disparities combine to reduce adaptive capacity at both household and institutional levels. The implications for climate resilience are profound:

- Poor housing increases susceptibility to flooding and storm damage.
- Lack of improved sanitation and health insurance weakens recovery from climate-related health crises.
- Poverty hotspots overlap with hazard-prone zones, amplifying risks.
- Rural and female-headed households face disproportionate burdens, reinforcing cycles of inequality.

CHAPTER THREE: ASSESSMENT OF VULNERABILITY TO CURRENT CLIMATE CHANGE

3.0 Introduction

This chapter assesses Nzema East Municipality's vulnerability to current climate change, drawing on both scientific evidence and community-based knowledge. It analyses observed climate trends, including changes in temperature and rainfall, and identifies the key drivers of vulnerability. The assessment examines the major hazards—such as flooding, sea-level rise, drought, heat stress, and storms—and their impacts on vulnerable locations, sectors, and population groups. Participatory hazard mapping, household surveys, and the Livelihood Vulnerability Index (LVI) provide a structured analysis of exposure, sensitivity, and adaptive capacity. Together, these tools offer a comprehensive picture of how climate risks are already affecting livelihoods, ecosystems, and development outcomes in Nzema East.

3.1 Analysis of the Observed Climate Changes

3.1.1. National Context

Ghana has experienced significant climatic shifts over the past century, marked by rising temperatures, shifting rainfall patterns, and an increase in the frequency and intensity of extreme weather events. These changes are not only altering ecological systems but also undermining socio-economic development, particularly in climate-sensitive sectors such as agriculture, water resources, health, and infrastructure (GMet, 2021; IPCC, 2022).

Ghana's climate is predominantly tropical, characterized by wet and dry seasons. However, rainfall distribution varies significantly between the northern and southern zones:

- Southern Ghana (including the coastal belt): experiences two rainy seasons — March–July (major) and September–November (minor).
- Northern Ghana: experiences a single prolonged rainy season from April–October.

Traditionally, Ghana's climate is analyzed across four distinct periods:

- December–February (DJF): dry season with minimal rainfall, higher temperatures.
- March–May (MAM): onset of first rains in the south, critical for early planting.
- June–August (JJA): peak of the rainy season across the country.
- September–November (SON): secondary rainy season in the south.

In recent decades, these seasonal cycles have become less predictable, with noticeable shifts in onset, duration, and intensity — leading to cascading impacts on agriculture, water management, and rural livelihoods.

3.1.1.1 Rainfall Characteristics

Rainfall patterns in Ghana have become increasingly variable and unpredictable over the past decades. The national climatology (1991–2020) indicates a bimodal rainfall regime in the south (major season: April–July; minor season: September–November) and a single prolonged rainy season in the north (April–October).

Analysis of rainfall trends from 1951–2020 shows significant fluctuations across decades. While mean monthly precipitation follows a distinct seasonal cycle, the intensity of rainfall events has increased in recent decades (**Figure 9**). This is reflected in more frequent extreme rainfall episodes during the peak rainy months (June–September), which have triggered destructive floods, particularly in southern urban areas such as Accra and Kumasi. Conversely, northern Ghana has recorded longer intra-seasonal dry spells, intensifying drought conditions.

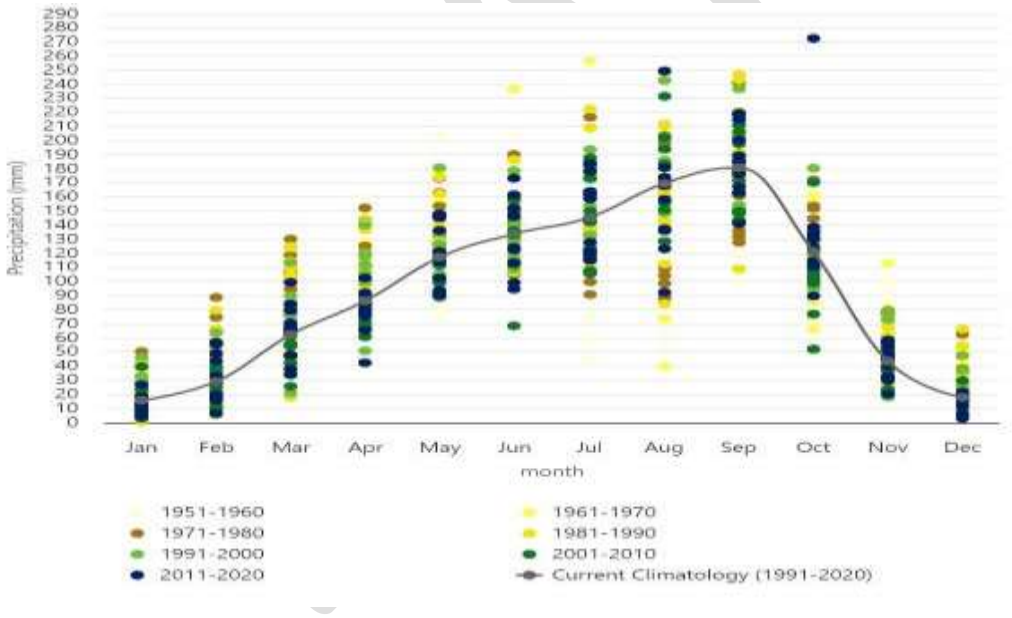

Figure 9: Observed monthly rainfall distribution (1951–2020), showing evolving seasonal cycle. It long-term rainfall variability across Ghana, with clear seasonality but significant fluctuations in intensity between decades. Recent periods show more concentrated peaks, reflecting the growing tendency for extreme rainfall events during the wettest month

Source: World Bank, 2025

3.1.1.2. Temperature Characteristics

Ghana has warmed steadily over the last century, with a national mean temperature increase of about 1.0–1.5°C since 1901. Warming has been particularly rapid since the 1970s, at a rate of 0.2–0.3°C per decade.

- Minimum Temperatures: Night-time temperatures have risen across all seasons, reducing cooling periods and increasing heat stress. For example, average dry season (DJF) minimums increased from ~20.5°C (1901–1930) to 21.5°C (1991–2020) (**Figure 10).**
- Maximum Temperatures: Daytime highs during the hottest months (March–April) now often exceed 35°C in the north and 33–34°C in the south. The number of very hot days (>35°C) has increased by 5–10 days per year in northern Ghana over the past two decades (**Figure 10**).
- Seasonal Mean Temperatures: Long-term data show a consistent upward shift across all seasons, with the most pronounced increases in the dry season (DJF) **(Figure 11).**

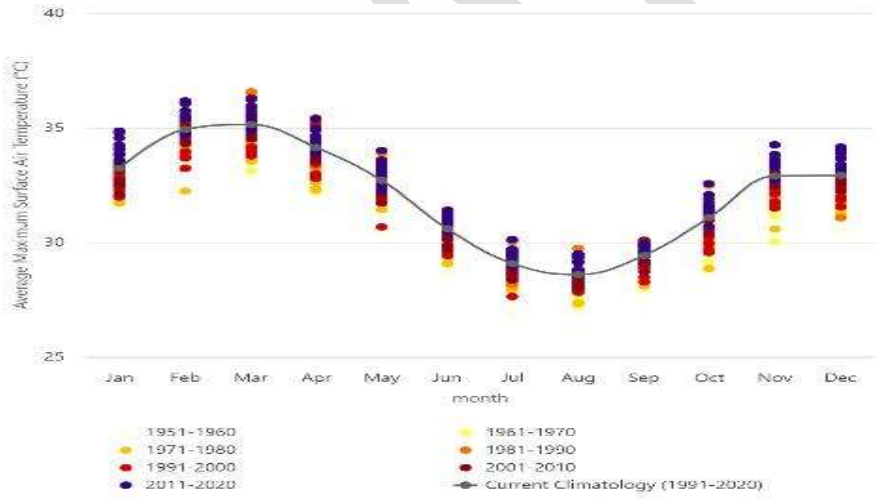

Figure 10: Observed seasonal minimum temperatures (1951–2020). Minimum temperatures reveal a steady upward trend, especially evident in recent decades. The shift toward warmer nights reduces natural cooling and signals a narrowing gap between day and night temperatures. Source: World Bank, 2025

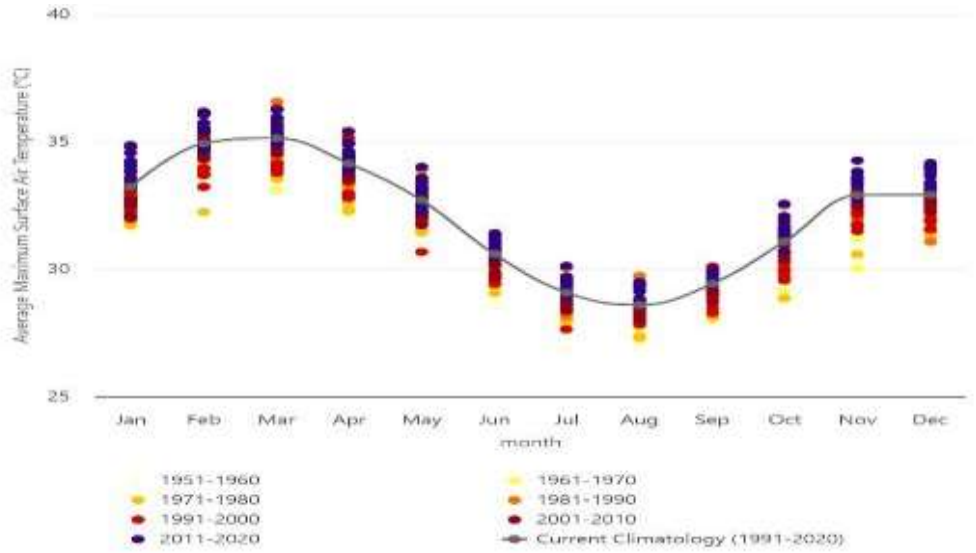

Figure 11: Observed seasonal maximum temperatures (1951–2020). Daytime highs demonstrate a consistent rise, with recent decades clustering at the upper range. This trend points to more frequent occurrences of very hot days, particularly around March–April.
Source: World Bank, 2025

3.1.1.3. Changing Rainfall and Temperature Seasonality

Nzema East experiences a bimodal rainfall regime, with a major season between April–July and a shorter minor season in September–October, separated by a brief dry spell in August. The long dry season spans November–March. Annual totals typically range between 1,500–1,800 mm, making the district one of the wetter parts of Ghana. However, recent records indicate that rainfall has become more erratic, with shifts in onset and cessation disrupting traditional farming calendars.

Temperature patterns are also changing. Daytime highs are rising, intensifying evapotranspiration and water stress, while night-time minimums remain unusually warm, reducing soil moisture retention. These combined effects increase crop stress, reduce yields, and heighten health risks.

Given Nzema East's low-lying coastal geography, these changes in rainfall and temperature seasonality interact with hazards such as coastal erosion, tidal flooding, and saltwater intrusion, placing added pressure on agriculture, fisheries, settlements, and critical ecosystems like mangrove swamps.

3.1.2. Observed Climate Changes in Nzema Municipal

3.1.2.1 Rainfall Characteristics

Rainfall in Nzema East Municipality follows a bimodal regime, with a major wet season from April to July and a minor season in September to October, separated by a short dry spell in August. The long dry season stretches from November to March and is often marked by prolonged dry spells and high evapotranspiration. Annual rainfall remains relatively high, averaging between 2,000 and 2,200 mm, but distribution has become increasingly erratic in recent decades (Figure 12).

Historical records highlight greater variability around the long-term mean, with rainfall deficits of 20–30% during El Niño years and surpluses of 15–25% during La Niña years. The frequency and intensity of heavy downpours during the peak rainy months (June–September) have increased, with single-month totals frequently surpassing 300 mm, thereby heightening the risk of localized flooding in low-lying and coastal communities (Figures 13 and 14). At the same time, rainfall during the dry season has shown a 5–10% decline, intensifying water scarcity for households and agriculture, particularly in inland farming settlements that rely on seasonal rains.

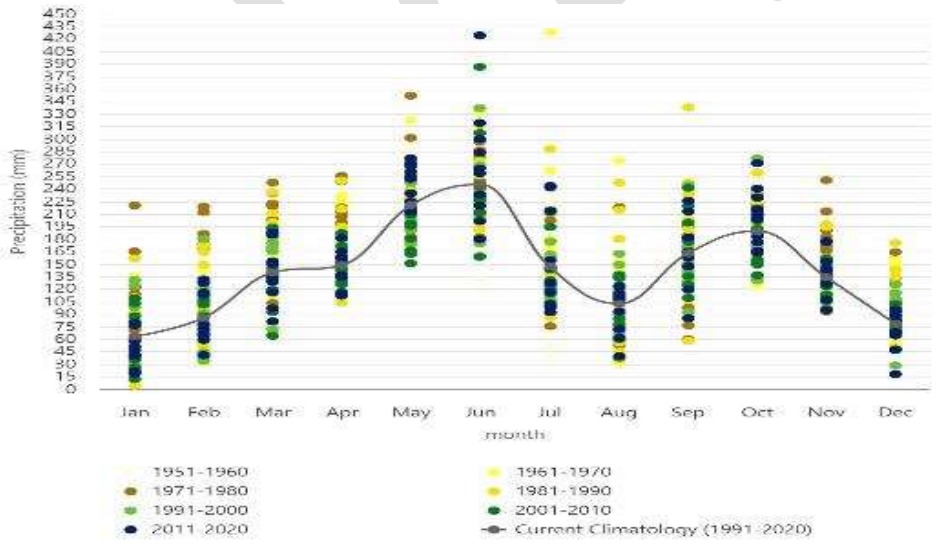

Figure 12. Monthly rainfall variability in the Western Region (1951–2020).

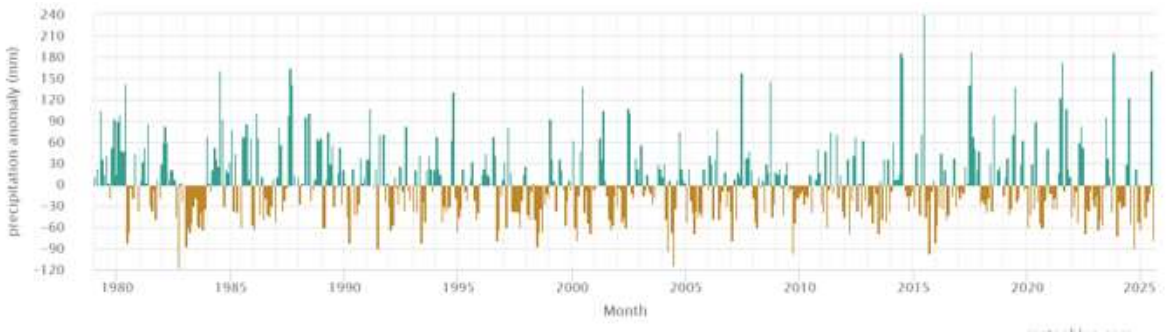

Figure 13. Precipitation anomalies for Nzema Municipal (Western Ghana) (1979–2025), showing increasing extremes with both severe deficits and surpluses.

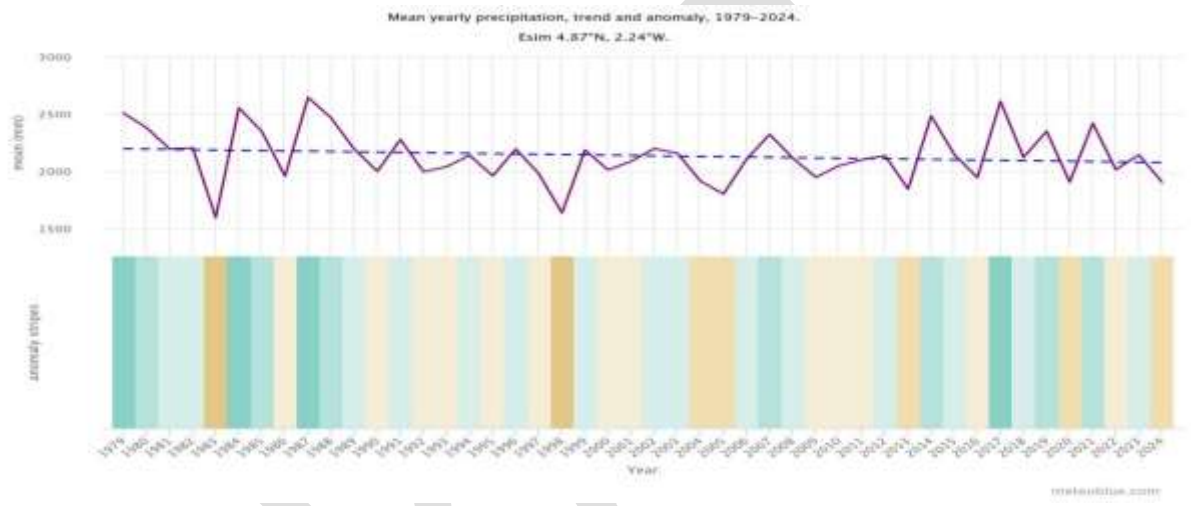

Figure 14 Mean Yearly Precipitation of NEMA (Source: meteoblue's History & Climate data (1979-2024)

Source: Meteoblue, 2025.

3.1.2.2 Temperature Characteristics

Temperature records (Figure 15 and Figure 16) for the Western Region (1951–2020) show a consistent rise in both maximum and minimum surface air temperatures, with recent decades markedly warmer than earlier periods. Nzema-specific data (1979–2024) confirms this trajectory, with mean annual temperatures increasing by about **2°C** to an average of **27°C**, daily highs of **28–32°C**, and lows of **22–25°C**. The warmest months are February–March, and the coolest are July–August (Figure 17).

As illustrated in **Figure 18**, the data demonstrates a steady long-term warming trend. Minimum temperatures are rising faster than maximums, reducing the diurnal range. These shifts heighten

heat stress, threaten **agricultural and fisheries productivity**, place additional strain on **household cooling and water use**, and intensify **health risks** such as malaria and meningitis.

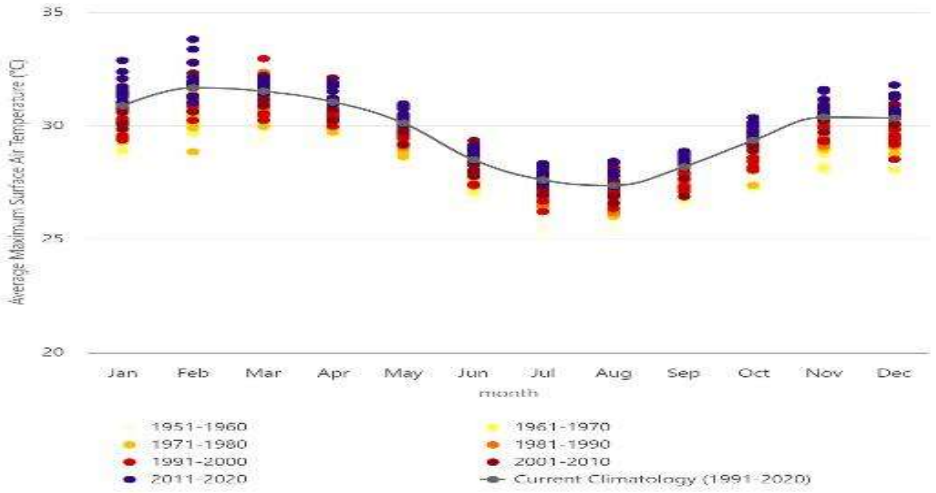

Figure 15: Maximum temperature trends in Western Region (1951–2020).

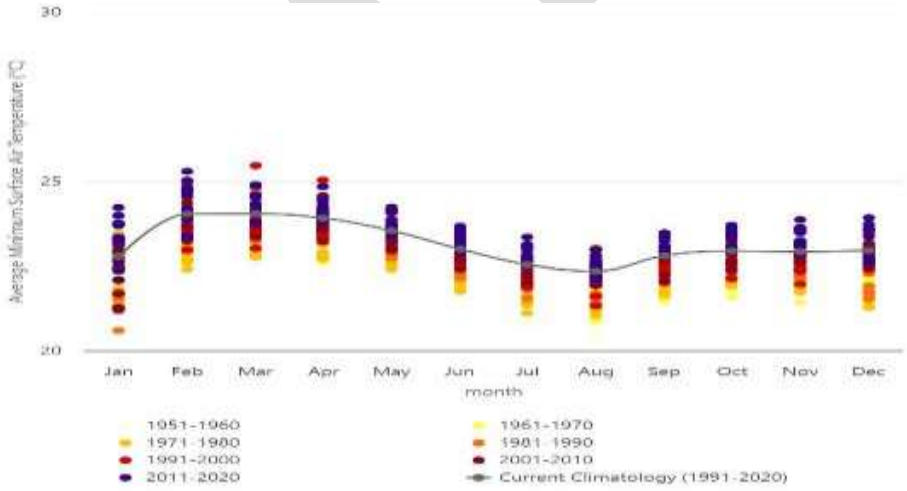

Figure 16: Minimum temperature trends in Western Region (1951–2020).
Source: World Bank, 2025

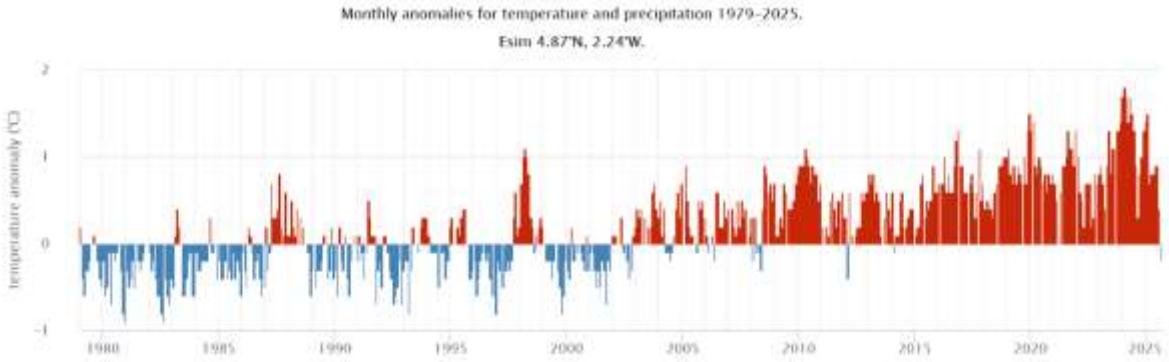

Figure 17: Temperature anomalies for Nzema (Western Ghana) (1979–2025), showing sharp warming since the early 2000s.
Source: World Bank, 2025

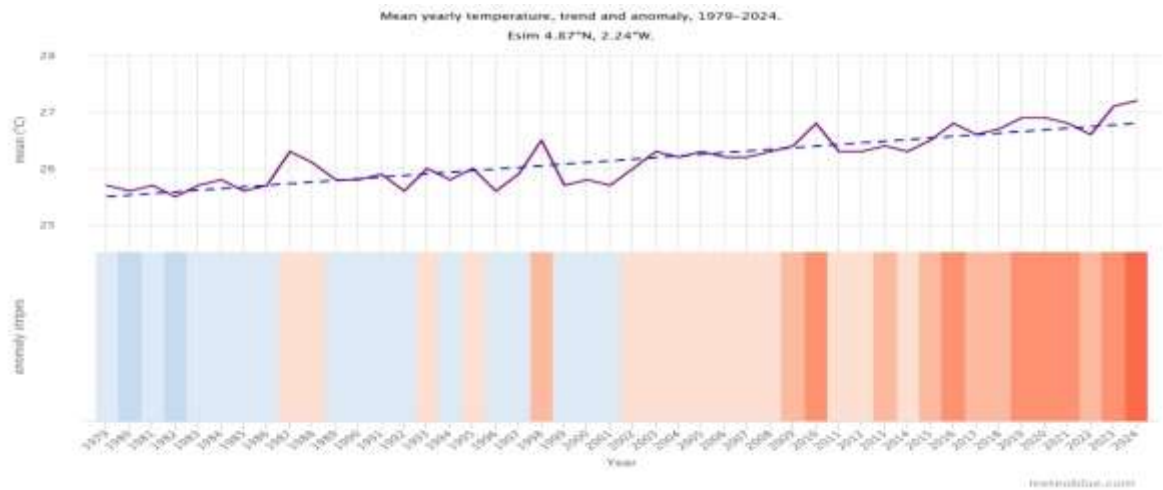

Figure 18 Mean Yearly Temperature for Nzema East (1979-2024)
Source: meteoblue.com

3.1.3 District Seasonal Change Calendar

The seasonal calendar for Nzema East (Table 2) shows a predictable cycle of climate risks linked to the major rains (Apr–Jul), minor rains (Sep–Nov), the Harmattan dry season (Dec–Feb), and the short August dry spell. Harmattan months bring water scarcity, heat stress, bushfires, and food insecurity, while the rainy seasons trigger flooding, coastal erosion, storms, and spikes in malaria and cholera. The brief August dry spell adds renewed water stress during the agricultural lean period. Overall, communities face recurring bushfires, floods, coastal hazards, and health risks at specific times of year, creating clear entry points for timed adaptation measures such as bushfire prevention, dry-season water management, and pre-rainy-season health preparedness.

Table 2: Seasonal Calendar for Nzema East Municipality

Activity / Hazard	Jan ○	Feb ○	Mar	Apr 🌧	May 🌧	Jun 🌧	Jul 🌧	Aug ○	Sep 🌧	Oct 🌧	Nov 🌧	Dec ○
Rainfall / Climate	Dry	Dry	Onset	Peak rains	Heavy rains	Heavy rains	Heavy rains taper	Short dry spell	Minor rains onset	Peak minor rains	Rains taper	Dry
Key Hazards	Bushfires, water scarcity	Heat stress, water shortage	Local flooding, storms	Flooding, erosion	Flooding, erosion	Flooding, crop loss	Floods, erosion	Drought, water stress	Floods, disease outbreaks	Floods, cholera	Storms, residual floods	Harmattan, salt intrusion

Farming	Land prep	Early clearing, yam/cassava	Major season planting	Planting continues	Weeding, spraying	Weeding, maintenance	First harvest (maize, vegetables)	Harvest early crops	Minor season planting	Crop growth, vegetables	Minor harvest, cocoa season	Cocoa harvest, land prep
Fishing	Peak season (calm seas)	Active fishing	Strong but storms	Low fishing (rough seas)	Very low fishing	Lull (stormy seas)	Recovery begins	Moderate fishing	Disrupted (storm surges)	Poor (rough seas)	Improves (calm seas)	Peak fishing, bumper landings
Other Livelihoods / Notes	Petty trade, mining	Food insecurity risks rise	Palm tapping, charcoal	Malaria risk	Rural roads inaccessible	School disruption	Market disruption	Household food shortages	Sanitation issues rise	Market access difficult	Cocoa trade peak	Festivals, tourism season
Health Impacts	Respiratory illness (Harmattan)	Heat stress, meningitis	Diarrhea outbreaks	High malaria cases	Cholera, malaria	Malaria peak	Malaria, cholera	Malnutrition risks	Cholera, dysentery	Cholera, diarrhea	Respiratory infections	Respiratory illness (dust, Harmattan)

3.2 Qualitative Assessment of Vulnerability to Current Climate Change

3.2.1 Extreme Events in Nzema East Municipality

Nzema East Municipality has experienced recurrent climate- and weather-related extreme events over the past decades (Table 3). Its low-lying coastal location, coupled with rapid population growth, deforestation, unregulated mining, and poor drainage systems, has heightened its vulnerability to hazards such as flooding, coastal erosion, droughts, and bushfires. These events have disrupted livelihoods, displaced communities, and caused significant damage to infrastructure, agricultural lands, and ecosystems. Flooding is the most frequent and damaging hazard, occurring almost annually during the peak rainy seasons, while coastal erosion continues to threaten fishing communities and critical infrastructure along the shoreline. Prolonged dry spells and seasonal droughts compound water scarcity and exacerbate public health risks. Meanwhile, bushfires during the harmattan season pose a growing threat to forests and farmlands. **Table 3** presents a consolidated record of historical extreme events in Nzema East Municipality, combining documented evidence from national and international reports with community-based accounts from participatory workshops. This provides a baseline understanding of the climate risks that shape local vulnerability profiles.

Table 3: Extreme events recorded in Nzema East

Date	Hazard Type	Community / Locality	Impacts	Source
~June 2023	Flooding / torrential rains	Several communities (105 persons evacuated)	Severe food & water shortages, building collapse, many buildings affected; displaced persons	GhanaWeb
27 June 2023	Flooding (River Ankobra overflow)	Adelekazo village	Village submerged; houses destroyed; roads & bridges affected; residents stranded without shelter or food	ModernGhana

Early July 2023	Flooding / heavy rains	10 communities in Nzema East (and others, ~21 overall)	Homes collapsed and flooded; over ~1,500 victims in three communities; ~4,000+ potentially affected across many communities; damage to property & possessions; people displaced	MyJoyOnline
21 June 2022	Flooding	Communities in Nzema East	Property damage, displacement; municipal assembly responded with assistance	Ghanaian Times
23 May 2022	Flooding (after heavy downpour)	Akosonu (near Gwira Dominase)	Homes submerged; many rendered homeless; property damage; concerns of building collapse; destroyed infrastructure like roads, etc.	GBC Ghana Online
June 2023	Flooding	Bamiankor	Homes and streets inundated after heavy downpour; residents forced to wade through floodwaters; household property damaged.	Ghana Web, 2023
June 2023	Flooding	ANzema East Eshiem	Access roads and bridges submerged; communities temporarily cut off; movement of people and goods severely disrupted.	Soiree News, 2023
June 2024	Flooding	Bokoro	Localized flooding affected homes and road access; residents called for urgent municipal response to drainage and infrastructure challenges.	Local Ghana media

3.2.2 Assessment of Drivers of Vulnerability in the District

Understanding the drivers of vulnerability (**Fig. 19**) is crucial in assessing the climate risk profile of Nzema East Municipality. These drivers are not singular or isolated; rather, they intersect across environmental degradation, socio-economic inequalities, governance weaknesses, infrastructure limitations, and demographic pressures. Each of these dimensions contributes to the heightened exposure and reduced capacity of the municipality to cope with and adapt to climate change. Below is a comprehensive analysis of the principal drivers of vulnerability in Nzema East, presented in an integrated, explanatory format.

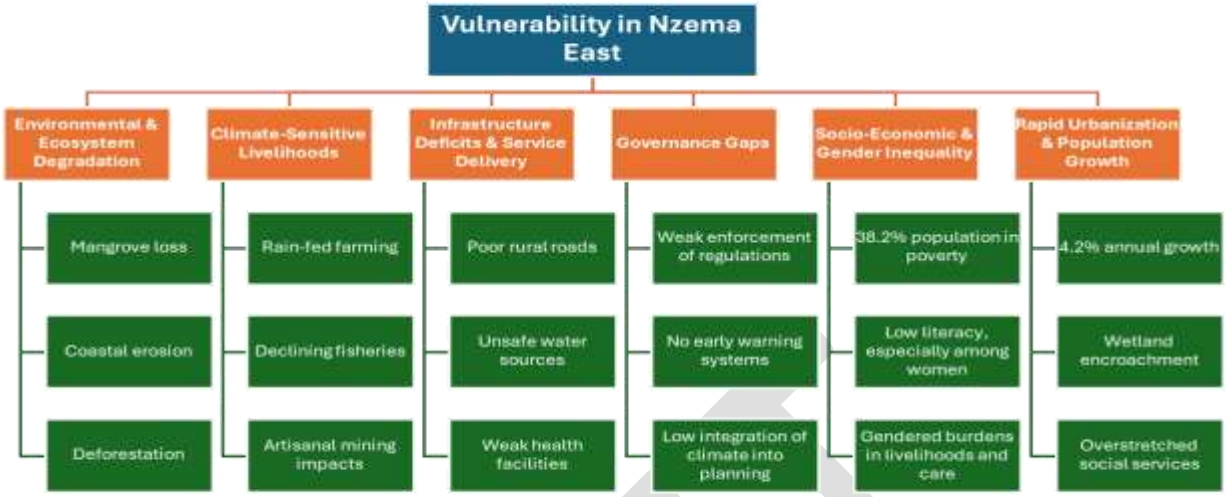

Figure 19: Drivers of vulnerability in Nzema Municipality

3.2.2. 1. Environmental and Ecosystem Degradation

One of the foremost drivers of vulnerability in Nzema East is degradation of natural ecosystems, especially in coastal and riparian areas. The municipality is highly exposed to coastal erosion, a phenomenon intensified by rising sea levels and destructive human activities such as sand winning, mangrove harvesting, and unregulated construction. Settlements such as Axim, Brawire, and Domunli are already losing habitable land to the sea, while essential infrastructure such as roads and fish landing sites are increasingly threatened by storm surges and shoreline retreat. The loss of mangroves, which act as natural barriers to coastal hazards, further amplifies the risks of flooding and erosion.

Additionally, deforestation and land cover loss in inland areas have weakened the soil structure, contributing to landslides, flash flooding, and the silting of rivers. Activities such as illegal logging, bush burning, and uncontrolled agricultural expansion are degrading natural resources at an unsustainable rate. The Ankobra River Basin, a critical ecological and economic zone, suffers from pollution due to illegal mining, threatening water quality and ecosystem health. These environmental pressures reduce the municipality's ability to withstand climate shocks and impede natural regeneration processes that would otherwise support resilience.

3.2.2.2. Dependence on Climate-Sensitive Livelihoods

A significant portion of Nzema East's population relies on climate-sensitive sectors such as agriculture, fishing, and artisanal mining for their livelihoods. This reliance renders the local economy highly vulnerable to climatic fluctuations. Farming activities are mostly rain-fed, and climate variability—manifested through erratic rainfall patterns, prolonged dry spells, and extreme rainfall events—directly affects agricultural yields. Staple and cash crops such as cocoa, cassava, and oil palm are especially vulnerable to shifting rainfall regimes and soil degradation caused by erosion and saltwater intrusion.

Similarly, the fisheries sector, vital to the economy of coastal communities like Axim, faces multiple threats. Changes in ocean temperature, destruction of breeding grounds, and illegal fishing practices have led to declining fish stocks. For women who dominate the fish processing and trade sectors, reduced availability of fish translates to income loss and food insecurity. The collapse of these livelihood systems increases socio-economic vulnerability and limits local adaptive capacity.

Small-scale and illegal mining, while providing economic opportunities for some, contributes to long-term vulnerability. Mining degrades land, contaminates water sources with hazardous chemicals like mercury and cyanide, and increases susceptibility to floods and landslides. The economic benefits are often short-term and are outweighed by environmental and public health costs, which disproportionately affect poor and marginalized communities.

3.2.2.3. Infrastructure Deficits and Service Delivery Constraints

Nzema East suffers from widespread infrastructure deficits, which significantly limit the municipality's resilience to climate change. Roads—especially feeder and rural access roads—are poorly maintained and often become impassable during heavy rains. This disrupts access to markets, healthcare, and emergency services, particularly in flood-prone areas. The absence of climate-resilient infrastructure compounds vulnerability by prolonging recovery after climate-related disasters.

In terms of water and sanitation, many households rely on unsafe water sources, including surface water and shallow wells. These are highly susceptible to pollution, especially in mining areas, and are increasingly compromised by saltwater intrusion in coastal zones. Water scarcity

during dry spells increases the burden on women and girls, who often travel long distances in search of water, further exacerbating gendered vulnerability.

The health sector is also underdeveloped, with limited medical facilities, understaffed clinics, and poor climate-proofing of buildings. Outbreaks of climate-sensitive diseases such as malaria, cholera, and heat-related illnesses are becoming more frequent, yet health systems lack the capacity for timely and widespread response. Overall, weak infrastructure creates bottlenecks in service delivery, undermining public health, mobility, education, and economic resilience.

3.2.2.4. Weak Institutional Capacity and Governance Gaps

Governance challenges in Nzema East also contribute significantly to climate vulnerability. Although the Medium-Term Development Plan (MTDP) acknowledges climate risks, the integration of climate adaptation into actual planning and budgeting processes remains limited. Municipal departments often lack technical capacity, climate data, and analytical tools necessary for risk-informed decision-making.

There is also a lack of effective enforcement of environmental regulations. Activities such as sand winning, mangrove harvesting, and construction in wetlands continue largely unchecked, due to weak monitoring, low compliance, and political interference. Furthermore, local planning systems do not fully align with community realities, leading to unsustainable land use and settlement expansion into high-risk areas.

Additionally, early warning systems and disaster preparedness mechanisms are virtually non-existent. The municipality lacks structured communication protocols for alerting communities about impending floods or storms, and emergency response teams are poorly resourced and rarely trained. The absence of a coherent disaster risk management framework limits the municipality's ability to respond rapidly and effectively to climate emergencies.

3.2.2.5. Socio-Economic and Gender-Based Inequality

The social structure of Nzema East is characterized by widespread poverty, with over 30% of residents living below the poverty line. Poor households are less able to invest in resilient housing, diversify income sources, or access financial instruments such as insurance. Many live in flood-prone or environmentally degraded areas due to low land costs, increasing their

physical exposure to hazards. Literacy and education levels, particularly among rural women, remain low. This limits awareness of climate risks reduces uptake of early warnings and impedes the dissemination of climate-resilient practices. In turn, this restricts people's ability to adapt and recover from climatic shocks.

Gender dynamics further complicate the vulnerability landscape. Women in Nzema East often engage in low-income, informal jobs such as fish smoking, petty trading, and subsistence farming. They have limited access to land, capital, decision-making platforms, and extension services. During periods of climate stress, such as drought or flood, women's care burdens increase, and they face higher risks of food insecurity, displacement, and health complications. The underrepresentation of women in leadership and planning structures means that their specific needs and knowledge are often overlooked in adaptation programming.

3.2.2.6. Rapid Urbanization and Population Growth

Nzema East's population has expanded rapidly, growing from approximately 60,000 in 2010 to over 94,000 in 2021—a growth rate of 4.2% annually. This growth places pressure on land, water, and social services. Unregulated urbanization is leading to the expansion of settlements into floodplains, wetlands, and ecologically sensitive areas. As more people migrate to towns such as Axim in search of livelihoods, the municipality faces increasing demand for housing, sanitation, electricity, and transportation. Without proper urban planning, such growth increases the risk of heat stress, urban flooding, and environmental degradation. Population growth also heightens demand for food and water, further straining climate-sensitive sectors like agriculture and fisheries.

3.2.3.1 Hazards and associated impacts on vulnerable sectors

The vulnerability of sectors in Nzema East is shaped by their dependence on climate-sensitive resources, weak adaptive capacity, and entrenched socio-economic inequalities. Hazard mapping, stakeholder consultations, and community validation workshops highlighted seven sectors where climate impacts are already undermining resilience and threatening development gains: agriculture and food security, fisheries and coastal livelihoods, water security and sanitation, community health, infrastructure and human settlements, gender and social inclusion, and natural resources and ecosystems.

Agriculture and Food Security

Agriculture in Nzema East is dominated by smallholder rain-fed farming, making it highly sensitive to rainfall variability and heat stress. In Bokoro, Gagredo, and Prangro (Severity 4), recurrent floods were reported to wash away crops, erode fertile topsoil, and damage farm infrastructure. Farmers further emphasized how prolonged dry spells and heat stress wilt seedlings and reduce livestock survival, particularly poultry and aquaculture. These hazards disrupt planting calendars, lower productivity, and discourage youth from farming, thereby increasing food insecurity and deepening rural poverty. Without significant adaptation, climate hazards threaten to erode the viability of agriculture as a livelihood and push households into chronic vulnerability.

Fisheries and Coastal Livelihoods

Fisheries remain the backbone of Nzema East's coastal economy but face mounting risks from sea-level rise, coastal erosion, and flooding. In Axim, Domunli, and Brewire (Severity 5), mapping exercises highlighted recurrent flooding of landing sites, destruction of sheds, and displacement of households. Canoe capsizing at sea has resulted in loss of life, while saltwater intrusion disrupts fish processing and storage. Women fish processors, who depend heavily on functional coastal infrastructure, are particularly affected as they lose access to safe drying and smoking spaces. The cumulative impacts threaten food security, heighten poverty, and accelerate migration pressures inland.

Water Security and Sanitation

Water systems in Nzema East are acutely affected by drought, flooding, and saline intrusion. In Ahunyame (Severity 5), floodwaters have repeatedly destroyed homes and contaminated water infrastructure, forcing discussions around relocation. Communities across the municipality reported seasonal shortages, with boreholes drying during the harmattan and saline intrusion undermining groundwater quality. These hazards directly compromise household water access and sanitation, increasing the incidence of cholera, diarrhea, and skin infections. Weak enforcement of riverbank by-laws and limited investments from the Ghana Water Company exacerbate risks, leaving many households dependent on unsafe or costly alternatives.

Community Health

The health sector is uniquely exposed to compounding hazards. In Raniangor and Adaklu (Severity 4), heavy rainfall and flooding cut off access to clinics, damaged facilities, and

triggered malaria outbreaks. In Apewosika (Severity 3), rising heat exacerbates respiratory illnesses and skin infections, particularly among children and the elderly. Stagnant floodwaters create breeding grounds for mosquitoes, intensifying malaria transmission, while weak WASH infrastructure facilitates outbreaks of waterborne diseases. Limited climate-resilient health facilities and overstretched municipal health services reduce the ability to respond, leaving vulnerable groups — especially children, women, and persons with disabilities — disproportionately exposed.

Infrastructure and Human Settlements

Settlements in Nzema East face escalating risks from flooding, erosion, and storms. In Apewosika and Domunli (Severity 5), households and public infrastructure have repeatedly been displaced or destroyed, while in Axim (Severity 4), poor drainage amplifies flooding during heavy rains, disrupting markets, transport, and livelihoods. Coastal roads, electricity poles, and schools are especially at risk, compounding recovery costs after each event. Without stronger enforcement of planning regulations and investment in resilient infrastructure, these hazards will continue to displace households and undermine socio-economic development.

Gender and Social Inclusion

Climate hazards intersect with social inequalities, amplifying the vulnerabilities of women, youth, and persons with disabilities (PWDs). In Axim and Ewuku (Severity 4), floods have inundated markets and fish-smoking sites, disproportionately affecting women traders and processors who rely on these facilities for income. Youth report that declining agricultural and fisheries prospects are pushing them toward unsafe migration pathways. PWDs often remain excluded from evacuation planning and disaster response, leaving them exposed to heightened risks during floods and storms. Climate stress thus compounds gendered and social burdens, making inclusive adaptation critical to resilience.

Natural Resources and Ecosystems

Nzema East's ecosystems — mangroves, wetlands, and forest patches — provide critical buffers and livelihood resources, yet they are under severe pressure. In Brewire and Ahunyame (Severity 4), communities reported that mangrove cutting and sand mining accelerate coastal erosion and flooding. Inland deforestation for farming and charcoal production reduces biodiversity and increases vulnerability to bushfires. The degradation of ecosystems removes natural defenses against hazards, threatens fish breeding grounds, and erodes opportunities for

eco-tourism. If unaddressed, the collapse of ecosystems will amplify vulnerability while undermining long-term development potential.

Table 4: Participatory analysis of sectoral climate hazards

Sector	Key Hazards (from Nzema maps & notes)	Direct Impacts	Indirect Impacts	Current Adaptation Responses	Proposed Interventions	Example Locations (from Nzema sources)
Agriculture & Food Security	Irregular/declining rainfall intensity; flash floods; heat stress; windstorms	Crop losses; topsoil erosion; damaged farm infrastructure; seedling wilting; occasional livestock/poultry loss	Income decline; food insecurity; youth out-migration; higher input/transport costs after road washouts	Indigenous planting calendars; ad-hoc bunds/ridges; small trials of improved seed; limited extension reach	Scale CSA (drought/heat-tolerant crops, mulching, cover crops, contouring); small-scale irrigation & rainwater harvesting; post-harvest storage & drying; integrated pest mgmt; last-mile climate advisories	Bokoro, Gagredo, Prangro; inland/peri-urban belts incl. Bamiangor, Agyan; Avrebo, New Esuawua
Fisheries & Coastal Livelihoods	Sea-level rise; coastal erosion; tidal flooding; storms	Loss of landing sites/sheds; gear/canoe damage; displacement; saltwater intrusion at processing sites	Fewer fishing days; lower incomes; higher post-harvest losses; pressure to relocate; rising debt	Ad-hoc repairs to sheds; limited mangrove planting; community discussions on relocation	Hard + nature-based defenses (sea walls/groynes where justified; dune/mangrove restoration); safer raised processing platforms & efficient kilns; cooperative cold storage; storm early-warning; livelihood diversification & aquaculture pilots	Axim, Brawire/Brewire, Domunli, Apewosika; Ankobra fringe; Akonu
Water Security & Sanitation	Drought/seasonal scarcity; flood contamination; saline intrusion; riverbank erosion	Drying wells/boreholes; unsafe sources; latrine overflow during floods	Cholera/diarrhea spikes; intra-community conflicts over water; time burden on women/girls	Community boreholes; sachet water reliance; basic water committees in a few areas	Household/institutional rainwater harvesting; community reservoirs/small dams; watershed protection (riparian buffers, reforestation); low-cost household treatment; enforce by-laws on riverbank farming & waste	Ahunyame (flooding), Upper Axim (flooding), Galaway (dry-season stress), Avrebo
Community Health	Flooding; heat stress; vector-borne & water-borne disease surges after extremes	Malaria peaks; diarrheal disease; skin/respiratory issues during heat; damaged/isolated facilities	Lost work/school days; higher household health costs; exclusion of elderly/PWDs in emergencies	Malaria control; NADMO relief; basic community health volunteers	Climate-resilient siting/retrofit of CHPS/clinics (elevated foundations, ventilation); WASH upgrades; flood/heat early-warning with risk comms; surge-response supplies; targeted outreach to vulnerable groups	Raniangor (flood access issues), Apewosika (heat stress); Ahunyame (flooding)

Infrastructure & Human Settlements	Coastal erosion & tidal flooding; intense rainfall/flash floods; storms	Housing damage; road/culvert failure; drainage blockage/overflow ; market/school disruption; recurrent displacement	Rising recovery costs; informal expansion into risky areas; service delivery interruptions	Periodic road fixes; emergency relief after events	Enforce climate-resilient codes; upgrade urban drainage (Axim/Brawire); climate-proof schools/markets/clinics; managed relocation planning for highest-risk coastal pockets; green/blue infrastructure (urban trees, wetlands)	Axim (drainage), Brawire/Brewire, Domunli, Upper Axim, Bokoro
Gender & Social Inclusion	Cross-sector hazards amplifying burdens in water, farming, fisheries, health	Increased unpaid care & water collection; unsafe/low platforms for fish processing; mobility barriers for PWDs; protection risks in displacement	Widening gender gaps; reduced participation in decisions; youth disenfranchisement/ migration; deepened poverty for female-headed households	Women's groups/coops; informal savings (susu)	Gender-responsive planning & budgeting; credit/land/extension access for women; safe raised processing hubs; PWD-inclusive shelters/alerts; youth skills for CSA/green jobs	Coastal processors (Axim/Brawire/Apewosika); inland water collectors (Avrebo, New Esuawua); multi-hazard zones (Domunli)
Natural Resources & Ecosystems	Mangrove cutting; sand winning; deforestation; bushfires; siltation from mining	Mangrove/forest loss; degraded wetlands; habitat decline	Reduced fish nurseries; weaker natural flood buffers; biodiversity & tourism losses	Sporadic NGO tree/mangrove planting; limited enforcement	Community co-management of mangroves/wetlands (Ankobra/Sanwoma fringe); riparian buffers; reforestation/agroforestry; strict by-law enforcement with alternative livelihoods support	Sanwoma mangroves & Ankobra estuary belt; coastal dune systems; inland riparian zones

3.2.3.2 Hazards and associated impacts on vulnerable groups

The vulnerability of specific social groups in Nzema East is closely tied to their differentiated roles, access to resources, and social status. While climate hazards affect all residents, their impacts are not evenly distributed. Women, men, children, the elderly, youth, PWDs, and migrant/settler communities each experience climate risks in distinct ways, shaped by livelihood dependence, health status, mobility, and access to decision-making processes.

Participatory consultations revealed that women face heightened burdens in caregiving, food production, and fish processing, while men often bear the brunt of asset losses in farming and fishing. Children are exposed through school closures, malnutrition, and disease outbreaks, whereas elderly residents and PWDs struggle with evacuation, access to services, and mobility constraints. Youth are particularly affected by the erosion of livelihood opportunities, driving out-migration and economic precarity. Migrant and settler communities, often residing in marginal or hazard-prone areas, also face disproportionate risks.

The table 6 below synthesizes these differentiated vulnerabilities, showing how hazards intersect with social inequality to intensify risks across groups.

***Table 5**: Hazards and Impacts on Vulnerable Groups in Nzema East*

Hazard	Women	Men	Children	Elderly	Youth	PWDs	Migrant/Settler Communities
Flooding	Loss of trading goods and fish-processing sites; increased caregiving during displacement	Destruction of farms and fishing gear; reconstruction burdens	School closures and heightened exposure to malaria/diarrheal outbreaks	Mobility challenges in evacuation; dependence on others for relocation	Loss of farming/fishing jobs; heightened migration pressures	Often excluded from evacuation planning; limited access to safe shelters	High exposure when settling in low-lying flood-prone zones; frequent loss of assets
Coastal Erosion	Reduced fish-processing space; increased insecurity of trading activities	Loss of canoes and landing sites; damage to housing	Displacement from schools and homes in shoreline communities	Loss of ancestral homesteads and cultural lands	Shrinking opportunities in coastal livelihoods	Housing destruction and inaccessible resettlement options	Informal housing along eroding coastlines faces repeated destruction
Irregular Rainfall / Drought	Food insecurity; added burden of water collection	Crop failure in cocoa/coconut farms; rising indebtedness	Malnutrition risk; children withdrawn from school to assist with water collection	Reliance on outdated farming practices undermined	Disrupted farming livelihoods; rising youth outmigration	Dependency on caregivers increases when water and food are scarce	Settlers on marginal lands face greater losses due to limited irrigation access
Heavy Rainfall / Storms	Damage to market stalls and trading goods	Loss of homes, farms, and community facilities	Injuries from debris; disrupted schooling	Reduced ability to rebuild; reliance on extended families	Financial losses for young traders and farmers; instability of new ventures	Excluded from evacuation and shelter systems	Poorer-quality housing increases destruction and losses

Heat Stress	Heat-related illnesses (skin rashes reported by women); exhaustion from water collection and fish processing	Occupational stress during farming and fishing at sea	Absenteeism from overheated classrooms; dehydration	Exacerbation of chronic health conditions	Reduced productivity and rising unemployment	Limited awareness of heat risk reduction strategies	Poor housing in marginal areas worsens exposure to heat
Waterborne Diseases	Increased caregiving for sick family members; reduced time for income generation	Loss of labour time due to illness	High exposure to cholera, diarrhoea, malaria during outbreaks	Elevated mortality risks; limited mobility to access clinics	Lost workdays and training opportunities	Higher risk due to exclusion from WASH facilities	Settlers often rely on unsafe water sources, increasing disease exposure

3.3 Vulnerability Index Assessment for Nzema East Municipality

3.3.1 Approach and Methods

3.3.1.1 Study Design

The CRVA in Nzema East Municipality was guided by Ghana's NAP framework and the IPCC AR5/AR6 conceptualization of vulnerability, which defines risk as the interaction between hazards, exposure, sensitivity, and adaptive capacity.

The objective of the assessment was to generate empirical, municipality-specific evidence to support climate adaptation planning, mainstream climate risk into local development frameworks, and identify sectoral and gender-responsive adaptation priorities. Unlike other studies that included participatory methods such as interviews and focus group discussions, this CRVA relied exclusively on structured household surveys and secondary data sources to ensure consistency and replicability.

Sampling Framework

A stratified sampling approach was applied to reflect the diversity of Nzema East's ecological and socio-economic settings. Communities were selected purposively from each zonal council, ensuring that both urbanized centres and relatively deprived rural/peri-urban communities were represented. In each zonal council:

1. The zonal capital was selected to reflect areas with relatively better infrastructure, access to services, and economic opportunities.
2. A smaller rural or peri-urban community was selected to capture the vulnerabilities of households more directly dependent on natural resources and climate-sensitive livelihoods.

In total, six communities across three zonal councils were surveyed, yielding 265 household surveys (Table 7).

Table 6: Nzema East Sampling Framework

Zonal Council	Community 1 (Capital)	Households Surveyed	Community 2 (Smaller Town)	Households Surveyed	Total Households
Nsein Zonal	Nsein	44	Avrebo	38	82
Axim Urban	Axim	57	Brawire	42	99
Bamiankor	Bamiankor	49	New Esuawua	35	84
TOTAL		**150**		**115**	**265**

Unit of Analysis

The household was the primary unit of analysis, as households are directly exposed to and affected by climate hazards. Household-level indicators included demographic characteristics, livelihood strategies, assets, exposure to hazards, and adaptive capacity measures.

Integration of Methods

- **Household survey:** A structured questionnaire was administered in each community, generating data for computing the Livelihood Vulnerability Index (LVI) and its IPCC reformulation.
- **Secondary data:** Municipal-level reports, statistical service publications, and climate datasets were reviewed to complement household-level findings.

This approach ensured that the CRVA was scientifically rigorous, gender- and socially inclusive, and policy-relevant, while remaining feasible within Nzema East's context.

3.3.1.2 Field data collection

Field data collection in Nzema East Municipality was designed to generate a robust and representative evidence base for applying the Livelihood Vulnerability Index (LVI) and its IPCC reformulation. The process relied on structured household surveys, supported by secondary datasets, ensuring that results were statistically rigorous and reflective of the municipality's diverse socio-ecological contexts.

Household Surveys

A structured household questionnaire was administered across six purposively selected communities in three zonal councils (Nsein, Axim Urban, and Bamiankor). This stratified sampling framework captured both zonal capitals (larger, urbanized centres with better infrastructure and access to services) and smaller rural/peri-urban communities, where households are more directly dependent on climate-sensitive livelihoods.

In total, 265 households were surveyed (see Table 8), with random sampling applied within each community to ensure broad representation of farmers, fisherfolk, traders, women-headed households, elderly persons, and persons with disabilities.

The questionnaire covered a comprehensive range of domains:

- Demographic and socio-economic characteristics
- Livelihood strategies (farming, fishing, trading, mining, artisanal work)
- Climate hazard exposure (flooding, drought, coastal erosion, sea-level rise, heat stress)
- Sensitivity indicators (food security, housing, health, water access, sanitation)
- Adaptive capacity factors (education, income, social networks, extension services, coping strategies)

Inclusivity of Vulnerable Groups

Deliberate steps were taken to capture differentiated vulnerabilities through the household survey design and sampling process. Enumerators ensured inclusion of:

- **Women-headed households**, often managing multiple roles with fewer resources.
- **Youth and migrant workers**, whose livelihoods are highly climate-dependent and often precarious.
- **Elderly persons**, particularly those in farming households, who face mobility and health-related challenges during extreme events.
- **Persons with disabilities (PWDs)**, who are frequently excluded from formal planning processes but experience disproportionate climate risks.

Secondary Data Sources

Household data were complemented with secondary datasets from Ghana Statistical Service, Municipal Medium-Term Development Plans, and relevant sectoral reports. These sources provided contextual information on socio-economic conditions, infrastructure, and environmental pressures, helping to situate household-level findings within the broader municipal development context.

3.3.1.3 Analytical Framework: IPCC–LVI

This study employed the LVI and the IPCC–LVI framework, both of which are widely recognized in vulnerability assessments across diverse socio-ecological systems. The LVI provides a composite index that aggregates household- and community-level indicators into major components, which are then normalized and averaged to reflect relative levels of vulnerability. To align with the conceptual definition of vulnerability adopted in the IPCC Fifth Assessment Report (IPCC, 2014), the framework reformulates the LVI into its three core

dimensions: Exposure, Sensitivity, and Adaptive Capacity.

(a). Indicator Selection: Indicators were selected from three domains of vulnerability:

- *Exposure:* frequency and intensity of climate hazards such as floods, droughts, windstorms, and rainfall variability.
- *Sensitivity*: household characteristics, livelihood dependencies, and environmental stressors shaping susceptibility to climate impacts.
- *Adaptive Capacity:* socio-demographic attributes, access to resources, institutional support, and information that enhance or constrain households' ability to cope and adapt.

Selection was guided by established applications of the LVI (Hahn et al., 2009; Shah et al., 2013) and adapted to reflect the local realities of Nzema Municipality as captured during surveys and consultations.

(b). Data Normalization: All indicators were transformed into a unit-free scale between 0 and 1 using min–max normalization to allow comparability across variables:

$$\mathbf{Ia = (Ii - Imin) / (Imax - Imin)}$$

where $\mathbf{I_a}$ is the normalized score, $\mathbf{I_i}$ the observed indicator value, and $\mathbf{I_{min}}$ and $\mathbf{I_{max}}$ the minimum and maximum values across households or communities. Indicators where higher values implied reduced vulnerability (e.g., educational attainment, access to potable water) were inversely transformed to ensure consistent interpretation—higher scores always reflected greater vulnerability (Sullivan et al., 2002; Hahn et al., 2009).

(c). Component and Sectoral Aggregation: Normalized indicators were grouped into sub-components (e.g., crop diversity, water access, housing condition). These were aggregated into major components representing broader dimensions such as Food Production, Water Resources, Fisheries, Health, Infrastructure & Shelter, and Sanitation. Each major component was calculated as the average of its associated sub-components.

The overall LVI score for each community was derived as the weighted average of all major

components, with equal weights applied, consistent with standard practice (Hahn et al., 2009; Pandey & Jha, 2012). In addition, sectoral disaggregation was undertaken to highlight vulnerabilities across domains critical to livelihoods.

(d) LVI–IPCC Framework: To capture climate vulnerability in line with IPCC definitions, the following formulation was applied:

$$\textit{Vulnerability} = (E - AC) \times S$$

where *E = Exposure, S = Sensitivity, and AC = Adaptive Capacity*. This approach emphasizes how exposure to hazards, offset by adaptive capacity, interacts with underlying sensitivities to produce differentiated vulnerability outcomes across locations and groups (IPCC, 2014).

(e). Level of Analysis: The LVI and LVI–IPCC indices were computed at the household level and then aggregated to the community level. This dual-level analysis allowed the identification of spatial variations in vulnerability within Nzema East, thereby providing evidence-based insights for policy recommendations and targeted adaptation planning.

3.3.2 VA results and discussions

3.3.2 1 Socio-demographic characteristics

Overall, the six Nzema East communities present a demographic profile that is slightly female dominated, concentrated in the middle-aged working population, and with relatively low levels of formal education. Farming and fishing remain the primary livelihood bases, though urban centres like Axim show more diversification. Household structures are generally large, with many dependents, while long-term residence and native dominance reflect community stability, except in New Esuawua, which has greater in-migration and returnees. These socio-demographic dynamics shape vulnerability in distinct ways: limited education and livelihood diversification reduce adaptive capacity, high dependency ratios strain household resources during shocks, and migration/returnee patterns alter social support systems. Together, they underscore the importance of tailoring adaptation measures to the social realities of each community, ensuring that interventions account for both structural vulnerabilities and opportunities for resilience.

3.3.2.1.1 Gender Distribution

Figure 20 shows a generally balanced gender pattern but with a slight female majority across most communities. Bamiankor has the widest gap, while Avrebo, New Esuawua, and Nsein also show small female majorities. Axim is evenly split, and Brawire is nearly equal.

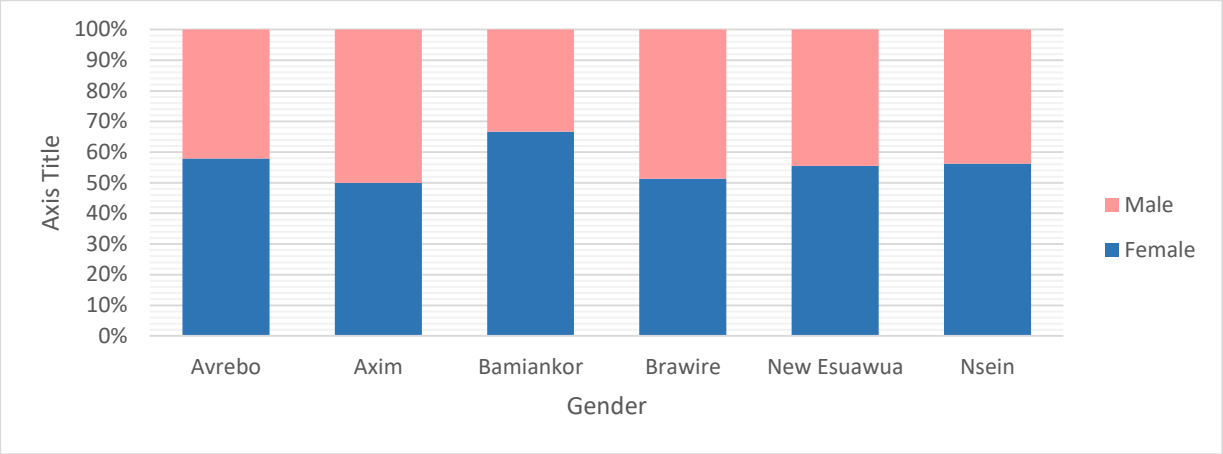

Figure 20: ***Gender distribution***

3.3.2.1.2 Age Distribution

Figure 21 shows that the Nzema communities are largely adult-dominated, with most residents falling within the 25–54 age range. Youth (18–24) are very few—almost absent in Brawire and Nsein—suggesting low youth presence or out-migration. New Esuawua is the youngest community, while Brawire has the highest share of older working adults (45–54). Older adults (55+) appear in all

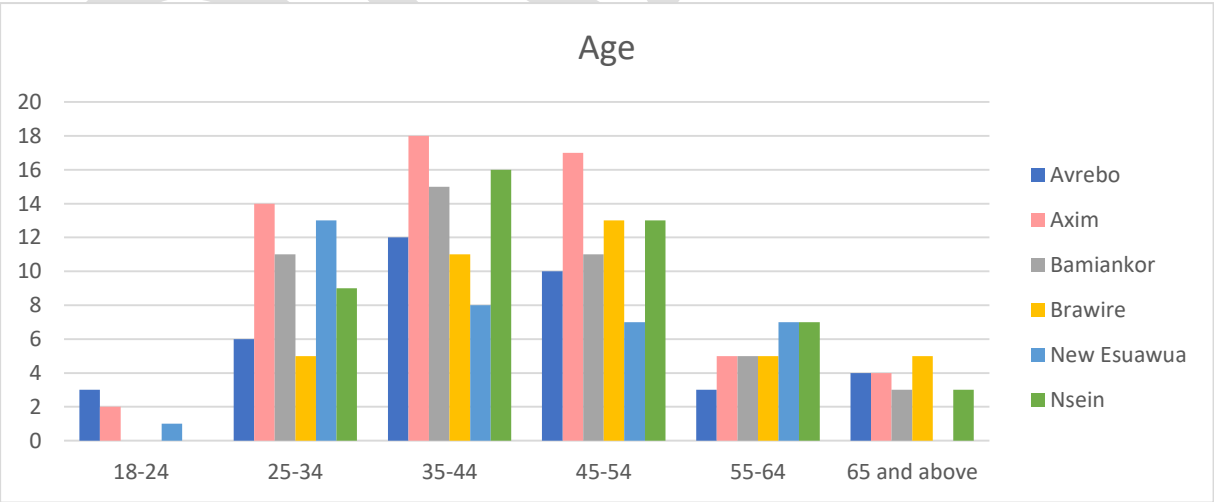

Figure 21: Age Distribution

3.3.2.1.3 Marital Status

Figure 22 shows that marital patterns across the communities are dominated by married households, though the proportions vary. Brawire and Nsein have the highest married shares,

while Bamiankor and New Esuawua show a more balanced split between married and single residents. Widowhood is highest in Bamiankor, and divorced/separated cases remain generally low across all communities.

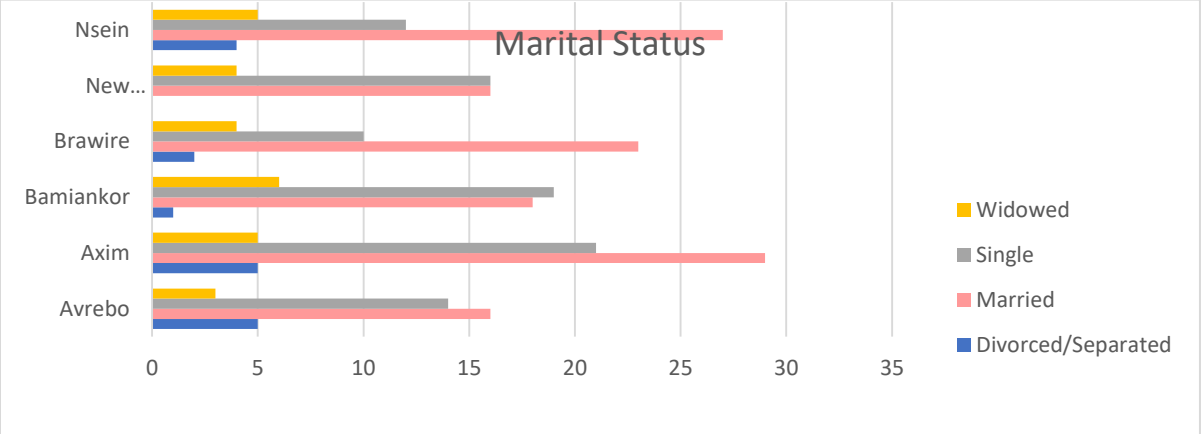

Figure 22: Marital Status

3.3.2.1.4 Educational Attainment

Figure 23 shows that education in the Nzema communities is dominated by primary schooling, with most residents attaining only basic education. Avrebo and Brawire rely most heavily on primary-level attainment, while New Esuawua and Nsein record the highest shares with no formal education. Axim stands out as the most educated community, and Bamiankor is notable for having the only postgraduate respondent and the highest vocational/technical training levels.

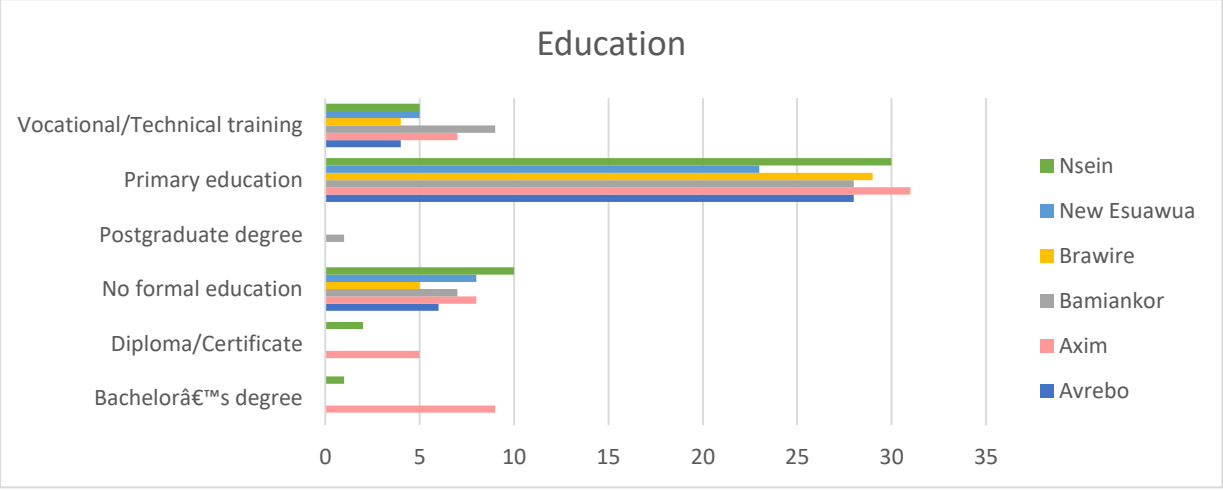

Figure 23: Educational level

3.3.2.1.5 Occupation

Figure 25 shows clear livelihood variation across the Nzema communities. Farming dominates in New Esuawua, Nsein, Bamiankor, and Avrebo, while Brawire is primarily a fishing community and Axim has the most diverse economic profile, combining business, fishing,

farming, and civil service work. Business is a major secondary livelihood in most communities, and unemployment is notably higher in Avrebo and Nsein but lowest in New Esuawua.

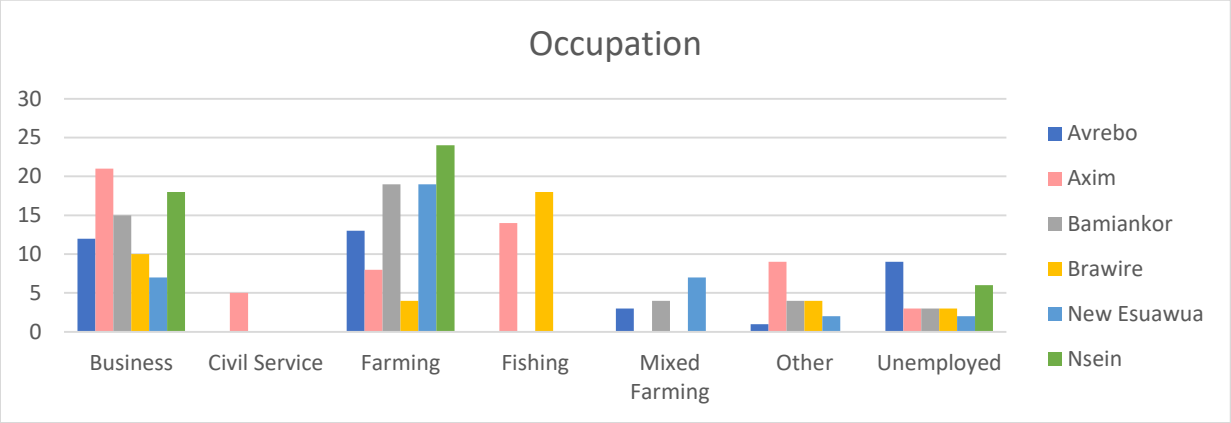

Figure 24: Household Occupation

3.3.2.1.6 Dependent level

Figure 24 shows that most households across the Nzema communities support 3–5 dependents, making this the dominant pattern in nearly all areas. Avrebo, Brawire, Bamiankor, and Nsein all have over 40–50% of households in this bracket, reflecting generally high dependency burdens. Larger households (6–9 dependents) are also common, especially in Avrebo and Brawire, while Axim uniquely records the highest share of very large households, with 12% supporting 10 or more dependents. New Esuawua shows the most balanced structure, with a sizeable number of households (32%) supporting only 1–2 dependents.

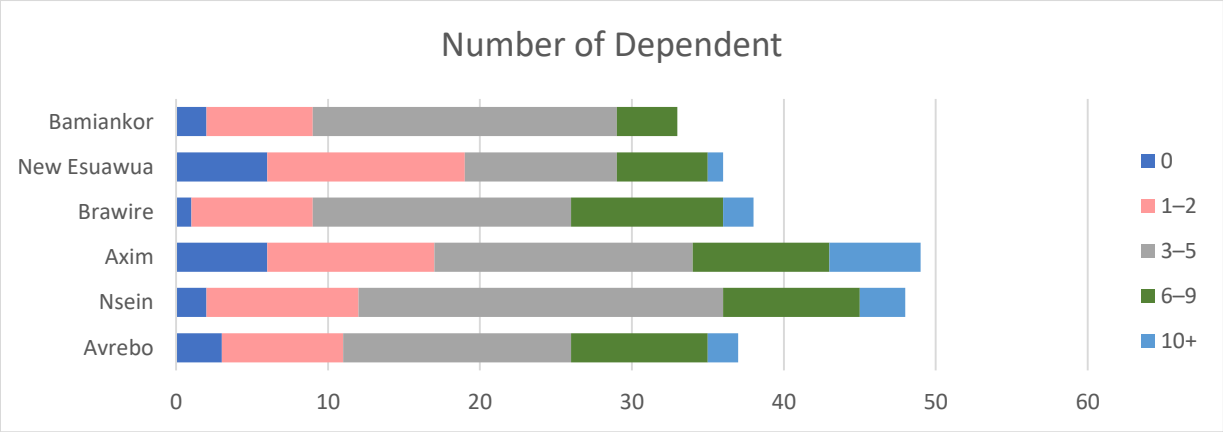

Figure 25: Household dependent level

3.3.2.1.7 Years lived in community

Figure 26 indicates that most Nzema East communities have highly settled, long-term populations, with the majority of residents living in their communities for 21–40 years or more. Brawire, Bamiankor, Nsein, and Axim show the strongest long-term residency patterns, with

large shares living 21–40+ years and very few recent arrivals. Avrebo also has many long-term residents but shows slightly more mobility. New Esuawua is the most mobile community, with a high share of 0–5-year and 11–20-year residents, suggesting more recent settlement compared to the others.

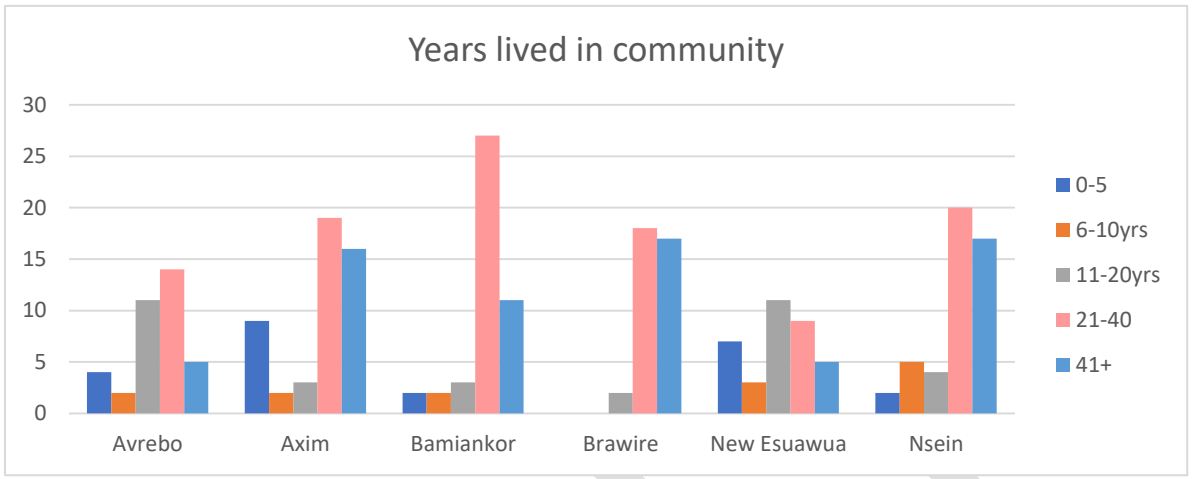

Figure 26: Respondent number of years lived in a community

3.3.2.1.8 Origin of respondents

Figure 28 shows that most Nzema East communities are dominated by native populations, though the share of settlers and migrants varies. Bamiankor and Brawire are the most homogenous, with over 75–80% natives. Avrebo, Axim, and Nsein also have strong native majorities but with moderate shares of settlers and small migrant populations. New Esuawua is the most mixed community, with less than half natives and a notably high proportion of settlers and migrants, reflecting greater mobility and in-migration than the other areas.

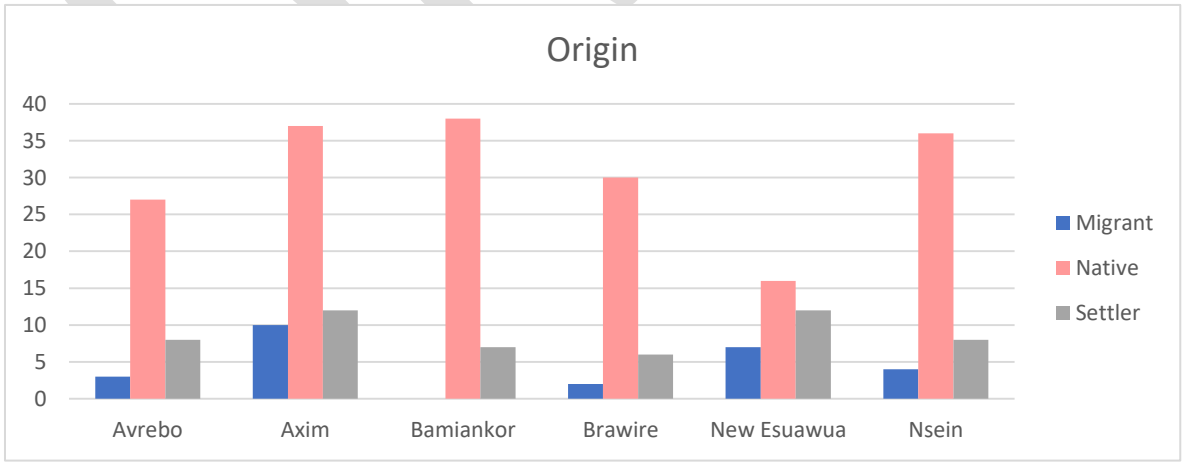

Figure 27: Respondents Origin

3.3.2.1.9 Returnee

Figure 27 shows that returnee presence differs across communities, with most areas having relatively few returnees. Avrebo, Axim, Bamiankor, Brawire, and Nsein all record modest returnee shares (16–24%), indicating limited return migration. New Esuawua is the major exception, with returnees forming 43% of its population—far higher than any other community—highlighting its role as a key destination for people returning home.

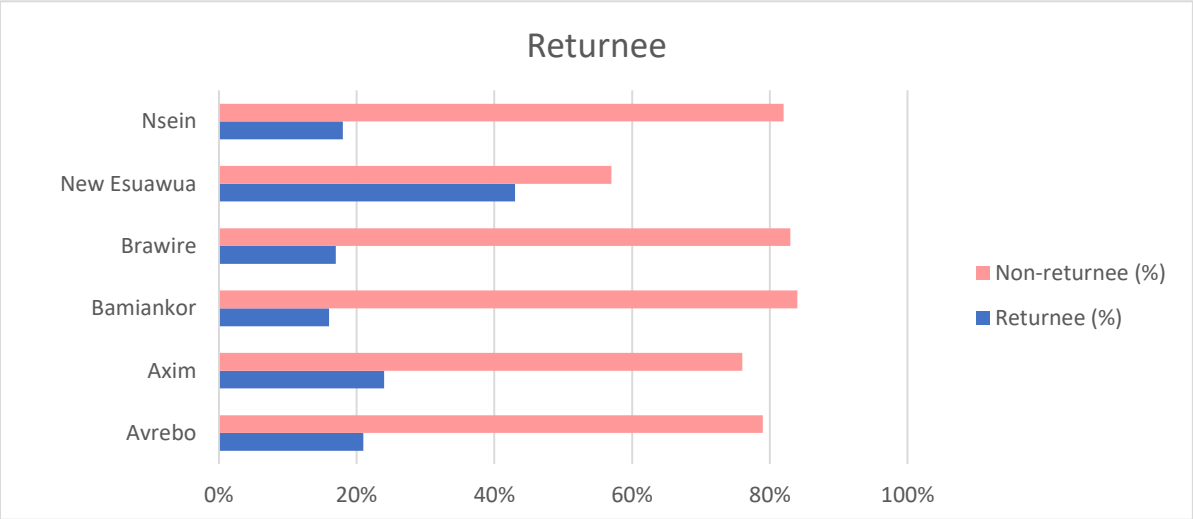

Figure 28: Household Returnee

3.3.2.2 IPCC-LVI Results

3.3.2.2.1. Spatial Vulnerability Findings

The composite overall LVI results integrate exposure, sensitivity, and adaptive capacity to provide a holistic picture of vulnerability across Nzema East communities

- ***High vulnerability**:*
    - Brawire (0.621) and Avrebo (0.600) are the most vulnerable communities. In both cases, high hazard exposure and sensitivity are coupled with relatively weak adaptive capacity, leaving them particularly at risk.
- ***Moderate vulnerability**:*
    - Axim (0.501) is moderately vulnerable, reflecting strong coastal exposure offset by moderate adaptive capacity.

- Bamiankor (0.426) and Nsein (0.425) also fall in the moderate category, shaped by inland sensitivities (livelihood and social burdens) but supported by somewhat stronger adaptive capacity than Avrebo and Brawire.

- ***Low vulnerability****:*
    - New Esuawua (0.354) stands out as the least vulnerable community. While still facing some exposure and livelihood sensitivity, its relatively higher adaptive capacity helps reduce overall vulnerability.

Vulnerability in Nzema East is spatially differentiated: coastal and peri-urban communities (Brawire, Avrebo, Axim) face the highest risks, while inland settlements (New Esuawua, Nsein, Bamiankor) demonstrate greater resilience, though still challenged by livelihood and sensitivity pressures.

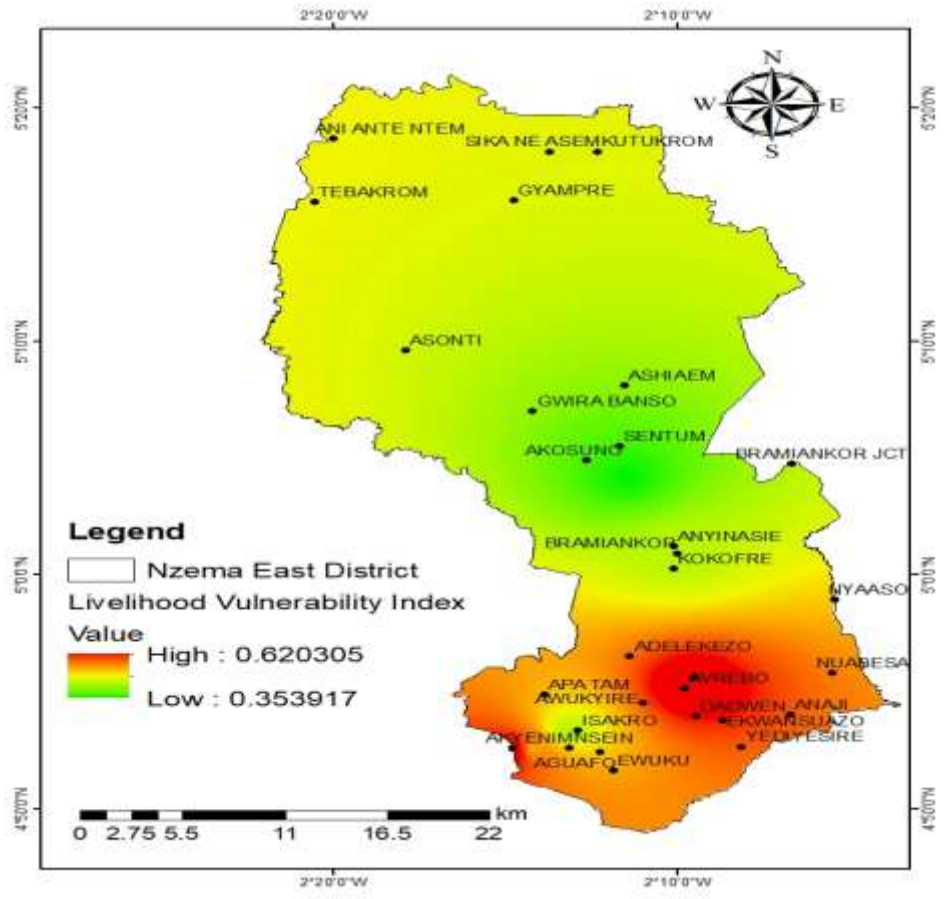

Figure 29. Overall vulnerability to climate change in Nzema East based on LVI results

(a). Climate Exposure

The exposure index (**Figure 30 and Appendix 1)** highlights how communities face varying degrees of hazard risks, including sea level rise, coastal erosion, flooding, drought, windstorms, and bushfires.

- High exposure: Communities highly exposed include Avrebo and Axim, both above the 0.50 threshold. Avrebo's score reflects strong exposure to drought, bushfires, and rainfall shocks, while Axim's is driven by proximity to the coast, making it highly vulnerable to sea level rise, erosion, and storm surges.
- Moderate exposure: Brawire and Nsein fall in the moderate range. Brawire faces risks from sea level rise, erosion, and flooding, though less intense than Axim, while Nsein's exposure is more evenly distributed across rainfall variability, wind force, and bushfires.
- Low exposure: Bamiankor and New Esuawua record low exposure. Both are inland communities with relatively limited direct impact from coastal hazards, though they remain susceptible to bushfires, drought, and water stress.

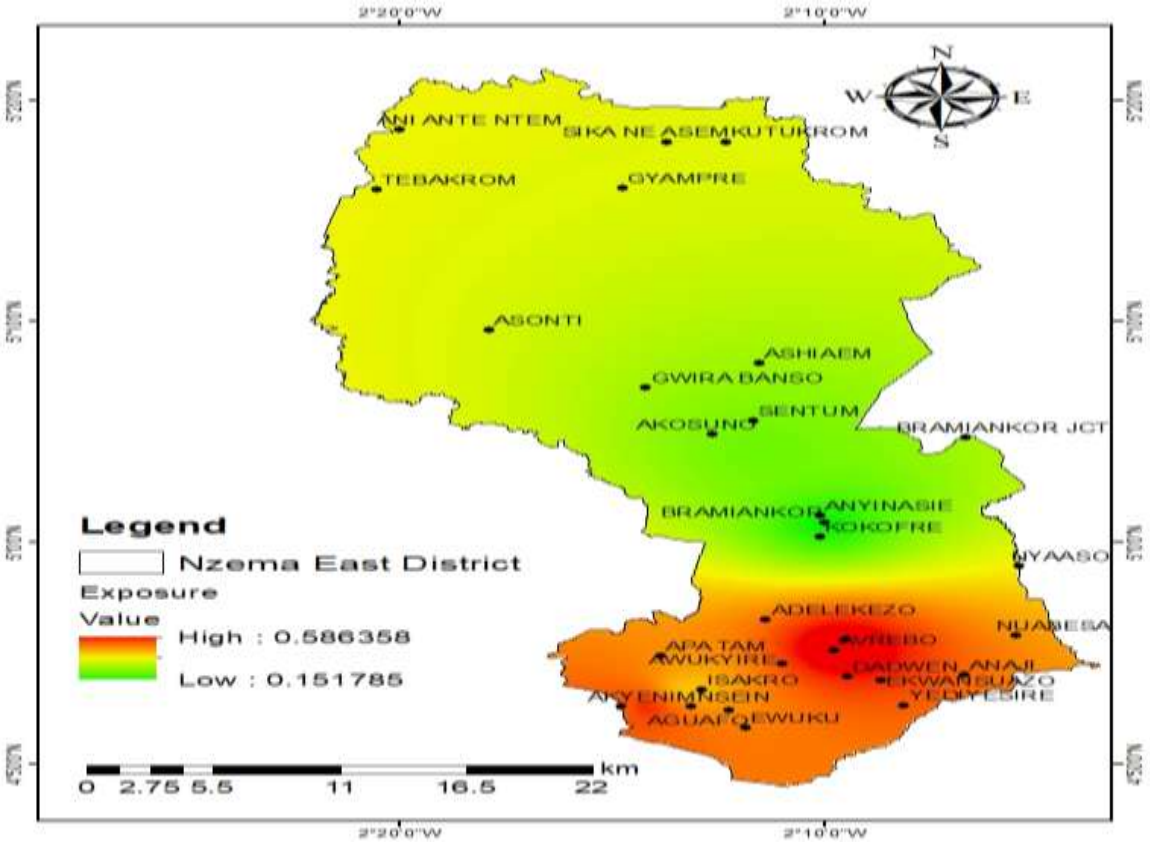

Figure 30. Exposure results for Nzema East Municipal based on LVI analyses

(b). Climate Sensitivity

The sensitivity assessment (**Figure 31 and Appendix 1**) reveals notable differences across communities in terms of housing quality, water access, health, gendered burdens, and livelihood dependence.

- High sensitivity: Brawire (0.675) is the only community in the high category, reflecting very weak housing conditions, poor water access, and strong reliance on fishing-based livelihoods. Its compounded vulnerability is evident in the near-total dependence on unsafe water sources and high social burden scores.
- Moderate sensitivity: Bamiankor (0.477) and Avrebo (0.463) show moderate sensitivity. Bamiankor's score is driven by housing weakness, gender burdens, and limited income diversity, while Avrebo's reflects poor housing and heavy reliance on farming/business with limited water treatment options.
- Low sensitivity: Axim (0.310) and Nsein (0.328) fall into the low category. Axim benefits from relatively stronger housing and service access, despite some gender/social burdens, while Nsein shows relatively balanced performance across all indicators.
- New Esuawua (0.199) records the lowest sensitivity, owing to comparatively better conditions in housing, gender roles, and diversified livelihoods, though some deficits in water and health access remain.

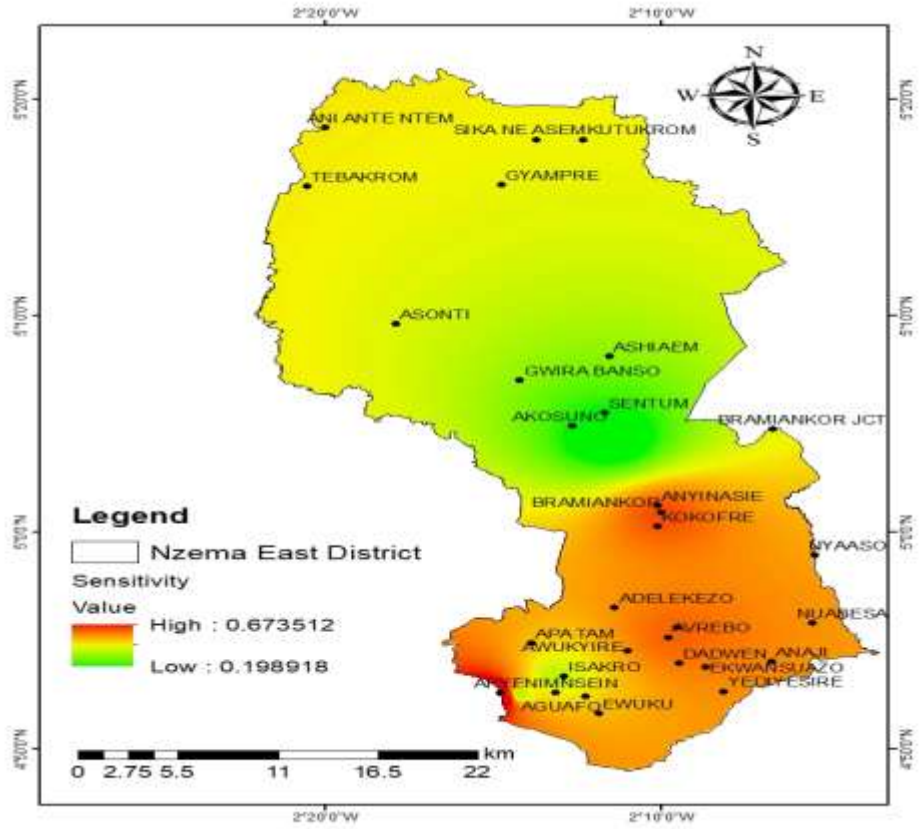

Figure 31: Sensitivity results for Nzema East Municipal based on LVI analyses

(c). Adaptive Capacity

The adaptive capacity analysis (**Figure 32 and Appendix 1**) shows clear disparities across the six Nzema East communities. Scores range from 0.25 (Avrebo, low) to 0.449 (Nsein, moderate), highlighting uneven access to resources, governance participation, and institutional support.

- Education and information access remains limited across all communities, with particularly low values in Avrebo (0.105) and New Esuawua (0.125).
- Social networks and institutional support are generally weak, with values close to zero in most communities, suggesting fragile or absent support structures for collective adaptation.
- Livelihood diversification is modest across the board, with Brawire (0.310) showing the strongest reliance on multiple livelihoods, compared to Avrebo (0.094).
- Infrastructure resilience is a major strength in Nsein (0.805) and Axim (0.829), reflecting stronger physical assets and services, while Avrebo lags behind (0.082).

- Asset ownership is highest in New Esuawua (0.486) and Avrebo (0.454), giving households more flexibility to respond to shocks.
- Participation and governance is strikingly high across most communities, particularly Nsein (0.953), Bamiankor (0.978), and New Esuawua (0.944), pointing to strong community-level engagement in local governance processes.

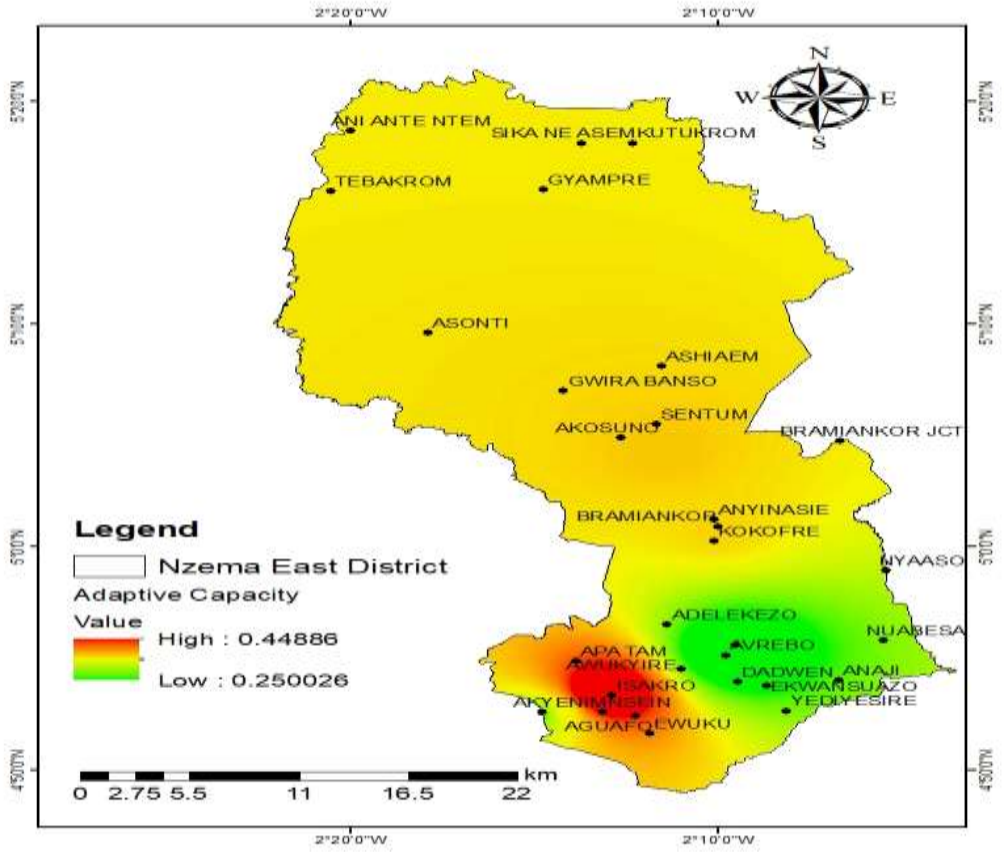

Figure 32: Adaptive capacity results for Nzema East Municipal based on LVI analyses

3.3.2.2.2. Vulnerable locations by sector

This section presents a sectoral analysis of vulnerability across six communities in the Nzema East Municipality, using the LVI framework. The results capture how exposure to climate hazards, sensitivity of livelihoods and systems, and adaptive capacities interact differently across locations, shaping community-specific vulnerabilities. By disaggregating findings across key sectors—agriculture and food security, fisheries and coastal livelihoods, health, infrastructure and human settlement, water resources, and gender dimensions—the assessment highlights both shared challenges and localized disparities. These sectoral insights provide a nuanced understanding of where vulnerabilities are most acute and where resilience is emerging, offering a foundation for targeted adaptation actions. The accompanying LVI map

illustrates (**Figure 39**) the spatial variation in vulnerabilities, making clear the differentiated risks communities face across the municipality.

(a). Agriculture & Food Security

The Agriculture and Food Security sector in Nzema East exhibits moderate levels of vulnerability overall, though with variation across communities. The sector was assessed using indicators such as farm size, post-harvest losses, irrigation use, livestock ownership, adoption of climate-resilient practices, proximity of farms to riverbanks/wetlands, and soil conservation practices.

- ***Exposure:*** Moderate across all communities, with Bamiankor (0.402) and Axim (0.347) recording relatively higher exposure. This reflects susceptibility to droughts, rainfall variability, and land degradation that threaten production systems. Communities like Avrebo (0.259) and Nsein (0.267) show lower exposure, possibly due to less direct hazard interaction or diversified farming practices.
- ***Sensitivity:*** Highest in Avrebo (0.462) and New Esuawua (0.458), reflecting greater dependence on climate-sensitive farming systems, higher post-harvest losses, and limited diversification. Axim (0.333) demonstrates lower sensitivity, benefiting from stronger links to markets and non-farm income activities that reduce dependence on agriculture alone.
- ***Adaptive Capacity:*** Uneven across the six communities. Brawire demonstrates the strongest adaptive capacity (0.738), underpinned by relatively higher uptake of climate-resilient practices, soil conservation, and livestock ownership. Axim also performs well (0.606), benefitting from access to inputs and extension services. By contrast, Avrebo (0.302) and Nsein (0.343) exhibit weaker adaptive capacities, reflecting limited irrigation, low adoption of conservation practices, and smaller farm sizes.
- ***Composite LVI:*** Vulnerability in the Agriculture sector is moderate across all communities, with Bamiankor (0.479), Avrebo (0.473), and New Esuawua (0.457) being relatively more vulnerable, while Brawire (0.319) and Axim (0.358) are less vulnerable due to stronger adaptive capacities and lower sensitivities.

The results point to clear spatial disparities in agricultural resilience. Farming-dependent rural settlements such as Avrebo, Bamiankor, and New Esuawua face heightened vulnerability due to high exposure and limited adaptive capacity. Meanwhile, semi-urban communities like Axim

and Brawire benefit from greater diversification, stronger institutional support, and wider adoption of adaptive practices, which reduce their vulnerability. Strengthening extension services, expanding irrigation, promoting climate-resilient farming methods, and addressing post-harvest losses are central to improving sector resilience across the municipality.

(b). Fisheries and Coastal Livelihood

The fisheries and coastal livelihood sector reflect nuanced differences in vulnerability levels across communities, shaped by varying degrees of exposure to climate-related coastal hazards, ecological degradation, and community-level adaptive mechanisms.

• High Vulnerability (LVI ≥ 0.50)

- **Brawire (0.561)** and **Axim (0.499)** fall at the upper end of the vulnerability spectrum.
- **Brawire** records the highest LVI, driven by elevated exposure (0.550) and sensitivity (0.569), likely reflecting its heavy dependence on marine resources and frequent disruption of fishing activities due to coastal hazards.
- **Axim**, though slightly lower, also shows high vulnerability with substantial exposure (0.476) and sensitivity (0.552), coupled with limited adaptive capacity (0.469), indicating fragile coping mechanisms in place.

• Moderate Vulnerability (0.34 – 0.49)

- **Avrebo (0.451)**, **Nsein (0.444)**, and **Bamiankor (0.401)** fall into the moderate vulnerability bracket.
- These communities show relatively balanced scores across all three dimensions. For instance:
    - **Avrebo** has moderate exposure (0.350) and sensitivity (0.483), with a slightly better adaptive capacity (0.519), helping reduce overall vulnerability.
    - **Nsein** exhibits similar characteristics, with slightly higher exposure (0.450) but better adaptive systems (0.486).
    - **Bamiankor**, though less exposed (0.350), maintains moderate adaptive capacity (0.468), indicating some resilience despite socio-ecological pressures.

• Low Vulnerability (≤ 0.34)

- **New Esuawua (0.366)**, while close to the threshold for low vulnerability, remains the **least vulnerable** among the six communities.
- Its relatively low exposure (0.200) and sensitivity (0.379) mitigate risk, despite only moderate adaptive capacity (0.518).
- The lower exposure suggests limited reliance on coastal fisheries or reduced exposure to direct marine climate hazards.

Key Indicators Driving Vulnerability

- **Exposure**: Frequency of fishing interruptions due to coastal erosion, storm surges, and sea-level rise.
- **Sensitivity**: Loss of income from fishing, damage to canoes and gear, declining fish stocks, and food insecurity.
- **Adaptive Capacity**: Availability of alternative livelihoods, access to early warning systems, insurance, social networks, and organized fisherfolk associations.

Communities such as **Brawire and Axim**, with high exposure and low resilience, are the most vulnerable in the fisheries and coastal livelihood sector and should be prioritized for adaptation interventions. **Avrebo, Nsein, and Bamiankor** demonstrate moderate but significant risk, needing sustained resilience-building efforts. **New Esuawua**, while currently less exposed, should not be overlooked—especially if climate dynamics shift or adaptive capacity weakens.

(c). Health

The health-related vulnerability analysis highlights variations across the six communities in terms of exposure to climate-induced health risks, sensitivity of populations, and the capacity to adapt through services and infrastructure. Indicators included access to health services, illness after floods and droughts, impacts on health facilities, prevalence of heat-related illness, extra health expenditures, and water and sanitation conditions (e.g., shortages, conflicts, use of unprotected wells, public toilet access, open defecation).

- **Exposure** levels are generally low across the municipality, with most communities registering values below 0.30. Brawire (0.2701) and Avrebo (0.2195) emerge as the more exposed communities, likely reflecting greater incidence of flood- and drought-related illness. By contrast, Bamiankor (0.0187) and New Esuawua (0.0415) record minimal exposure.

- **Sensitivity** varies more strongly, with Brawire (0.362) and Avrebo (0.2489) standing out as the most sensitive. These communities face a combination of limited water quality, higher disease burdens, and greater reliance on vulnerable health services. In comparison, Axim (0.1539) and New Esuawua (0.1646) report lower sensitivity, indicating relatively better resilience in terms of population health and service access.
- **Adaptive Capacity** is highest in Bamiankor (0.5789) and Nsein (0.5598), suggesting stronger ability to cope with health risks, possibly due to better household-level water treatment practices, stronger social networks, or more consistent access to services. Axim (0.1891) and Avrebo (0.1968) display the weakest adaptive capacity, exposing them to greater challenges during climate-related health shocks.
- **Overall LVI scores** for health rank Brawire (0.4254) and Avrebo (0.3908) as the most vulnerable, while Bamiankor (0.2258) and Nsein (0.2639) appear relatively less vulnerable. This pattern reflects the interplay between low exposure but strong adaptive capacity in the latter, versus moderate-to-high exposure combined with weak coping mechanisms in the former.

(d). Infrastructure & Human Settlement

The results highlight differentiated vulnerabilities across the six study communities, reflecting how exposure to hazards, infrastructure conditions, and adaptive capacities interact (Table 12).

- **High vulnerability** is evident in Brawire (0.471) and Bamiankor (0.425). Brawire's vulnerability is largely driven by high sensitivity (0.427) combined with a complete absence of adaptive capacity (0.000). This indicates limited resilience infrastructure, inadequate sanitation, and relocation challenges. Similarly, Bamiankor records elevated exposure (0.386) and sensitivity (0.331), while very low adaptive capacity (0.041) further amplifies risk.
- **Moderate vulnerability** is observed in Avrebo (0.400) and New Esuawua (0.332). In Avrebo, exposure (0.337) and sensitivity (0.342) are moderately high, but adaptive capacity (0.522) is relatively stronger, buffering risks. New Esuawua, by contrast, shows lower sensitivity (0.083) but faces minimal adaptive capacity (0.014), keeping vulnerability at a moderate level.
- **Lower vulnerability** is recorded in Nsein (0.286) and Axim (0.281). Both communities benefit from moderate exposure and sensitivity scores, coupled with adaptive capacity

values that, while not particularly high, are sufficient to offset extreme risks. These results point to relatively better infrastructure resilience and settlement stability compared to other communities.

Key drivers: Indicators such as lack of access to sanitation facilities, prevalence of open defecation, reliance on unprotected water sources, and past experiences of relocation strongly shaped outcomes. Communities with limited infrastructure and weak coping options (e.g., Brawire and Bamiankor) are more exposed to cascading risks from climate shocks, while those with stronger services and institutions (e.g., Axim and Nsein) demonstrate greater resilience.

(e). Water Resources

The Water Resources LVI highlights significant variations across the six communities, with vulnerabilities shaped by water shortages, cost, conflict, NGO involvement in water protection, reliance on unprotected wells, and household water treatment practices.

- **Avrebo** records an LVI of 0.361 (Moderate). Vulnerability is primarily due to exposure to shortages (0.37) and limited adaptive capacity (0.29). While some households adopt water treatment, high dependency on unsafe sources increases risk.
- **Axim** stands at 0.420 (Moderate), reflecting relatively higher sensitivity (0.43) and moderate exposure (0.33). Water costs are among the highest here, and despite some adaptive practices, vulnerability remains.
- **Bamiankor** has the lowest LVI, 0.203 (Low). Households show relatively better adaptive capacity (0.58) and limited exposure, suggesting more secure access and protection systems.
- **Brawire** is the most vulnerable, with an LVI of 0.795 (High**)**. Extremely high exposure (1.0) and sensitivity (0.76) reveal acute shortages, conflicts, and weak resilience measures, making water access precarious.
- **New Esuawua** records 0.400 (Moderate). Exposure and sensitivity are low, but adaptive capacity is absent (0.00), leaving households reliant on unsafe sources without sufficient coping strategies.
- **Nsein** shows an LVI of 0.448 (Moderate), with moderate exposure (0.30) and higher sensitivity (0.54). Despite relatively better adaptive capacity (0.50), reliance on unprotected wells and treatment gaps sustain vulnerability.

Water vulnerability is highest in Brawire (High), lowest in Bamiankor (Low), and moderate in all other communities. The main drivers are shortages, high costs, conflicts over water, and insufficient adaptive practices.

(f). Gender dimensions of vulnerability

The gender dimension of vulnerability reveals nuanced patterns across the Nzema East communities, reflecting both structural inequalities and differentiated climate impacts.

Exposure levels are generally low across all communities, indicating that direct gender-related exposure to climate shocks is not as pronounced as in other sectors. However, sensitivity scores show consistently moderate values, pointing to entrenched social burdens placed on women, such as caregiving responsibilities and livelihood insecurity.

Adaptive capacity varies but remains weak in most cases. While some communities, such as Axim and Nsein, show relatively higher adaptive capacity (linked to women's access to land, credit, or decision-making roles), their LVI values still reflect vulnerability because these gains are uneven and not fully institutionalized.

The overall **Gender LVI scores** are low to moderate, with Avrebo (0.175) showing the highest vulnerability, largely due to high sensitivity and limited adaptive capacity. By contrast, Axim (–0.093) and Nsein (–0.036) record negative scores, suggesting stronger relative resilience in gender dynamics compared to other communities, likely due to women's stronger decision-making roles and access to resources.

Key indicators shaping gender vulnerability include:

- Additional caregiving burdens on women due to climate stressors.
- Limited but emerging programs supporting climate-vulnerable women and PWDs.
- Uneven access to credit, land, and agricultural extension.
- Decision-making power in household finances and farming, where female participation varies significantly across communities.

Overall, the gendered vulnerability results emphasize the need for targeted gender-responsive adaptation strategies, especially in Avrebo and Brawire, while also consolidating the gains in Axim and Nsein to strengthen inclusivity and resilience.

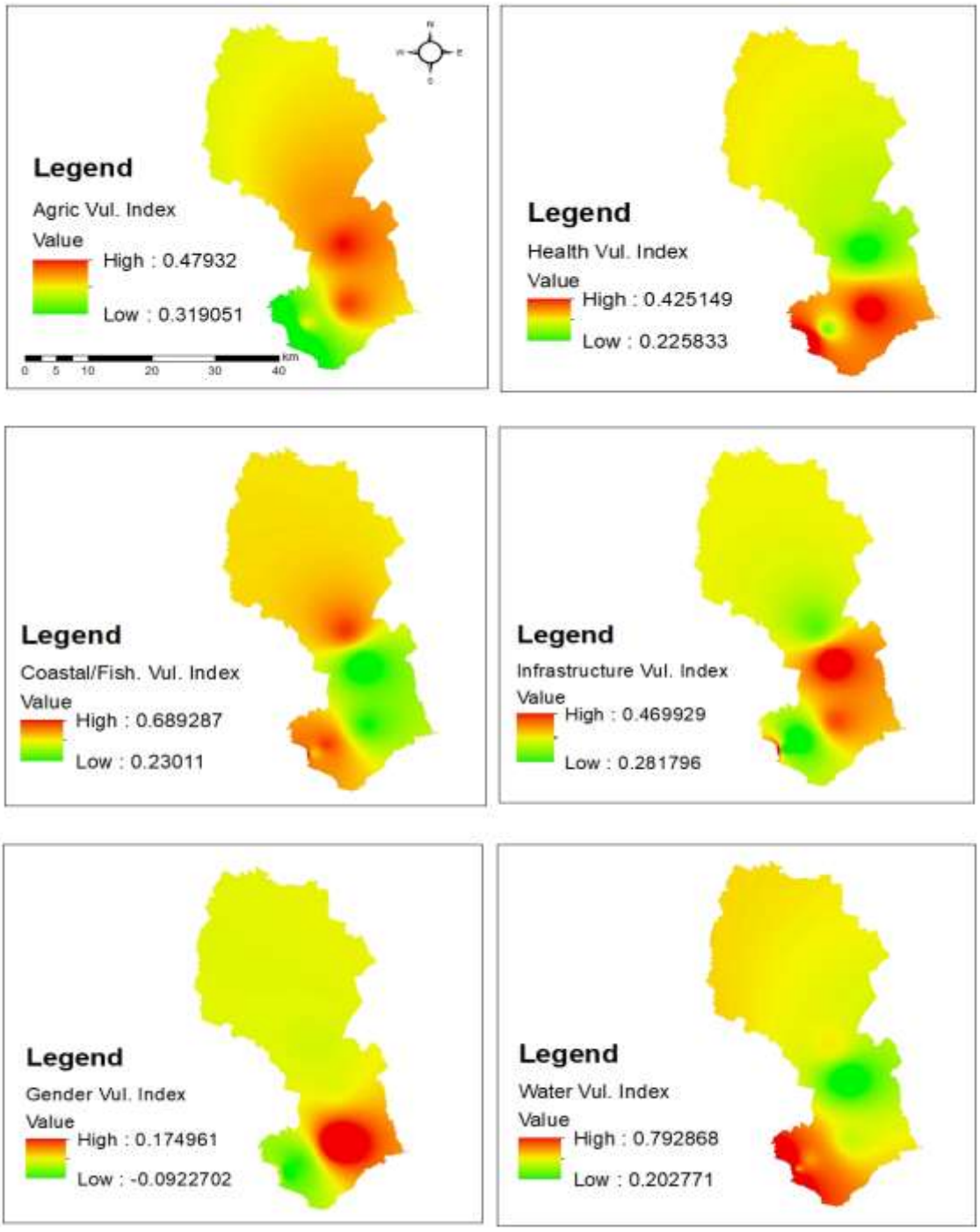

Figure 33: Sectoral LVI maps for Nzema East Municipality.

CHAPTER FOUR: ASSESSMENT OF VULNERABILITY TO FUTURE CLIMATE CHANGE

4.0 Introduction

This chapter assesses the Nzema East Municipality vulnerability to future climate change. It begins by presenting downscaled climate projections for the region, leveraging the latest global climate models (CMIP6) to forecast changes in temperature, rainfall, and extremes through the end of the century. The analysis then synthesizes these climate signals with local conditions to evaluate their potential impacts and risks across key sectors. This section will detail the projected threats to food production, water resources, human health, infrastructure, and fisheries, highlighting the specific gendered implications of climate-related disruptions on the municipality's communities and livelihoods.

4.1 Climate Change Projections

4.1.1 Description of the Climate Projection Method

The climate projections for Nzema East were developed following the Intergovernmental Panel on Climate Change framework, which defines vulnerability and risk in terms of exposure, sensitivity, and adaptive capacity. Projections combine historical climate observations with future scenarios to understand how rainfall, temperature, and extremes may change over time.

The method rests on three main steps:

1. Establish a historical baseline (1991–2020), using high-resolution rainfall and temperature datasets to capture past climate patterns.
2. Project future climate conditions using global climate models (GCMs) under two possible futures:
    - SSP2-4.5 (a moderate scenario where emissions peak mid-century).
    - SSP5-8.5 (a high-emission pathway where fossil fuel use continues strongly).
3. Analyze climate extremes using the ETCCDI indices (**Table 7),** which measure not just averages but also events such as very heavy rainfall days, long dry spells, and hot nights.

This framework allows us to see how climate change might alter both typical weather patterns and rare, extreme events that cause the greatest damage to live, infrastructure, and livelihoods.

Table 7. ETCCDI Climate Indices Used for the Analysis

Index	Full Name	Description
RR	Total Precipitation	Annual total of daily precipitation (mm)
Rx1	Max 1-day Precipitation	Highest daily rainfall total in a year (mm)
Rx5	Max 5-day Precipitation	Highest 5-day cumulative rainfall in a year (mm)
R10mm	Heavy Rain Days (≥10mm)	Number of days with precipitation ≥ 10 mm
R20mm	Very Heavy Rain Days (≥20mm)	Number of days with precipitation ≥ 20 mm
R95p	Very Wet Days	Number of days with precipitation above the 95th percentile
R95pTOT	Total Precip. from Very Wet Days	Total precipitation from days exceeding the 95th percentile
WD	Wet Days	Number of days with measurable precipitation (≥1 mm)
DD	Dry Days	Number of days with precipitation <1 mm
SDII	Simple Daily Intensity Index	Average precipitation amount on wet days (mm/day)
CWD	Consecutive Wet Days	Maximum number of consecutive days with ≥1 mm precipitation
CDD	Consecutive Dry Days	Maximum number of consecutive days with <1 mm precipitation
TX90p	Warm Days	Percentage of days when daily max temperature > 90th percentile
TX10p	Cool Days	Percentage of days when daily max temperature < 10th percentile
TN90p	Warm Nights	Percentage of days when daily min temperature > 90th percentile
TN10p	Cool Nights	Percentage of days when daily min temperature < 10th percentile
DTR	Diurnal Temperature Range	Difference between daily max and min temperature (°C)

4.1.2 Data Collection for Climate Projection

To make the analysis robust, data came from both observed records and climate model outputs:

Observed Datasets (for baseline and bias correction):

- **CHIRPS** – Rainfall dataset combining satellite and ground station data. Provides daily rainfall at a very fine resolution (0.05° ≈ 5 km) across Ghana.
- **ERA5 Reanalysis** – A dataset that blends weather observations and models to provide hourly temperature and humidity data at 0.25° ≈ 30 km resolution.

Climate Projection Datasets:

- **CMIP6 models** – The latest set of global climate models coordinated by the World Climate Research Programme. Fifteen models from across the world were used (e.g., ACCESS-CM2 from Australia, EC-Earth3-Veg from Europe, MIROC6 from Japan, UKESM1-0-LL from the UK). These models differ in structure and resolution but together provide a strong multi-model ensemble (see Table 8).
- **Shared Socioeconomic Pathways (SSPs):**
    - SSP2-4.5 – a stabilization scenario with moderate warming.
    - SSP5-8.5 – a high-emission "worst-case" pathway, leading to more rapid warming.

Study Periods Analyzed:

- **Historical baseline:** 1991–2020.
- **Near Future (NF):** 2026–2050.
- **Mid Future (MF):** 2051–2075.
- **Far Future (FF):** 2076–2100.

This combination ensures that the projections are both locally relevant (CHIRPS/ERA5) and globally consistent (CMIP6).

Table 8: CMIP6 Models Applied for Projections) Spatial Resolution and Country of Selected CMIP6 Models)

Model name	Country	Grid Size (lon × lat in degrees)
ACCESS-CM2	Australia	1.9° × 1.3°
CNRM-CM6-1	France	1.41° × 1.41°
CNRM-ESM2-1	France	1.41° × 1.41°
CNRM-CM6-1-HR	France	0.5° × 0.5°
EC-Earth3-Veg	Europe	0.7° × 0.7°
FGOALS-g3	China	2.0° × 2.3°

GFDL-ESM4	USA	1.3° × 1.0°
INM-CM4-8	Russia	2.0° × 1.5°
INM-CM5-0	Russia	2.0° × 1.5°
IPSL-CM6A-LR	France	2.5° × 1.3°
KACE-1-0-G	South Korea	1.9° × 1.9°
MIROC6	Japan	1.4° × 1.4°
MPI-ESM1-2-LR	Germany	1.9° × 1.9°
MRI-ESM2-0	Korea	1.13° × 1.13°
UKESM1-0-LL	UK	1.9° × 1.3°
KIOST-ESM	Korea	2.0° × 2.5°

4.1.3 Simulation and Downscaling

Global climate models are powerful but too coarse to directly guide planning at the district level. For example, a single grid cell may cover hundreds of kilometers, missing local features such as coastlines, wetlands, and elevation that strongly influence Nzema East's climate. To address this, a downscaling and bias correction process was applied:

1. **Bias Correction:** Observed datasets (CHIRPS and ERA5) were used to correct systematic errors in the global models. This ensures the projections match the "real climate" experienced in Nzema East.
2. **Multi-Model Ensemble (MME):** Instead of relying on one model (which may over- or under-estimate), results were averaged across multiple CMIP6 models. This reduces uncertainty and highlights consistent trends.
3. **District-Level Extraction:** Using Nzema East's administrative boundary, climate data was extracted specifically for the municipality, ensuring that results are **geographically tailored**.
4. **Temporal Aggregation:** Data was analyzed at both **annual and seasonal scales**, aligned with Ghana's rainfall regimes:
    - Major rainy season: March–July.
    - Minor rainy season: September–November.
    - Dry season: December–February.
5. **Calculation of Extremes:** ETCCDI indices were computed to capture extreme rainfall and temperature events beyond averages. For instance:
    - **Rx5:** Maximum rainfall over five days (linked to flood risk).

- **CDD:** Longest dry spell (linked to drought risk).
- **TX90p:** Hot days (linked to heat stress on humans and crops).

Through this process, the analysis delivers district-specific, reliable projections, bridging the gap between global science and local policy needs.

4.1.4 Analysis of Downscaled Results

4.1.4.1 Precipitation

Annual rainfall in Nzema East historically ranges between 1350 mm and 1850 mm, with a mean near 1580 mm (**Figure 34**). Projections under SSP2-4.5 remain close to historical values across all future periods. In contrast, SSP5-8.5 shows a declining trend from the mid to far future, with mean values falling below the historical average. Variability narrows under both scenarios, particularly in the far future.

Rainfall indices (**Figure 35**) show that total rainfall (RR) remains stable under SSP2-4.5 but declines slightly under SSP5-8.5. Extreme rainfall events (Rx1, Rx5) and moderate to heavy rain days (R10mm, R20mm) all decrease in future periods across both scenarios. The frequency of very wet days (R95p) increases, but the total rainfall accumulated from those days (R95pTOT) declines. This suggests a shift toward more frequent but less intense extremes. Rainfall intensity (SDII) decreases, supporting the reduction in extreme precipitation strength.

Wet days (WD) and consecutive wet days (CWD) increase across all future periods, indicating more frequent but weaker rainfall events. Dry days (DD) and dry spells (CDD) decrease compared to historical values, pointing to a reduction in the length of dry periods. Figure 16 shows the historical and projected mean precipitation patterns under SSP 5-8.5 and SSP 2-4.5 scenarios for Nzema East district, segmented into four periods: Historical (1990-2020), Near Future (NF, 2026-2050), Mid Future (MF, 2051-2075), and Far Future (FF, 2076-2100). The SSP 5-8.5 scenario (red) shows higher precipitation amounts compared to SSP 2-4.5 (green) within the NF period, with notable and significant declines towards the far future. Historical mean and future scenario means are marked with horizontal, continuous lines along with the standard deviations (dashed lines) for comparative analysis across different timeframes and regions.

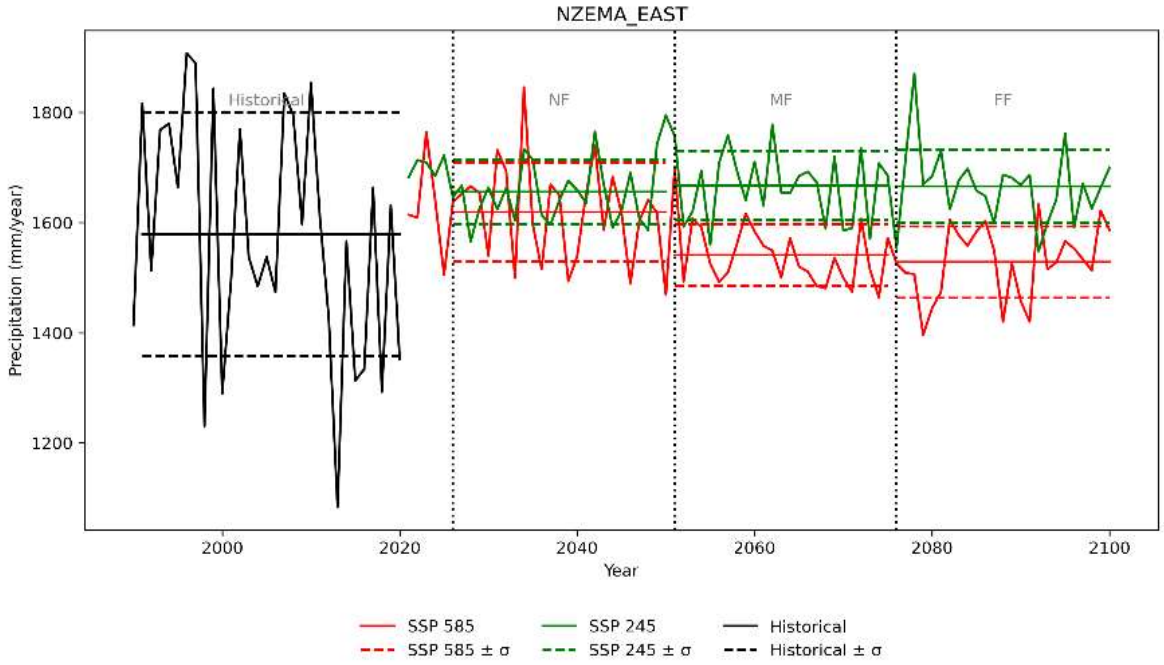

Figure 34: Historical and projected mean precipitation patterns under SSP 5-8.5 and SSP 2-4.5 scenarios for Nzema East district.

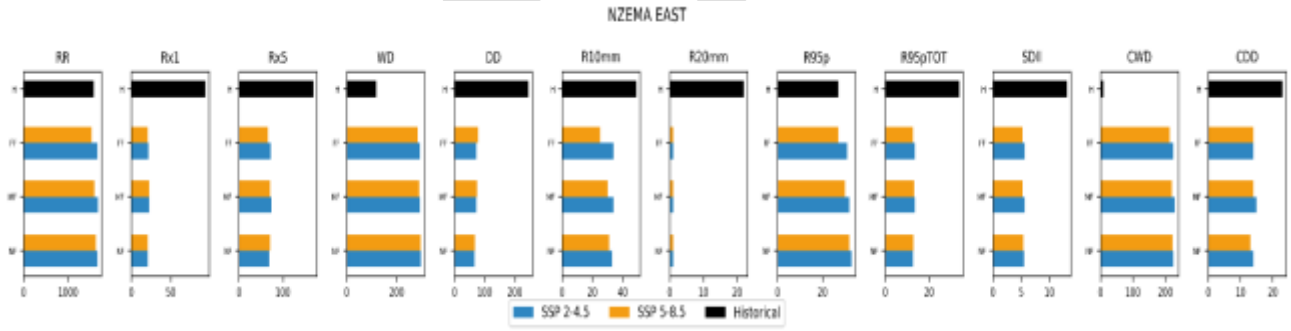

Figure 35: Historical and projected climate extreme metrics across Nzema East district.

4.1.4.2 Monthly Rainfall Seasonality

Nzema East exhibits a clear bimodal rainfall pattern, with peaks in June and a secondary peak in October (**Figure 36**). This seasonal structure persists across all future periods. However, the second peak becomes less pronounced under both scenarios, and rainfall concentrates more heavily between May and August. This reflects a subtle transition toward a more unimodal pattern, particularly in the far future under high emissions. **Figure 36** shows Monthly rainfall patterns across all time periods and scenarios for Nzema East district. The panels are ordered chronologically as historical (H), near-future (NF), mid-future (MF) and far-future (FF), from left to right respectively. The blue lines in the future projections are SSP2-4.5 scenarios and the orange lines in the projection phase are SSP5-8.5 scenarios.

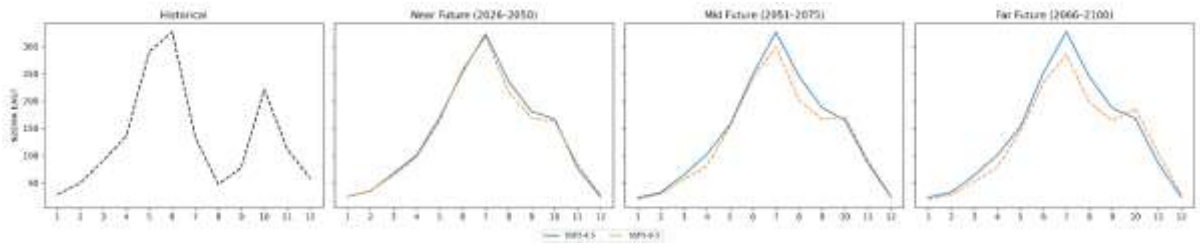

Figure 36: Monthly rainfall patterns across all time periods and scenarios for Nzema East district.

4.1.4.3 Temperature

Annual temperature in Nzema East historically ranges between 25.0°C and 26.5°C, with a mean near 25.5°C (**Figure 37).** Future projections under both SSP2-4.5 and SSP5-8.5 indicate consistent warming, with temperatures rising steadily across all periods. SSP2-4.5 shows moderate increases, reaching around 27.5°C by the far future. Under SSP5-8.5, warming is more pronounced, with mean temperatures exceeding 29°C by the end of the century.

Temperature indices (**Figure 38)** reveal strong warming signals. Hot days (TX90p) and warm nights (TN90p) increase sharply, particularly under SSP5-8.5, with TX90p exceeding 180 days in the far future. Cool days (TX10p) and cool nights (TN10p) decline significantly, with TX10p almost disappearing after the historical period. Diurnal temperature range (DTR) narrows slightly in future periods, suggesting relatively uniform warming between day and night temperatures.

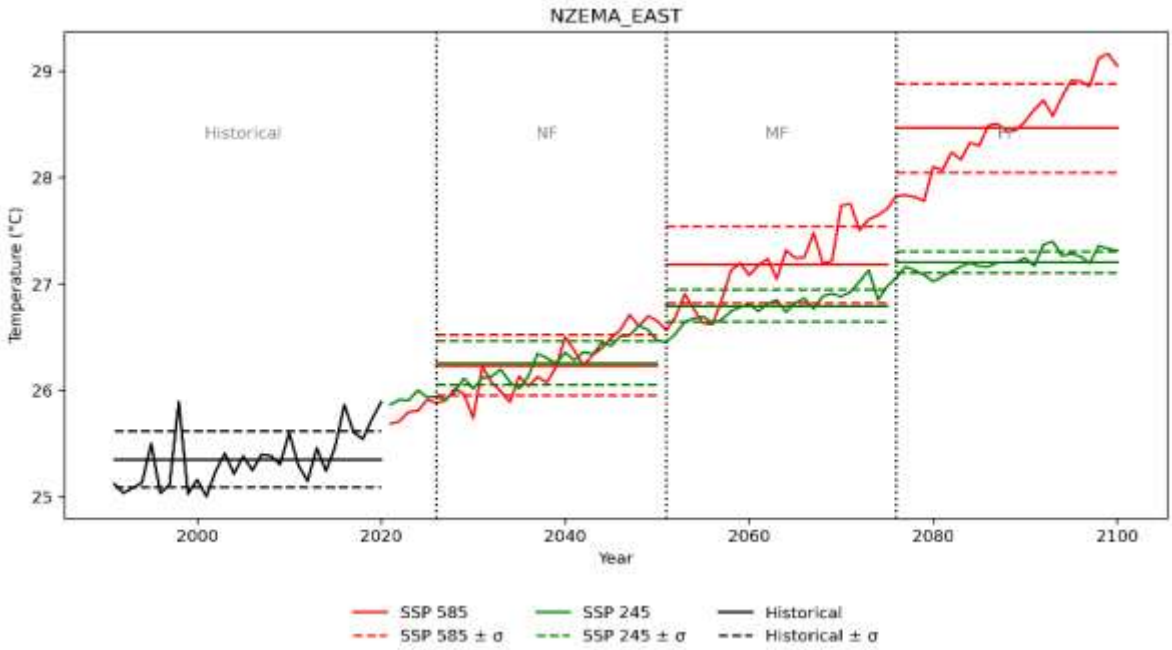

Figure 37: Historical and projected mean temperature patterns under SSP 5-8.5 and SSP 2-4.5 scenarios for Nzema district.

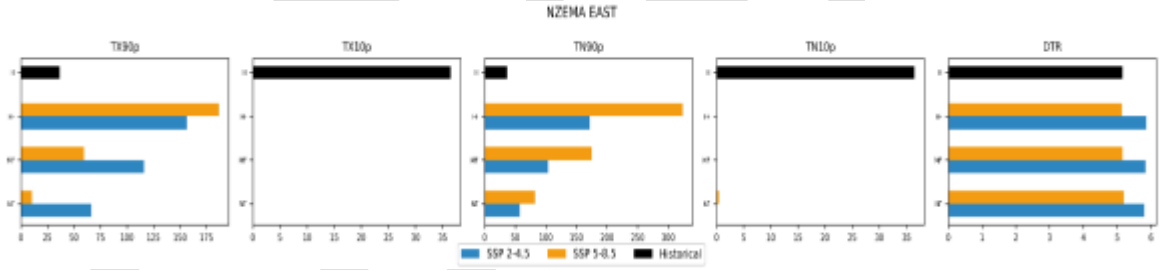

Figure 38: Historical and projected climate extreme metrics across the Nzema East district. Black bars denote the historical pattern, and the red and blue boxes denote SSP 2-4.5 and SSP 5-8.5 respectively for the projection periods.

4.1.4.4. Monthly Temperature Seasonality

Nzema East displays a unimodal temperature pattern, with a peak from February to April and a trough between July and September (**Figure 39**). This seasonal cycle persists in all future scenarios but shifts upward due to consistent warming. The most substantial increases occur during the dry season months and early transition periods. By the far future, SSP5-8.5 projects monthly averages above 29°C in the hottest months, highlighting increased thermal stress under high-emission scenarios. As seen in figure 21, the panels are ordered chronologically as historical (H), near-future (NF), mid-future (MF) and far-future (FF), from left to right

respectively. The blue lines in the future projections are SSP2-4.5 scenarios and the orange lines in the projection phase are SSP5-8.5 scenarios.

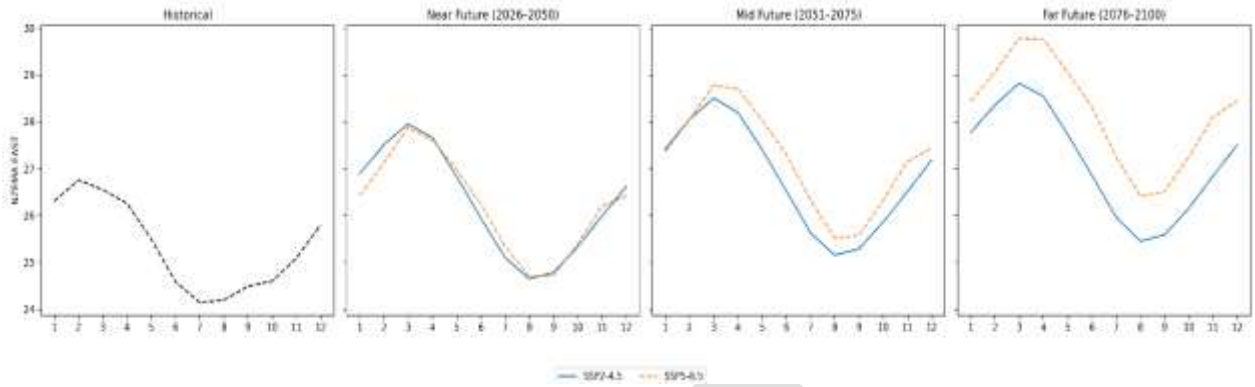

Figure 39: Monthly temperature patterns across all time periods and scenarios for Nzema East district.

4.1.4.5. Relative Humidity

Relative humidity in Nzema East historically ranges between 72% and 77%, with a mean around 74.5% (**Figure 40**). Future projections under both SSP2-4.5 and SSP5-8.5 indicate a gradual decline in mean relative humidity across all future periods. The drop is more pronounced under SSP2-4.5, particularly in the early years of the far future.

Monthly climatology (**Figure 41**) shows a clear seasonal cycle, with relative humidity peaking between June and August and reaching its lowest between December and February. This seasonal pattern remains intact in future projections. However, peak humidity values slightly decrease, especially under SSP5-8.5. The decline is more noticeable during the drier months, indicating intensified atmospheric drying outside the core rainy season.

These patterns suggest that Nzema East may experience drier atmospheric conditions in the future, especially under high-emission scenarios. Combined with rising temperatures, this could increase evaporative demand and pose challenges for water balance and agricultural productivity. **Figure 40** shows the historical and projected mean RH patterns under SSP 5-8.5 and SSP 2-4.5 scenarios for Nzema East district, segmented into four periods: Historical (1990-2020), Near Future (NF, 2026-2050), Mid Future (MF, 2051-2075), and Far Future (FF, 2076-2100). The SSP 5-8.5 scenario (red) consistently shows higher temperatures compared to SSP 2-4.5 (green) across all locations, with notable and significant increases in the far future. Historical mean and future scenario means are marked with horizontal, continuous lines along with the standard deviations (dashed lines) for comparative analysis across different

timeframes and regions. Whereas Fig. 36 shows monthly relative humidity patterns across all time periods and scenarios for Nzema East district. The panels are ordered chronologically as historical (H), near-future (NF), mid-future (MF) and far-future (FF), from left to right respectively. The blue lines in the future projections are SSP2-4.5 scenarios and the orange lines in the projection phase are SSP5-8.5 scenarios.

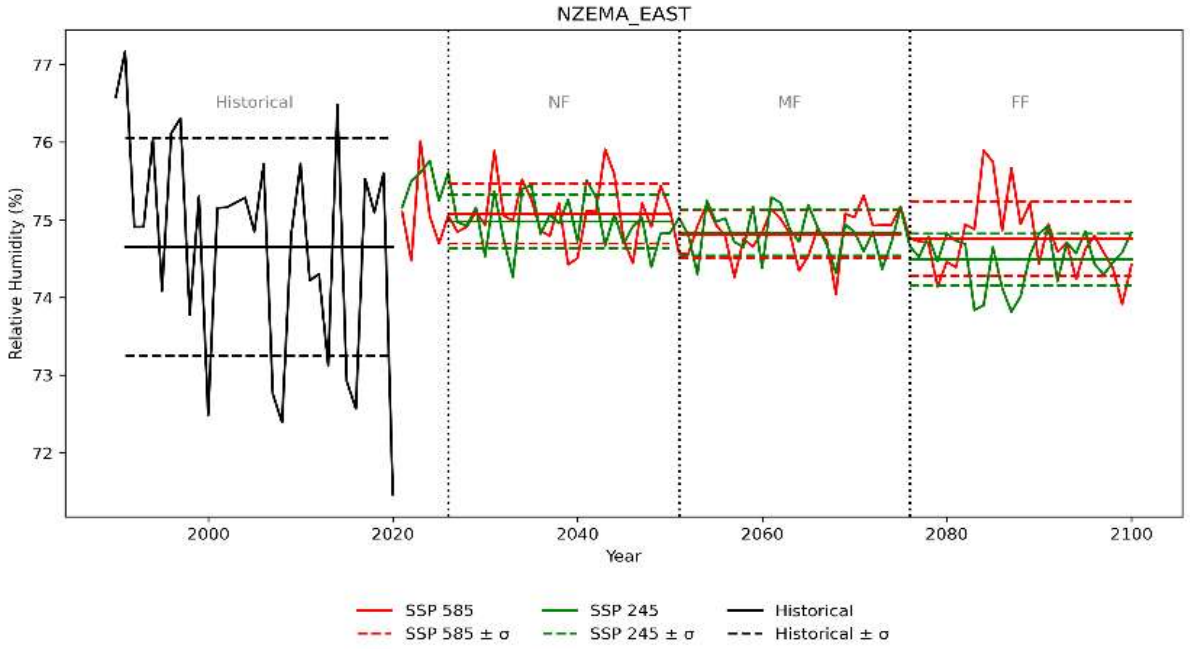

Figure 40: Historical and projected mean RH patterns under SSP 5-8.5 and SSP 2-4.5 scenarios for Nzema East district.

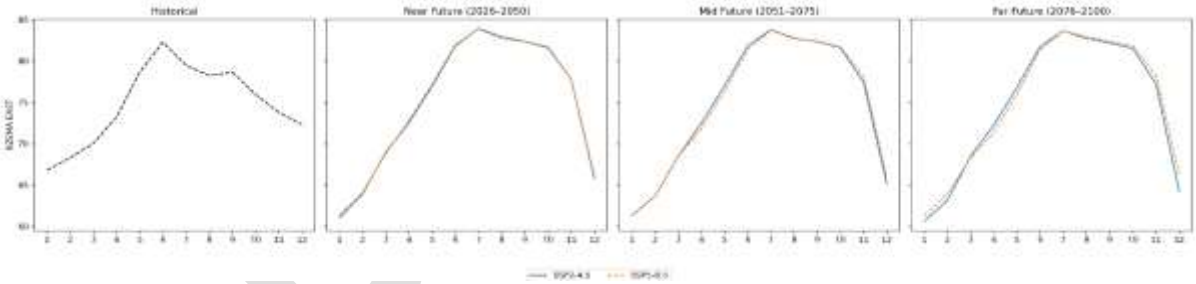

Figure 41: Monthly relative humidity patterns across all time periods and scenarios for Nzema East district. The panels are ordered chronologically as historical (H), near-future (NF), mid-future (MF) and far-future (FF), from left to right respectively. The blue lines in the future projections are SSP2-4.5 scenarios and the orange lines in the projection phase are SSP5-8.5 scenarios.

4.1.5 Summary of Climate Change Projections

Nzema East historically receives annual rainfall between 1350 mm and 1850 mm, with a mean of around 1580 mm. Under SSP2-4.5, rainfall remains close to historical levels throughout all future periods. SSP5-8.5, however, shows a decline from the mid-century onward, with mean

rainfall falling below the historical average by the far future. Rainfall variability narrows under both scenarios, particularly in the long term, suggesting more stable but potentially reduced rainfall under high emissions.

Rainfall indices show that total annual rainfall (RR) remains stable under SSP2-4.5 but declines slightly under SSP5-8.5. Extreme rainfall events (Rx1 and Rx5) and moderate to heavy rain days (R10mm and R20mm) decline across both scenarios, while the frequency of very wet days (R95p) increases. The total rainfall from these events (R95pTOT) decreases, indicating more frequent but less intense extremes. Rainfall intensity (SDII) also declines. Wet days (WD) and consecutive wet days (CWD) increase across all future periods, pointing to more frequent but weaker rainfall. Conversely, dry days (DD) and dry spells (CDD) shorten, suggesting less prolonged dry periods.

The district's rainfall seasonality remains bimodal, with peaks in June and October. This pattern persists, but the October peak weakens under both scenarios, leading to greater rainfall concentration between May and August. The gradual shift toward a more unimodal regime could limit the effectiveness of the secondary rainy season for farming.

Nzema East's annual temperature historically ranges from 25.0°C to 26.5°C, with an average around 25.5°C. Future projections show a steady increase under both scenarios. SSP2-4.5 reaches approximately 27.5°C by the far future, while SSP5-8.5 surpasses 29°C by the end of the century. Temperature indices confirm this warming trend, with significant increases in hot days (TX90p) and warm nights (TN90p), particularly under SSP5-8.5, where TX90p exceeds 180 days in the far future. Cool days (TX10p) and nights (TN10p) decline sharply, with TX10p nearly disappearing. The diurnal temperature range (DTR) narrows slightly, reflecting uniform warming during day and night.

The temperature cycle is unimodal, peaking from February to April and dipping between July and September. This structure persists but shifts upward due to consistent warming, with the most intense increases during the dry months and early transition seasons. By the far future, SSP5-8.5 projects monthly averages exceeding 29°C in the hottest months, intensifying heat stress risks.

Relative humidity in Nzema East historically ranges between 72 and 77 percent, averaging about 74.5 percent. Future projections show a gradual decline across all scenarios, with a sharper reduction under SSP5-8.5. Monthly humidity patterns peak from June to August and reach their lowest between December and February, a structure that persists. However, peak

values decline slightly under future conditions, especially in the drier months, indicating intensified atmospheric drying outside the rainy season.

These combined changes suggest that Nzema East could face greater challenges related to evapotranspiration and water management due to rising temperatures and atmospheric drying, particularly under high-emission scenarios.

4.2. Potential Impacts and Future Climate Change Risk

Climate change projections for Nzema East show consistent warming, shifts in rainfall seasonality, weakening of the secondary rainy season, and gradual atmospheric drying. These changes, when combined with the socio-economic realities of the municipality, translate into sector-specific risks. The following subsections outline the likely impacts on key livelihood and well-being domains, as structured in the vulnerability assessment.

4.2 Agriculture and Food Security

Agriculture in Nzema East remains predominantly rainfed, with a high dependence on farming and mixed farming in communities such as Avrebo, Nsein, and New Esuawua. The climate projections suggest multiple risks:

- *Rainfall reduction and variability:* The decline in mean rainfall under SSP5-8.5, coupled with the weakening of the October rainy season, threatens the reliability of planting and harvesting calendars. Farmers may experience shorter effective growing seasons.
- *Heat stress on crops*: Rising mean temperatures (up to +4°C by the far future under SSP5-8.5) will increase evapotranspiration, reduce soil moisture and increase irrigation demand.
- *Food security implications:* With farm sizes small and post-harvest losses already high, increased climate stress could exacerbate food insecurity, particularly in farming-dominated communities like Nsein and New Esuawua.
- *Livelihood vulnerability:* Limited adoption of climate-resilient practices and soil conservation measures in surveyed households' compounds sensitivity, making agricultural livelihoods highly vulnerable to projected climate stressors.

Overall, agriculture faces moderate to high future risk, particularly under high-emission scenarios.

4.2.2 Fisheries and Coastal Livelihoods

Fisheries and related activities are concentrated in Axim and Brawire, which also face high exposure to coastal hazards. The following risks emerge:

- Sea-level rise and erosion: With Axim and Brawire already exposed to coastal erosion (scores near 1.0), continued sea-level rise is expected to disrupt landing sites, damage canoes and gear, and increase relocation risks.
- Declining fish catch: Ocean warming and ecological shifts will reduce the availability of marine fish stocks, while the survey indicated fishing interruptions are already frequent during extreme events.
- Livelihood insecurity: In Brawire, where nearly half of households depend on fishing, the combination of declining catch and damaged infrastructure raises significant risks to income and food security.
- Future climate change may therefore undermine fisheries as a reliable livelihood source, with very high risk for Brawire and Axim.

4.2.3 Health

Health risks in Nzema East are shaped by both climatic hazards and limited health system resilience. From the projections and survey results:

- Heat-related illnesses: Projected warming, especially under SSP5-8.5, will increase risks of heat stress and cardiovascular strain, particularly among the elderly and outdoor workers (farmers, fisherfolk, traders).
- Water- and vector-borne diseases: Increased wet days and more frequent flooding could expand breeding grounds for mosquitoes, increasing malaria and dengue incidence. At the same time, water contamination during floods may elevate risks of diarrheal diseases.
- Infrastructure stress: Many health facilities are vulnerable to flooding, reducing service access during climate events.
- Existing vulnerability: Survey data indicated significant sensitivity from open defecation, use of unprotected wells, and inadequate water treatment at the household level, further heightening health risks.

The sector faces high future risk, particularly from compounding effects of heat stress and poor water, sanitation, and hygiene (WASH) conditions.

4.2.4 Water Resources

Water resources are critical for domestic, agricultural, and economic activities. Climate projections highlight the following risks:

- Reduced rainfall intensity and humidity: Despite more frequent wet days, the weakening of the secondary rainy season and projected atmospheric drying point to reduced effective water availability.
- Higher demand under warming: Rising temperatures will increase evapotranspiration and household water demand, further stressing supply systems.
- Local vulnerabilities: Survey results revealed frequent water shortages, reliance on unprotected sources, and high household expenditure on water, especially in Brawire and Nsein.
- Conflict risk: Competition over scarce water resources could intensify, as was already evident in reports of water-related disputes.

Overall, water resources in Nzema East face moderate to high risk, with the greatest stress expected in coastal and more urbanized zones.

4.2.5 Infrastructure and Human Settlements

Human settlements, particularly along the coast and flood-prone areas, are exposed to increasing climate hazards:

- Flooding and sea-level rise: Communities such as Axim, Brawire, and Avrebo face direct threats from recurrent flooding, storm surges, and erosion, with households already reporting past relocations.
- Housing quality: Many households occupy poorly constructed housing, increasing structural damage risks under windstorms and flooding.
- Critical facilities: Roads, health centres, and markets are often sited near vulnerable areas (e.g., riverbanks, low-lying coastal strips), making them highly exposed.
- Future intensification: Projected increases in heavy rainfall episodes and sea-level rise will amplify risks of infrastructure damage and displacement.

This sector faces high future risk, particularly in coastal settlements where both exposure and sensitivity are extreme.

4.2.6 Gender and Social Dynamics

The gendered impacts of climate change are pronounced in Nzema East, reflecting household roles and decision-making structures:

- Care burdens: Survey results show that climate impacts disproportionately increase caregiving burdens for women, particularly during water shortages, illness outbreaks, and food insecurity.
- Access and decision-making: Women reported limited access to land, credit, and information, while men often dominate farming and financial decisions. These gaps constrain adaptive capacity.
- Exposure of vulnerable groups: Women-headed households, elderly persons, and persons with disabilities are more sensitive to hazards, particularly during relocation and evacuation events.
- Projected risks: Future warming and resource stress will exacerbate these burdens, widening existing gender inequalities.

Gender and social dynamics therefore represent a cross-cutting area of vulnerability, with moderate to high risk depending on the community and livelihood type.

4.2.7 Natural Resources and Ecosystems

Nzema East Municipality is endowed with rich ecosystems, including mangrove forests, wetlands, rivers, and coastal habitats that provide critical ecosystem services such as shoreline protection, fish nursery grounds, water purification, and climate regulation. However, these ecosystems are highly vulnerable to projected climate change.

- **Mangroves and Coastal Wetlands**: Mangrove stands along the Ankobra River estuary and coastal fringes serve as natural buffers against coastal erosion, tidal flooding, and storm surges. Climate change impacts—particularly sea-level rise and increased coastal erosion—threaten to degrade or permanently submerge mangrove habitats. Salinization of estuarine wetlands is expected to intensify, potentially altering species composition and reducing fish nursery habitats. Loss of mangroves will directly affect local fisheries, biodiversity, and the resilience of shoreline communities such as Apewosika, Domunli, and Axim.
- **Forests and Terrestrial Ecosystems**: Inland areas of Nzema East host forest reserves and community-managed woodlands that support livelihoods through timber, fuelwood,

and non-timber forest products (NTFPs) like fruits, medicinal plants, and honey. Rising temperatures and longer dry spells are projected to increase the frequency of bushfires, leading to forest degradation and biodiversity loss. Agricultural expansion and charcoal production, compounded by climate stress, further weaken forest ecosystems, reducing their ability to regulate local microclimates and sustain water flows.

- **Freshwater Systems and Wetlands**: The Ankobra River and smaller tributaries are essential for irrigation, domestic use, and fishing. Projections of reduced rainfall intensity combined with higher evapotranspiration are expected to lower river flows and dry seasonal wetlands. This could compromise agricultural productivity, increase water scarcity, and trigger ecological imbalances. Reduced base flows in rivers will also diminish the self-cleansing capacity of waterways, exacerbating pollution risks from mining, farming, and settlements.
- **Biodiversity and Ecosystem Services**: The cumulative impacts of rising temperatures, habitat loss, and human pressures are expected to reduce biodiversity across both terrestrial and aquatic systems. Declines in pollinator populations (e.g., bees, butterflies) may affect crop yields, while fish stock depletion due to habitat loss will undermine food security. Ecosystem services such as soil fertility maintenance, water filtration, and storm protection are at risk, making households and livelihoods more exposed to climate hazards.

Summary of Risks

- **High exposure** to sea-level rise, coastal erosion, and salinization affecting mangroves and wetlands.
- **Moderate sensitivity** of inland forests and freshwater systems to heat stress, bushfires, and reduced flows.
- **Weak adaptive capacity** due to limited ecosystem restoration initiatives, low enforcement of conservation rules, and inadequate integration of ecosystem-based adaptation in district planning.

Nzema East faces differentiated but interlinked risks across sectors. Agriculture, fisheries, health, and infrastructure show high vulnerability under future climate conditions, while water resources and gender dynamics amplify these risks. Communities along the coast (Axim, Brawire, Avrebo) are at the highest overall risk, while inland communities such as Bamiankor and New Esuawua face more moderate but still significant challenges.

CHAPTER FIVE: IMPLICATIONS FOR ADAPTATION PLANNING

5.0. Introduction

The CRVA for Nzema East Municipal Assembly demonstrates that climate change is reshaping the municipality's ecological, economic, and social systems. Vulnerability arises not only from climate hazards but also from their interaction with development pressures, degraded ecosystems, and inequitable access to resources and services.

Geographically, Nzema East is exposed to multiple risks. Coastal settlements face sea-level rise, tidal surges, and shoreline erosion, which threaten housing, fishing infrastructure, and tourism assets. Inland areas are affected by erratic rainfall, prolonged dry spells, and rising temperatures, with direct consequences for cocoa farming, food crop production, and water availability. Ecosystems such as mangroves, wetlands, and forest reserves are increasingly degraded, reducing their role as natural buffers.

Socio-economic dependence on smallholder farming and artisanal fisheries heightens climate sensitivity. Weak storage and market systems amplify losses, while limited livelihood diversification restricts adaptive capacity. Rapid population growth, sand mining, and settlement expansion further strain land and natural resources.

Social vulnerabilities are unevenly distributed. Women carry disproportionate burdens in farming, fish processing, and water collection but remain excluded from finance, technology, and decision-making. Youth face declining employment opportunities and often migrate, while elderly persons and PWDs are particularly exposed during floods and other hazards yet remain marginal to adaptation planning.

Institutional weaknesses compound these challenges. Limited enforcement of land-use regulations, inadequate early warning systems, and resource constraints reduce the effectiveness of climate responses. While some climate actions have been integrated into municipal planning, adaptation remains fragmented and donor dependent.

As highlighted in Chapter 3, Nzema East communities are already employing a range of coping strategies and have identified possible interventions. However, these efforts are piecemeal and reactive. Building on that foundation, this chapter translates those proposals into a comprehensive framework for adaptation planning that is inclusive, cross-sectoral, and aligned with the Municipal Medium-Term Development Plan (MTDP) and Ghana's NAP.

This chapter therefore distills the implications of the CRVA for adaptation planning in Nzema East across four interlinked dimensions:

- Geographic implications – identifying hazard hotspots.
- Sectoral implications – assessing impacts on agriculture, fisheries, water, health, and infrastructure.
- Socially differentiated implications – examining gender, youth, elderly, and other vulnerable groups.
- Institutional and governance implications – highlighting the systems and resources required for effective adaptation.

Together, these dimensions provide an evidence base for sector-specific and cross-cutting strategies to guide Nzema East toward a climate-resilient development pathway.

5.1. Location-Specific Implications

The geography of Nzema East shapes distinct patterns of climate risk, producing uneven adaptation needs across coastal, inland, urban, and rural zones. Effective planning must therefore adopt a spatially differentiated approach that reflects these local realities.

- **Coastal settlements** such as Axim, Brawire, and Nsein face acute threats from sea-level rise, tidal flooding, and erosion. These hazards are already displacing households, destroying farmland, and undermining fisheries infrastructure. Adaptation in these areas must combine engineered defenses (revetments, groynes, drainage rehabilitation) with ecosystem-based solutions, including mangrove restoration and dune stabilization. In the most exposed neighborhoods, managed relocation should be planned in advance, guided by participatory processes and supported by social protection to safeguard livelihoods and cultural assets. Saline intrusion into groundwater further underscores the need for alternative water supplies through rainwater harvesting, boreholes sited outside saline zones, and, where viable, small-scale desalination.
- **Inland farming communities** such as Avrebo, Bamiankor, and New Esuawua are more vulnerable to erratic rainfall, dry spells, and soil fertility decline. These risks erode both subsistence and cash crop productivity, with direct implications for household income and food security. Adaptation must therefore prioritize climate-smart agriculture, including water-efficient irrigation, soil-moisture retention practices, agroforestry, and the promotion of drought-tolerant crop varieties.

Diversifying livelihoods beyond rain-fed farming—through aquaculture, agro-processing, and non-farm enterprises—is also critical. To complement these measures, localized climate information services should provide timely forecasts on rainfall onset, cessation, and dry spells to guide planting and harvesting decisions.

- **Urban areas**, particularly Axim, experience recurrent flooding linked to inadequate drainage, poor waste management, and unregulated settlement expansion into flood-prone zones. Adaptation here requires upgrading drainage networks, strengthening solid waste systems, enforcing land-use regulations, and integrating flood-risk zoning into urban planning.
- **Rural communities** are disproportionately affected by fragile infrastructure, with feeder roads, bridges, and health posts frequently damaged by floods and storms. In these settings, adaptation priorities must emphasize resilient basic services—climate-proofing transport networks, strengthening community health facilities, and supporting cooperatives to improve collective risk management.

Overall, these variations highlight the need for a **zonal adaptation strategy** that distinguishes between coastal defense and water security at the shoreline, climate-smart agriculture inland, flood-resilient urban planning in Axim, and rural infrastructure upgrading. A uniform approach would obscure these spatial differences, whereas a tailored strategy ensures that resources and interventions deliver maximum impact where risks are most severe.

5.2 Implication for Vulnerable Groups

The vulnerability assessment for Nzema East demonstrates clearly that climate risks are not evenly distributed across the population. Different groups face differentiated exposures, sensitivities, and barriers to adaptation. Recognizing these variations is essential, because adaptation strategies that fail to address social inequities may inadvertently deepen them.

- **Women and female-headed households** are disproportionately affected by climate change. In coastal towns such as Axim and Brawire, women dominate fish processing and petty trading, but their businesses are highly exposed to flooding, saltwater intrusion, and storm surges that disrupt markets and damage processing platforms. In inland farming communities, women often manage subsistence food crops while also bearing responsibility for household water and fuel collection. With rainfall variability and groundwater stress, this workload intensifies, reducing women's time for income-

generating activities and heightening risks of health complications. The adaptation implication is the need for gender-responsive measures—such as providing raised and improved fish-smoking platforms, supporting women's cooperatives with access to credit and insurance, and integrating women into disaster management committees so that their priorities shape local resilience planning.

- **Fisherfolk**, particularly artisanal fishers, also face acute risks. Coastal erosion and sea-level rise threaten landing sites and storage sheds, while warming waters and seasonal variability affect fish availability and increase the unpredictability of catches. Adaptation in this sector must go beyond physical protection to include diversification of livelihoods, investment in cold storage facilities to reduce post-harvest losses, and promotion of sustainable fishing practices. Partnerships with fisheries extension services and co-management groups can enhance adaptive capacity, but this requires deliberate municipal investment and alignment with national fisheries adaptation frameworks.
- **Youth** are another critical group. Climate risks reduce agricultural yields, destabilize fisheries, and increase migration pressures, leaving many young people with limited livelihood opportunities. In towns such as Avrebo and Bamiankor, youth outmigration is already eroding community resilience by reducing local labor supply. Adaptation planning must therefore include **green jobs and skills development**, enabling youth to find opportunities in renewable energy, aquaculture, agro-processing, or ecosystem restoration. This not only reduces the risks of unsafe migration but also positions young people as active agents of adaptation.
- **The elderly and persons with disabilities (PWDs)** represent groups often overlooked in planning but acutely vulnerable during climate shocks. Elderly farmers experience mobility and health challenges that make it difficult to adjust to longer farming hours under heat stress or to evacuate during floods. Similarly, PWDs are frequently excluded from emergency preparedness planning, which can leave them stranded during disasters. The implication for adaptation is the need for inclusive design standards—accessible evacuation shelters, early warning systems that reach all residents, and health services tailored to climate-sensitive diseases affecting older populations.
- **Migrant workers and transient populations**, especially in trading hubs like Elubo, face vulnerabilities linked to insecure tenure and limited social protection. With no permanent housing and restricted access to basic services, these groups are among the

least able to recover from climate shocks. Adaptation strategies here must integrate **social protection mechanisms** such as cash transfers or targeted livelihood support, while also ensuring that informal workers are included in municipal adaptation and disaster risk reduction programs.

Collectively, these differentiated vulnerabilities underscore the central implication that adaptation in Nzema East must be socially inclusive and equity-driven. Tailoring measures to the realities of women, fisherfolk, youth, the elderly, PWDs, and migrants will not only reduce their specific risks but also strengthen the resilience of the municipality as a whole. Without such attention, adaptation efforts risk privileging the most visible and resourced groups while leaving the most at-risk populations further behind.

5.3 Sectoral Implications

Agriculture and Food Security

Agriculture in Nzema East remains highly dependent on rainfall and traditional practices, with limited irrigation and low adoption of modern technologies. The CRVA findings highlight that increasingly erratic rainfall patterns, shorter wet seasons, and rising temperatures are already disrupting planting calendars and lowering yields. Soil fertility decline, post-harvest losses, and pest outbreaks compound these stresses. For adaptation, agriculture must be reoriented toward climate-smart practices, including drought-tolerant crop varieties, agroforestry, and improved water and soil conservation. Extension services will need to support farmers with timely climate advisories and technical knowledge, while investments in storage and processing infrastructure are critical to reduce losses. Strengthening farmer cooperatives and improving access to credit and insurance will further enhance resilience at the household level.

Fisheries and Coastal Livelihoods

Coastal livelihoods, particularly in Axim and Brawire, face severe exposure to sea-level rise, tidal surges, and coastal erosion. These hazards damage landing sites, fishing gear, and processing areas, directly threatening the livelihoods of fisherfolk and women processors. Ecological degradation, especially of mangroves, undermines breeding grounds essential for sustaining fish stocks. The implications for adaptation are clear: safeguarding fisheries and coastal livelihoods will require investments in ecosystem restoration, particularly mangrove rehabilitation and co-management. Fish processing infrastructure must be upgraded to raised, climate-resilient platforms, and diversification into aquaculture and alternative livelihoods

should be promoted. Ensuring access to credit, insurance, and safe landing facilities will also reduce the vulnerability of fishing communities.

Water Resources

Nzema East experiences a dual challenge of seasonal water scarcity and saline intrusion in coastal aquifers. Inland communities such as Avrebo and Nsein face shortages during prolonged dry spells, while settlements along the coast struggle with declining groundwater quality. Adaptation will therefore require integrated water resource management strategies that combine rainwater harvesting, small reservoirs, and borehole protection. Investments in water treatment and household-level filtration are equally critical to reduce the health risks of climate-driven contamination. Community water user associations can play a vital role in governance, ensuring equitable distribution and sustainable use of limited supplies, particularly during prolonged drought periods.

Human Health

Climate-sensitive diseases such as malaria, cholera, and diarrheal infections are likely to increase under rising temperatures and frequent flooding. Health facilities in Nzema East remain under-equipped, with poor drainage and infrastructure that is vulnerable to floods. The CRVA findings imply the need for significant investment in climate-proofing health facilities, ensuring they are resilient to floods, heat, and power disruptions. Strengthening disease surveillance systems and linking them to early warning mechanisms will be crucial for managing outbreaks. Public awareness campaigns on sanitation, heat stress, and safe water use should target vulnerable groups, while expanding affordable healthcare access remains essential for building community resilience.

Infrastructure and Human Settlements

Settlements in low-lying coastal zones such as Axim and Brawire are exposed to sea-level rise and erosion, while inland towns face repeated flooding and damage to road networks. Weak enforcement of planning and building codes has allowed settlements to expand into high-risk areas. Adaptation will require strict enforcement of land-use regulations, relocation planning for at-risk households, and investment in climate-resilient infrastructure. Roads must be redesigned with improved drainage systems, schools and markets elevated, and designated shelters equipped with safe WASH facilities and renewable energy. Expanding affordable

housing in safe zones will also be critical to reduce informal settlement growth in vulnerable areas.

Gender and Social Dimensions

Vulnerability in Nzema East is highly gendered and socially differentiated. Women, particularly those engaged in fish processing and farming, face intensified workloads due to climate shocks, while also carrying caregiving responsibilities. Youth face limited opportunities as climate-sensitive livelihoods decline, driving migration and loss of local labor. Elderly persons and persons with disabilities often remain excluded from adaptation initiatives and face mobility and health challenges during floods. Adaptation planning must therefore be explicitly gender-responsive and socially inclusive. This requires ensuring women's access to credit, safer workspaces, and participation in decision-making platforms, while also expanding youth employment opportunities in climate-resilient sectors. Adaptation infrastructure such as shelters, water systems, and health facilities must be designed to be accessible to all, ensuring that no group is left behind.

Natural Resources and Ecosystems

Wetlands, mangroves, and forest patches across Nzema East play a crucial role in buffering floods, stabilizing soils, and sustaining fisheries, yet they are increasingly degraded due to settlement expansion, sand mining, and unsustainable harvesting. Their continued loss will heighten exposure to floods and erosion, while reducing natural adaptive capacity. Adaptation planning must therefore prioritize ecosystem-based approaches, focusing on wetland and mangrove restoration, agroforestry, and landscape management. Community-led co-management frameworks, supported by traditional authorities, will be critical for sustaining these ecosystems. Incentive schemes such as payment for ecosystem services can also support conservation while providing alternative livelihoods for resource-dependent households.

5.4 Cross-Cutting and Systemic Implications

Adaptation in Nzema East cannot be approached purely at the sectoral or community level; it is shaped and constrained by systemic factors that cut across all dimensions of development. These factors — governance, finance, knowledge, and social equity — determine the success or failure of adaptation efforts. Addressing them is therefore fundamental for creating an enabling environment where local adaptation can thrive.

Governance and Institutional Capacity

The capacity of the Nzema East Municipal Assembly and its decentralized departments is a critical determinant of adaptation effectiveness. Weak enforcement of spatial planning regulations has allowed settlements to expand into wetlands and flood-prone coastal areas such as Axim and Brawire, exacerbating exposure to climate hazards. Similarly, institutional fragmentation has limited coordination between departments such as agriculture, fisheries, health, and works, resulting in adaptation initiatives that are piecemeal rather than integrated. Without stronger institutional linkages — both horizontally across departments and vertically with regional and national frameworks like Ghana's NAP — climate risks will continue to outpace response capacity. Building municipal governance capacity is therefore essential to mainstream climate considerations into all planning, monitoring, and service delivery functions.

Finance and Resource Mobilization

Adaptation planning in Nzema faces the persistent challenge of inadequate and unpredictable funding. Most climate-related interventions are donor-driven or project-based, leaving little fiscal space for sustained, locally owned responses. Limited internally generated funds further constrain the Assembly's ability to allocate resources for climate-sensitive investments. This creates a reliance on ad hoc external projects, which may not always align with municipal priorities. For effective adaptation, Nzema must strengthen its capacity to tap into diverse funding streams, including LoCAL performance-based grants, the Green Climate Fund, and bilateral partnerships. At the same time, municipal budgetary allocations need to explicitly earmark funds for adaptation actions in agriculture, fisheries, water, and health, ensuring continuity beyond project cycles.

Knowledge, Data, and Early Warning Systems

A major systemic implication is the absence of consistent climate data and early warning systems tailored to Nzema's realities. Local farmers and fisherfolk still rely largely on traditional knowledge, which is increasingly unreliable given the erratic nature of rainfall and temperature. Scientific projections exist but remain inaccessible to local users due to technical barriers and weak dissemination. This knowledge gap undermines adaptive decision-making, from crop selection to fishing schedules. Strengthening localized climate information services — delivered through radio, SMS, and extension networks — is critical to empower communities with actionable guidance. Equally important is the establishment of a district-level monitoring and learning framework that tracks the outcomes of adaptation investments and generates evidence to refine future planning.

Social Equity and Inclusion

The implications of climate change in Nzema are not evenly distributed; they are deeply shaped by gender, age, and social status. Women, who dominate fish processing and petty trading, face amplified burdens from market flooding, declining fish stocks, and limited access to credit or decision-making spaces. Youth experience disrupted schooling during floods and are forced into precarious migration due to the absence of sustainable livelihoods. Persons with disabilities (PWDs) and the elderly are often excluded from disaster preparedness and adaptation programmes, despite being among the most vulnerable during emergencies. If adaptation planning does not explicitly prioritize these groups, interventions risk deepening inequalities. Socially inclusive adaptation must therefore be mainstreamed — ensuring that investments in infrastructure, livelihood support, and governance processes are accessible, equitable, and responsive to the needs of all.

Table 9. Differential Impacts of Climate Hazards on Vulnerable Groups in Nzema East

Sector	Current Vulnerabilities	Future Climate Risks	Socio-Economic & Institutional Implications	Adaptation Priorities & Strategies	Potential Co-Benefits & Trade-Offs
Agriculture & Food Security	• Agriculture in Nzema East is dominated by rain-fed smallholder farming with limited irrigation. • Farm sizes are small, and dependence on staple crops is high. • Post-harvest losses are widespread due to poor storage facilities, weak market linkages, and lack of processing. • Soil conservation practices are limited, and farming near riverbanks increases exposure to flooding and erosion. Livestock ownership is minimal and climate-resilient practices are not widely adopted.	• Climate projections indicate shorter and less reliable rainy seasons, increasing temperature stress on crops, and declining rainfall intensity, especially under SSP5-8.5. • Pest and disease outbreaks are expected to intensify with warmer and wetter conditions, while soil fertility may decline under prolonged heat.	• Without adaptation, food insecurity will rise, farm incomes will fall, and poverty will deepen. • Younger populations may migrate, leaving elderly and women to manage farms. • Institutional weaknesses (extension services, credit access) will limit farmers' ability to adopt innovations.	• Promote climate-smart agriculture (CSA), including drought- and heat-tolerant crop varieties, soil moisture conservation, and agroforestry. • Expand irrigation and water harvesting. Strengthen post-harvest storage and market systems. • Train farmers in integrated pest management. Strengthen extension services and access to climate information.	• CSA improves productivity and resilience, enhances nutrition, and reduces rural poverty. • Agroforestry and soil conservation protect biodiversity and reduce erosion. However, initial investment costs are high, and uptake may be limited without strong institutional support.
Fisheries & Coastal Livelihoods	Artisanal fishing dominates, but fishers face recurrent gear loss and interruptions due to storms. Coastal erosion and mangrove degradation have worsened vulnerability. Over-reliance on fisheries limits livelihood diversity. In some areas,	• Sea-level rise and stronger storms threaten landing sites and coastal communities. • Warmer seas may shift fish stocks offshore, reducing catches. • Ecosystem degradation, including mangroves and	• Collapse of coastal livelihoods would push households into poverty and increase migration inland or to urban centers. • Conflicts over alternative income sources may rise.	• Invest in coastal defenses (seawalls, groynes) and soft measures like mangrove restoration. • Promote aquaculture and alternative livelihoods (eco-	• Ecosystem-based adaptation protects both fisheries and coasts. • Alternative livelihoods reduce poverty and diversify income. However, relocation and

	relocation is already under consideration.	lagoons, will reduce breeding grounds for fish.	• Weak enforcement of fishing regulations may worsen overfishing as stocks decline.	tourism, small businesses). • Introduce early-warning systems for storms. Support fisheries cooperatives to improve resilience.	aquaculture expansion may disrupt cultural ties and require significant community engagement.
Water Resources	Communities rely heavily on unprotected wells, streams, and costly sachet water. Access is uneven, and treatment practices are limited. Households report frequent shortages and conflicts over water, particularly during the dry season. Water infrastructure is weak, and NGOs play only a limited role in water protection.	• Projections show fewer intense rainfall events but more frequent wet days, alongside higher temperatures and reduced relative humidity. • Iincrease evapotranspiration and demand for water while reducing supply reliability.	• Water scarcity will increase competition between households, agriculture, and industry. • Health risks will rise from unsafe drinking water. • Without reliable water, agricultural productivity and food security will decline.	• Promote rainwater harvesting at household and institutional levels. • Invest in community reservoirs and small-scale dams. • Protect watersheds through reforestation and wetland conservation. • Scale up affordable household water treatment (filters, chlorination). • Strengthen by-laws on water resource management.	• Improved access to safe water reduces health burdens and enhances agricultural productivity. • Watershed conservation also protects biodiversity. However, infrastructure requires substantial investment, and community compliance with conservation may be uneven.
Health	Communities report frequent malaria, diarrheal disease outbreaks after floods and droughts, and increasing heat-related illness. Access to health services is limited, especially in smaller settlements. Sanitation gaps	• Rising temperatures will expand malaria transmission and increase heat-related illness. • Flood-related outbreaks of cholera and diarrhea will become more frequent.	• Disease burden will rise, affecting productivity and straining already weak health facilities. • Vulnerable groups—elderly, children, PWDs—will face	• Strengthen health systems, with climate-resilient infrastructure (elevated clinics, flood-proof facilities).	• Improved health systems save lives and reduce long-term costs. • Better sanitation also improves dignity and well-being. However,

	(open defecation, reliance on public toilets) increase vulnerability to waterborne diseases. Health facilities themselves are vulnerable to flooding.	• Health costs are projected to rise, straining household budgets.	disproportionate impacts. • Institutional response capacity (NADMO, health directorates) may be overstretched.	• Expand malaria control and vaccination programs. • Improve sanitation infrastructure and household hygiene practices. • Establish early-warning systems for floods and heatwaves. Train community health volunteers.	expanding health infrastructure requires sustained government and donor funding.
Infrastructure & Human Settlements	Housing is often poorly constructed, with weak materials and no climate-proofing. Drainage systems are limited, especially in peri-urban and rural areas. Coastal settlements face erosion and flooding, while inland ones are vulnerable to storms. Relocation is already considered in some communities.	• Projections show higher flood risks, coastal erosion, and storm surges. • Sea-level rise threatens low-lying settlements. • Heat stress will also increase demand for electricity and cooling infrastructure.	• Housing damage and displacement will increase, leading to higher recovery costs. • Schools, clinics, and roads are at risk of flooding and erosion. Informal settlements may expand as displaced people seek new housing.	• Enforce climate-resilient building codes. • Expand drainage infrastructure in urban areas. • Plan for managed relocation of the most at-risk coastal communities. Integrate climate risk into district spatial planning. • Invest in green infrastructure (urban trees, wetlands).	• Climate-resilient infrastructure reduces long-term losses and protects lives. • Green infrastructure improves urban livability and biodiversity. However, relocation may cause social tensions and loss of cultural heritage.
Gender & Social Inclusion	Women bear heavy caregiving and water-collection burdens, especially during climate stress. They have limited access to land,	• Climate change will amplify existing gender inequalities: women's unpaid labor will rise, female farmers will lose	• Widening gender gaps will undermine community resilience.	• Ensure women's and PWD participation in all adaptation committees.	• Greater gender equity strengthens household and community resilience.

	credit, and extension services. Decision-making is often male-dominated, and youth/women are underrepresented in committees. PWDs are often excluded entirely.	crops, and exclusion from adaptation planning will deepen vulnerability. PWDs face increased exclusion during evacuations and recovery.	• Female-headed households risk falling into deeper poverty. • Youth unemployment may worsen, increasing migration. • Without inclusion, adaptation plans may fail.	• Expand access to land, credit, and extension services for women. • Strengthen cooperatives and women's climate action groups. • Develop targeted training for youth and women in CSA and small businesses.	• Empowered women improve decision-making and innovation. However, cultural resistance may slow adoption, requiring sustained sensitization.
Natural Resources & Ecosystems	Deforestation, mangrove cutting, farming in wetlands, and sand mining degrade ecosystems. Biodiversity loss is evident in forests and coastal wetlands. Weak enforcement of natural resource by-laws limits conservation.	• Higher temperatures, sea-level rise, and changing rainfall threaten mangroves, forests, and wetlands. • Ecosystem collapse could reduce fish stocks, carbon sinks, and natural flood protection. Bushfire risks may also increase.	• Loss of ecosystems will erode natural defenses against floods and storms, increase soil erosion, and reduce cultural/ecological services. • Tourism potential (e.g., Ankobra River, coastal mangroves) may be lost.	• Promote ecosystem-based adaptation (EbA): mangrove and forest restoration, wetland conservation, agroforestry. • Establish community-based natural resource management committees. • Integrate EbA into district development planning.	• EbA provides co-benefits of biodiversity protection, tourism, and carbon sequestration. However, restrictions on resource use may reduce short-term incomes unless alternative livelihoods are provided.

5.5 Pathways for Climate-Resilient Development in Nzema East

The findings of the vulnerability assessment as summarised in Table 9 make it clear that adaptation in Nzema East must move beyond isolated, short-term responses toward a comprehensive and inclusive development agenda that integrates climate resilience into every sector and governance process. The following pathways are proposed as entry points for building a climate-resilient municipality that safeguards lives, secures livelihoods, and sustains ecosystems.

Strengthening Municipal Governance and Institutional Capacity

Effective adaptation begins with strong and capable institutions. For Nzema East, this requires embedding climate risk management into the core functions of the Municipal Planning and Coordinating Unit (MPCU) and sector departments. Planning regulations must be enforced to restrict settlement expansion into wetlands, riverbanks, and erosion-prone coastal zones. A Municipal Climate Adaptation Taskforce could be established to harmonize efforts across agriculture, fisheries, water, health, NADMO, and public works, ensuring that adaptation priorities are cross-sectoral and aligned with the Medium-Term Development Plan (MTDP) and Ghana's NAP.

Advancing Ecosystem-Based and Nature-Based Solutions

Ecosystem degradation is a major driver of vulnerability in Nzema. Restoring and co-managing mangroves and wetlands will protect fisheries nurseries, buffer against storm surges, and sustain biodiversity. Agroforestry and soil conservation techniques — such as planting shade trees, mulching, and contour farming — can stabilize soils and regulate microclimates in inland farming areas. Along the coast, nature-based defenses such as dune stabilization and re-vegetation should be piloted alongside hard engineering solutions to provide cost-effective and sustainable protection.

Building Climate-Resilient Infrastructure and Services

Infrastructure in Nzema East is highly exposed to flooding, coastal erosion, and extreme weather. Drainage systems in Axim and Brawire need upgrading to withstand intense rainfall events. Rural road networks should be improved with durable surfacing and culverts designed using updated rainfall intensity-duration-frequency (IDF) curves. Public facilities — including schools, health posts, and markets — must be climate-proofed through elevated foundations, reinforced roofing, and heat-mitigating designs. At the community level, multipurpose safe

shelters should be designated and retrofitted to serve during emergencies, with adequate WASH and renewable energy facilities.

Securing Water Resources and Sanitation Systems

The decline in rainfall reliability and saline intrusion into groundwater present growing water security challenges. Expanding household and institutional rainwater harvesting systems can reduce dependence on overstressed boreholes. Aquifer protection measures — such as recharge structures, borehole siting standards, and monitoring systems — are needed to safeguard water quality. Flood-resistant WASH infrastructure, improved waste management, and safe latrines will reduce contamination and disease outbreaks during extreme weather. Community water user groups can be strengthened to ensure sustainable and equitable management of small-scale water systems.

Supporting Climate-Smart Livelihoods and Coastal Economies

Given the heavy dependence of Nzema East on agriculture and fisheries, diversifying and climate-proofing livelihoods is a critical pathway. Farmers should be supported with resilient seed varieties, integrated pest management, small-scale irrigation systems, and training in climate-smart agriculture (CSA). Fisheries-dependent households need investments in mangrove restoration, resilient landing sites, improved fish-smoking technologies, and value-addition processing facilities. Women processors and traders should receive targeted support, including safer processing platforms, credit facilities, and insurance schemes. Youth need training and opportunities in green jobs such as eco-tourism, aquaculture, renewable energy, and sustainable construction.

Expanding Climate Information and Early Warning Systems

Local decision-making is severely constrained by weak climate information services. Farmers and fisherfolk need timely advisories on rainfall onset, storms, and tidal surges. Partnerships with the Ghana Meteorological Agency and NADMO should be strengthened to establish community-based early warning systems, disseminated through radios, SMS platforms, and local networks. At the same time, indigenous knowledge systems — such as seasonal indicators used by farmers and fishers — should be documented and integrated with scientific forecasts to ensure locally grounded and trusted adaptation guidance.

Mobilizing Finance for Adaptation

Building resilience in Nzema East requires sustained and predictable financing. The Municipal Assembly should earmark specific budget lines for adaptation within its annual action plans, while actively leveraging international climate finance mechanisms such as the Green Climate Fund and Adaptation Fund. Partnerships with UNCDF, UNDP, and bilateral donors should be deepened to access technical and financial support. Local private sector actors — particularly in construction, renewable energy, and agro-processing — can be incentivized to invest in climate-resilient ventures. Community-level savings groups and cooperatives also offer entry points for mobilizing grassroots finance for small-scale adaptation.

5.6. Conclusion

This CRVA for Nzema East Municipal Assembly has provided a comprehensive analysis of the municipality's exposure, sensitivity, and adaptive capacity in the context of a changing climate. The results underscore that climate change in Nzema East is a structural development challenge rather than a discrete environmental issue. Shifts in rainfall seasonality, increasing temperature extremes, and intensified hazards such as flooding, droughts, and coastal erosion are already manifesting, with profound implications for livelihoods, ecosystems, and infrastructure.

The assessment demonstrates that **exposure** in Nzema East is strongly shaped by its geographic position along Ghana's southwestern coast and its reliance on climate-sensitive sectors. **Sensitivity** is reinforced by socio-economic factors including dependence on smallholder agriculture and artisanal fisheries, limited water security, weak physical infrastructure, and persistent gender and social inequalities. Although **adaptive capacity** is present in the form of social networks, indigenous coping practices, and ongoing development initiatives, it remains constrained by institutional gaps, inadequate finance, limited access to technology, and insufficient integration of climate information into local planning.

From an adaptation perspective, the findings reveal the necessity of moving beyond reactive, sector-specific interventions toward a holistic and integrated approach. Adaptation in Nzema East must simultaneously address structural drivers of vulnerability, safeguard natural systems, and strengthen institutional and governance capacity. Priority areas include: advancing climate-smart agriculture and fisheries, enhancing water resource management, investing in resilient health and WASH systems, improving infrastructure design and spatial planning, and restoring critical ecosystems such as mangroves and wetlands. Equally important are cross-cutting measures — embedding climate risk into municipal planning and budgeting, ensuring gender-

responsive and socially inclusive adaptation, strengthening early warning and monitoring systems, and mobilizing sustainable finance.

In conclusion, the CRVA establishes a robust evidence base for mainstreaming climate resilience into Nzema East's Medium-Term Development Plan (MTDP) and aligning local adaptation actions with Ghana's NAP, the Paris Agreement, and the Sustainable Development Goals (SDGs). By pursuing the adaptation pathways outlined, Nzema East can reduce vulnerability, protect critical assets, and enhance human and ecological resilience. More broadly, the findings contribute to national and international discourse on locally grounded adaptation, offering insights into how place-specific vulnerabilities intersect with structural development challenges in coastal municipalities across West Africa.

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Appendix 1: LVI results for exposure, sensitivity and adaptive capacity

Nzema exposure by community

Community	Sea Level Rise	Coastal Erosion	Extreme Heat	Water Drying	Rainfall Qty	Wind Force	Temp	Drought	Flood Vol	Bush Fires	Exposure Index
Axim	0.711864	0.915254	0.309627	0.31186	0.522411	0.435704	0.506479	0.428571	0.193103	1	0.53349
Brawire	1	1	1	1	0.112849	0.316066	0.300743	0.135338	0.099819	0	0.49648
Bamiankor	0	0	0.031304	0.140456	0.202207	0.045533	0	0	0.389163	0.70851	0.15172
New Esuawua	0	0	0.288889	0.215366	0	0	0.081945	0.857143	0	0.704898	0.21482
Avrebo	0	0	0.084967	0	1	1	0.8684 5	1	1	0.910588	0.5864
Nsein	0	0	0	0.193127	0.957156	0.696299	1	0.214286	0.258621	0.62724	0.39467

Climate sensitivity in Nema

Community	Housing	Water Access	Water Treatment & Quality	Health	Gender & Social Burden	Livelihood & Income	Sensitivity Index
Axim	0.142673	0.252103	0.162281	0.347202	0.558246	0.39889	0.31023
Brawire	1	1	0.5	0.49216	0.435474	0.6235	0.67519
Bamiankor	0.810665	0	0.42	0.405195	0.666667	0.55766	0.4767
New Esuawua	0.154762	0.095765	0	0.333333	0.103242	0.506166	0.19888
Avrebo	0.827109	0.316748	0.289655	0.573737	0.183371	0.588475	0.46318
Nsein	0.017663	0.548776	0.544048	0.224447	0.208499	0.425638	0.32818

Adaptive capacity of Nzema by community

Community	Education & Information Access	Social Networks & Institutions	Livelihood Diversification	Infrastructure Resilience	Asset Ownership	Participation & Governance	Adaptive Capacity Index
Avrebo	0.105	0	0.094	0.082	0.454	0.763	0.250
Nsein	0.167	0.141	0.192	0.805	0.436	0.953	0.449
Axim	0.207	0.220	0.136	0.829	0.258	0.400	0.342
Brawire	0.154	0.079	0.310	0.333	0.212	0.769	0.309
New Esuawua	0.125	0.042	0.069	0.444	0.486	0.944	0.352
Bamiankor	0.364	0.056	0.138	0.312	0.250	0.978	0.349