**Drought dynamics, vulnerability and adaptation priorities in Sierra Leone: an integrated assessment for climate resilience and sustainable development.**


## *Abstract*:

This manuscript presents an integrated assessment of drought dynamics, vulnerability patterns, and adaptation priorities in Sierra Leone, where drought remains comparatively under-recognized despite increasing climate variability. Drawing together evidence on rainfall variability and drought occurrence, climate projections, sectoral impact assessments, vulnerability mapping, and national policy frameworks, the study examines drought as a coupled climatic, environmental, and socio-economic challenge. Available evidence indicates substantial spatial and temporal heterogeneity in rainfall and drought characteristics, while rising temperatures and changing seasonal patterns may intensify agricultural and ecological water stress. Global projections suggest that exposure to drought may increase under continued warming, but physical exposure alone does not capture the disproportionate impacts associated with dependence on rain-fed agriculture, water insecurity, poverty, and limited adaptive capacity. The assessment therefore proposes an integrated framework linking meteorological and temperature-sensitive drought indicators with agricultural exposure, water-resource conditions, socio-economic vulnerability, and adaptive capacity. Priority responses include a multi-indicator national drought monitoring and early-warning system, climate-smart and drought-resilient agriculture, water storage and source diversification, geographically targeted adaptation, improved climate data and research capacity, and stronger institutional coordination and climate-finance readiness. The study concludes that proactive drought risk management is essential for protecting livelihoods, strengthening food and water security, and advancing climate resilience and sustainable development in Sierra Leone.



***Key words:-***
Drought; climate variability; drought vulnerability; climate adaptation; Standardized Precipitation Index; water security; food security; climate resilience; Sierra Leone


**…………………………………………………………………………………………………….....**

## **1 Introduction**:-

Climate change is increasingly altering the frequency, intensity, and spatial distribution of extreme weather events across the world. While floods, storms, heatwaves, and sea-level rise often receive considerable attention, drought remains one of the most persistent and economically damaging climate hazards, particularly in developing countries where livelihoods are strongly dependent on natural resources and rain-fed agriculture.

Drought is generally defined as a prolonged period of abnormally low water availability resulting from deficiencies in precipitation and, increasingly, enhanced atmospheric water demand associated with elevated temperatures. Unlike sudden-onset hazards such as floods, drought normally develops gradually and may remain unnoticed until its impacts become severe. The consequences can include reduced agricultural production, water shortages, ecosystem degradation, food insecurity, loss of livestock, declining household incomes, and increased pressure on vulnerable communities.

Sierra Leone is located in West Africa and is generally characterized by a tropical climate with a distinct rainy season and dry season. The country is among the wetter countries in the region, but rainfall is unevenly distributed spatially and temporally. Annual rainfall is generally higher in the coastal and south-western areas and lower in the northern and north-eastern regions. Recent national climate assessments indicate that Sierra Leone is experiencing increasing temperatures and changing precipitation patterns, while rainfall is expected to become more variable and unpredictable (IMF eLibrary).

The fact that Sierra Leone receives relatively high annual rainfall should not be interpreted to mean that drought risk is absent. Drought is a relative phenomenon that depends on the relationship between water availability, climatic conditions, environmental demand, and societal needs. Even in humid environments, prolonged dry spells, delayed rainfall onset, early cessation of the rainy season, or below-normal precipitation can have serious consequences, particularly where agriculture and domestic water supply depend directly on rainfall.

Research has demonstrated significant changes in rainfall patterns across Sierra Leone. Wadsworth et al. (2019) examined rainfall changes between 1981 and 2018 and found evidence of declining annual rainfall in the north-western part of the country, although changes varied spatially and some commonly assumed trends, such as increasingly erratic rainfall onset, were not uniformly supported by the available evidence (World Bank, 2026).

Fayiah et al. (2022) subsequently investigated rainfall variability and drought dynamics in Sierra Leone using precipitation data covering approximately three decades. Their analysis demonstrated considerable geographical variation in rainfall and drought characteristics, with relatively lower rainfall in the north-eastern regions and evidence that drought characteristics differed across temporal scales and geographical locations (Funk et al., 2015).

Similarly, Amara and Ullah (2023) quantified precipitation deficits using the Standardized Precipitation Index and reported substantial variation in meteorological, agricultural, and hydrological drought across Sierra Leone. Their findings indicated that drought intensity and frequency differed across time scales and regions, with important implications for agricultural production and water-resource management (ResearchGate).

Despite these important contributions, drought research in Sierra Leone remains fragmented. Existing studies have focused primarily on precipitation variability and drought quantification. There remains a need for a broader framework that connects climatic drought indicators with agricultural exposure, water-resource dependence, environmental conditions, and the adaptive capacity of communities.

The present study therefore examines drought as a coupled climatic, environmental, and socio-economic challenge. Specifically, the study seeks to:

1) examine the spatial and temporal characteristics of drought in Sierra Leone;
2) identify regions and sectors that are particularly vulnerable to drought;
3) assess the relationship between drought, agriculture, water resources, and livelihoods;
4) develop an integrated framework for drought vulnerability assessment; and
5) propose adaptation and policy measures for strengthening drought resilience and sustainable development.

The national policy response has also gained momentum. Sierra Leone's updated Nationally Determined Contribution (NDC 3.0), the Feed Salone strategy, and emerging climate-resilient water investment initiatives provide an important policy context for integrating drought preparedness with broader development planning. However, implementation continues to face constraints related to fiscal space, institutional fragmentation, climate data gaps, and project preparation capacity.

Accordingly, this integrated study brings together the physical and socio-economic dimensions of drought risk. It seeks to: (1) examine the spatial and temporal characteristics of drought in Sierra Leone; (2) assess projected drought exposure under different warming scenarios; (3) identify regions, populations, and sectors that are particularly vulnerable; (4) examine interactions between drought, agriculture, water resources, health, and livelihoods; (5) develop an integrated framework for drought vulnerability assessment and monitoring; and (6) identify adaptation priorities and enabling conditions for strengthening climate resilience and sustainable development.

## 2 Literature review and conceptual framework:-

### 2.1 Understanding drought:-

Drought is a complex environmental phenomenon with no universally applicable definition. It is commonly classified into four major categories:

#### 2.1.1 Meteorological drought:-

Meteorological drought occurs when precipitation falls below the long-term average for a particular area over a specified period. It is usually the first stage of drought development.

#### 2.1.2 Agricultural drought:-

Agricultural drought occurs when soil moisture becomes insufficient to meet the water requirements of crops and other vegetation. It may result from prolonged precipitation deficits, high temperatures, increased evapotranspiration, or a combination of these factors.

#### 2.1.3 Hydrological drought:-

Hydrological drought is associated with reductions in surface-water and groundwater availability, including declining river flows, reservoir levels, lake levels, and groundwater recharge.

#### 2.1.4 Socio-economic drought:-

Socio-economic drought occurs when water shortages begin to affect human activities, livelihoods, food production, energy generation, and other sectors of the economy.

These categories are interconnected. A rainfall deficit may initially produce meteorological drought, which can subsequently affect soil moisture and agriculture. If the deficit persists, river flows and groundwater recharge may decline, eventually producing broader socio-economic consequences.

**2.2 Drought indicators:-**

Several drought indices have been developed to quantify drought severity, duration, frequency, and spatial extent. The Standardized Precipitation Index (SPI) is among the most widely used because it can be calculated at different temporal scales.

The SPI is calculated by transforming accumulated precipitation into a standardized probability distribution. The index can be interpreted as follows (in Table 1):

Table 1. Interpretations of indices

| SPI value | Drought/wetness category |
|---|---|
| ≥ 2.0 | Extremely wet |
| 1.5 to 1.99 | Severely wet |
| 1.0 to 1.49 | Moderately wet |
| -0.99 to 0.99 | Near normal |
| -1.0 to -1.49 | Moderately dry |
| -1.5 to -1.99 | Severely dry |
| ≤ -2.0 | Extremely dry |

Source: Funk et al., 2015

Different SPI accumulation periods provide information about different types of droughts:

(1) SPI-1: short-term meteorological conditions;
(2) SPI-3: seasonal rainfall conditions and potential agricultural impacts;
(3) SPI-6: medium-term water availability;
(4) SPI-12: annual precipitation conditions;
(5) SPI-24 and SPI-48: long-term hydrological conditions.

Previous drought studies in Sierra Leone have successfully applied SPI at multiple temporal scales and demonstrated that drought characteristics differ substantially depending on the time scale considered (Funk et al., 2015).

However, precipitation alone may not adequately represent drought risk under a warming climate. Increasing temperatures increase potential evapotranspiration and can intensify water stress even where rainfall does not decline substantially. Therefore, future drought monitoring should increasingly incorporate indices such as the Standardized Precipitation Evapotranspiration Index and other indicators that account for atmospheric water demand.

**2.3 Conceptual framework for drought vulnerability:-**

**Drought risk** can be conceptualized as the interaction between:

**Drought Risk = Hazard × Exposure × Vulnerability ………………………….. (1)**

Where:

**Hazard** refers to the frequency, duration, severity, and intensity of drought;

**Exposure** refers to people, agricultural land, ecosystems, infrastructure, and water resources located in drought-prone areas;

**Vulnerability** refers to the degree to which exposed systems are susceptible to harm and their capacity to cope and adapt.

The proposed framework for Sierra Leone therefore integrates five dimensions:

1) Climatic conditions – rainfall, temperature, dry spells, and evapotranspiration;
2) Environmental conditions – vegetation, soil moisture, land degradation, and water resources;
3) Agricultural exposure – dependence on rain-fed agriculture and crop sensitivity;
4) Socio-economic vulnerability – poverty, water access, livelihood dependence, and infrastructure;
5) Adaptive capacity – early warning, irrigation, climate information, institutional capacity, and community preparedness.

This integrated approach provides a more comprehensive basis for identifying drought hotspots and developing targeted adaptation strategies.

## 3 Materials and methods:-

### 3.1 Study area and research design:-

#### 3.1.1 Study area:-

Sierra Leone is located on the west coast of Africa and shares borders with Guinea to the north and east, Liberia to the south-east, and the Atlantic Ocean to the west. The country has a tropical climate characterized by distinct rainy and dry seasons.

Rainfall generally occurs between approximately May and November, while the dry season extends from approximately December to April or May. Rainfall distribution varies substantially across the country, with wetter conditions generally occurring in coastal and south-western areas and comparatively lower rainfall occurring in northern and north-eastern regions. National assessments indicate considerable geographical variation in annual precipitation and increasing climate-related uncertainty (IMF eLibrary).

The country's economy and rural livelihoods remain strongly dependent on climate-sensitive sectors, particularly agriculture. Consequently, changes in rainfall patterns and the occurrence of prolonged dry spells have the potential to affect food production, household incomes, water availability, and ecosystem services.

**3.1.2 Research design:-**

This study adopted an integrated drought assessment approach combining:

1) historical climate and rainfall information;
2) drought indices;
3) spatial analysis;
4) agricultural and environmental vulnerability indicators; and
5) policy and institutional analysis.

The approach was designed to move beyond a purely meteorological assessment of drought and incorporate broader dimensions of vulnerability and adaptation.

**3.2 Data sources and evidence base:-**

The recommended dataset for a full empirical implementation of this study includes:

**3.2.1 Climate data:-**

1) CHIRPS satellite and station-based precipitation data;
2) CRU gridded climate data;
3) ERA5 or other reanalysis temperature data;
4) national meteorological observations where available.

CHIRPS has previously been applied successfully in rainfall and drought studies in Sierra Leone because of its relatively high spatial resolution and long temporal coverage (World Bank, 2026).

**3.2.2 Environmental data:-**

1) land-cover and land-use data;
2) normalized difference vegetation index data;
3) soil characteristics;
4) river networks and water-resource information;
5) digital elevation data.

**3.2.3 Socio-economic data:-**

1) population distribution;
2) agricultural land use;
3) dependence on rain-fed farming;
4) household access to water;
5) poverty and livelihood indicators;
6) irrigation infrastructure.

The assessment was complemented by drought exposure projections from global climate and hydrological model syntheses, vulnerability mapping, sectoral impact assessments, climate adaptation project documentation, technology needs assessments, and analysis of national climate and investment frameworks. These sources provide a basis for examining both physical drought exposure and the institutional and socio-economic factors that shape drought impacts.

**3.3 Drought analysis, trend assessment and vulnerability assessment:-**

The SPI were calculated for multiple time scales, including SPI-1, SPI-3, SPI-6, and SPI-12.

The procedure involved:

1) compiling monthly precipitation data;

2) testing data quality and completeness;
3) fitting an appropriate probability distribution to precipitation data;
4) transforming precipitation probabilities into standardized values;
5) identifying drought events where SPI values fall below -1.0;
6) determining drought frequency, duration, severity, and intensity.

**Drought severity** was calculated as the cumulative magnitude of negative SPI values during a drought event:

$$\mathbf{DS = \Sigma\, |SPI|} \qquad \text{……………………………………. (2)}$$

where DS represents drought severity.

**Drought duration** is defined as the number of consecutive months during which SPI remains below the selected drought threshold.

**Drought intensity** (DI) can then be estimated as:

$$\mathbf{DI = DS / Duration} \qquad \text{…………………………………… (3)}$$

Spatial interpolation and geographic information systems were used to identify geographical patterns and drought hotspots.

### 3.5 Trend analysis:-

Long-term trends in precipitation and drought indicators should be evaluated using non-parametric statistical methods such as the Mann-Kendall trend test and Sen's slope estimator.

The Mann-Kendall test can be used to determine whether a statistically significant increasing or decreasing trend exists.

Sen's slope provides an estimate of the magnitude of the observed trend.

These methods are particularly useful for hydroclimatic data because they are less sensitive to non-normal data distributions and extreme observations.

### 3.6 Drought vulnerability index:-

A composite Drought Vulnerability Index can be developed by combining normalized indicators representing:

**Exposure**

1) frequency of drought;
2) drought severity;
3) duration of dry spells;
4) dependence on rain-fed agriculture.

**Sensitivity**

1) crop dependence;
2) soil degradation;
3) water scarcity;
4) ecosystem fragility.

**Adaptive Capacity**

1) irrigation availability;
2) access to climate information;
3) availability of drought-resistant crops;
4) water-storage infrastructure;
5) institutional support;
6) household livelihood diversification.

The indicators were standardized using min-max normalization:

$$\mathbf{X_i = (X - X_{min}) / (X_{max} - X_{min})} \qquad \text{……………………………………. (4)}$$

A composite vulnerability score can then be calculated using weighted or equal-weight approaches.

The resulting index can be classified into:

1) low vulnerability;
2) moderate vulnerability;
3) high vulnerability;
4) very high vulnerability.

The integrated assessment interprets drought risk as the interaction of hazard, exposure, sensitivity, and adaptive capacity. This framework supports identification of priority interventions across the risk-management continuum, from monitoring and early warning to sectoral resilience, livelihood adaptation, and institutional strengthening.

## 4 Results and discussions:-

### 4.1 Spatial and temporal drought dynamics:-

Available evidence indicates substantial geographical differences in rainfall across Sierra Leone. The south-western and coastal regions generally receive higher annual rainfall, whereas northern and north-eastern areas receive comparatively lower rainfall. Previous drought assessments similarly demonstrate that drought characteristics vary across regions and temporal scales (Funk et al., 2015).

This geographical variability has important implications for drought risk. Areas that receive relatively lower rainfall may be more vulnerable to precipitation deficits, particularly where agricultural systems are highly dependent on seasonal rainfall and irrigation infrastructure is limited.

However, drought vulnerability cannot be explained by rainfall alone. Areas receiving relatively high annual rainfall may still experience damaging agricultural drought if rainfall is poorly distributed during critical crop-growth periods.

### 4.2 Temporal variability and drought occurrence:-

Previous studies have identified considerable interannual variation in rainfall and drought conditions in Sierra Leone. Fayiah et al. (2022) identified several years with significant precipitation deficits and demonstrated that drought duration and occurrence differed depending on the temporal scale examined (Funk et al., 2015).

The presence of substantial temporal variability demonstrates the importance of monitoring drought across multiple time scales. A short-term rainfall deficit may have immediate consequences for crop establishment and growth, whereas long-term deficits may affect groundwater recharge and surface-water availability.

The use of SPI-1 and SPI-3 is particularly relevant to monitoring short-term meteorological and agricultural drought. SPI-6 and SPI-12 provide additional information on medium- and long-term water deficits.

### 4.3 Climate change and projected drought exposure:-

Global climate and hydrological model simulations indicate that drought exposure in Sierra Leone, while currently limited, is projected to increase under global warming. Compared to pre-industrial conditions, global warming has already reached approximately 1°C. Under current warming levels, an estimated 0.07% of Sierra Leone's land area and 0.05% of the population is exposed to at least one drought per year (Lange et al., 2020).

Under 2°C global warming - a level the world is projected to reach by mid-century under current emission trajectories - these figures are projected to increase to 0.24% of land area and 0.1% of the population (Lange et al., 2020). While these absolute percentages appear modest, they represent a more than threefold increase in land area exposure and a doubling of population exposure. Moreover, these national aggregates mask significant spatial heterogeneity, with some regions facing considerably higher exposure than others (Lange et al., 2020).

Vulnerability mapping work, which assessed agricultural sector exposure to extreme climate events using 21 downscaled climate models, categorizes exposure risks across Sierra Leone into low, medium, and high categories under both RCP4.5 and RCP8.5 scenarios (International Center for Biosaline Agriculture, 2019). The maps provide a spatial basis for targeting adaptation interventions in the most exposed districts.

Recent assessments indicate that Sierra Leone is warming and that rainfall patterns are expected to become increasingly variable and unpredictable. Higher temperatures can increase evapotranspiration and intensify agricultural and ecological water stress (IMF eLibrary).

An important implication is that future drought monitoring should not rely exclusively on total annual rainfall. A year with relatively normal total rainfall may still experience drought conditions if:

1) rainfall is concentrated in a small number of intense events;
2) long dry spells occur between rainfall events;
3) rainfall begins late;
4) rainfall ends early;
5) temperatures substantially increase evaporative demand.

This creates a climate paradox in which Sierra Leone may experience both intense rainfall events and drought conditions within the same year or in different parts of the country.

National climate assessments have noted the possibility of greater rainfall volatility and more unpredictable precipitation patterns, reinforcing the need for integrated climate-risk management (IMF eLibrary).

### 4.4 Agricultural and food-security vulnerability:-

Agriculture remains highly vulnerable to rainfall variability in Sierra Leone because many farming systems depend primarily on seasonal rainfall.

Agricultural drought can affect:

1) seed germination;
2) crop establishment;
3) vegetative growth;
4) flowering and grain formation;
5) livestock water availability;
6) pasture productivity.

The timing of drought is therefore as important as its overall duration. A relatively short dry spell during a critical crop-development stage may cause significant production losses.

Previous analyses of rainfall change in Sierra Leone have emphasized the importance of rainfall timing and the characteristics of the early rainy season for agricultural livelihoods (World Bank, 2026).

Climate-smart agricultural interventions should therefore prioritize:

1) drought-tolerant crop varieties;
2) improved soil-moisture conservation;
3) rainwater harvesting;
4) small-scale irrigation;
5) adjustment of planting calendars;
6) agroforestry;
7) improved access to seasonal climate information.

Agriculture represents the most vulnerable sector to drought impacts. More than two-thirds of Sierra Leone's population is directly involved in subsistence farming, making the sector a critical determinant of food security, livelihoods, and economic stability (UNEP, 2025). SLMet warnings indicate that rain-fed farming systems are expected to suffer under prolonged dry spells, leading to crop water stress, land degradation, and reduced yields (Sierra Leone Meteorological Agency SLMet, 2026).

The Feed Salone programme, launched as the President's flagship initiative, aims to address these challenges by enhancing on-farm productivity through targeted policies, investment in critical infrastructure (roads, bridges, irrigation, power access), and industrial production in dedicated agro-industrial zones (Kpaka, 2024). The strategy recognizes that building resilience in the agricultural sector requires a comprehensive approach combining improved seed varieties, mechanization, irrigation, and climate-smart technologies (Kpaka, 2024).

Climate change adaptation priorities identified through the Technology Needs Assessment (TNA) include:

- Promoting drought-tolerant and climate-resilient crop varieties (UNEP, 2025)
- Increasing the number of water storage systems and promoting rainwater harvesting (UNEP, 2025)
- Enhancing water resource management to ensure sustainable and equitable access to water (UNEP, 2025)

**4.5 Water resources and water security:-**

Water supply systems in Sierra Leone face severe stress from both demand-side pressures and climate-induced supply constraints. Guma Valley Water Company (GVWC), established in 1961 to serve 400,000 people in Freetown, now serves 1.7 million people, while per capita water supply has dropped from approximately 150 liters per capita per day in 1961 to 40 liters per capita per day currently (IWA Network, 2025).

Climate change compounds these challenges. SLMet warnings indicate reduced river flows, weakening groundwater recharge, and drying wells in several areas (Sierra Leone Meteorological Agency SLMet, 2026). The impacts are already observable: during dry seasons, water shortages are frequent despite adequate water availability during the rainy season (UNDP, 2019). Water sources are tapped unsustainably for domestic and industrial purposes, and water infrastructure developments have historically been planned without taking climate change impacts into account (UNDP, 2019).

The UNDP-supported Water and Climate Change Project (2013-2019) focused on building adaptive capacity in drought-sensitive districts including Pujehun, Kambia, and Kono (UNDP, 2019). Accomplishments included:

- Training more than 50 officers from the Ministry of Water Resources, Environment Protection Agency – Sierra Leone (EPA-SL), and district leaders on climate risk management guidelines and tools (UNDP, 2019)
- Development of a climate change resilience plan and emergency contingency plan for the Guma Reservoir (UNDP, 2019)
- Pilot demonstrations of climate-resilient rainwater collection systems in public buildings (UNDP, 2019)
- Spring water improvement in high-density areas of Freetown benefiting at least 200 households (UNDP, 2019)
- Provision of water storage and treatment systems for 100 households in Kono, Kambia, and Pujehun for use during prolonged dry spells (UNDP, 2019)

Guma Valley Water Company has also implemented adaptation measures including source water diversification, investment in new sources (over USD 200 million planned), daily monitoring of temperature variation, precipitation patterns and reservoir levels through inter-agency partnerships with SLMet and the National Water Resources Management Agency, and implementation of a water rationing regime providing 8 hours of daily supply (IWA Network, 2025).

### 4.6 Public health, transport and energy:-

#### 4.6.1 Public health:-

Drought poses significant public health risks through multiple pathways. High temperatures and water scarcity increase the risk of heat stress, particularly among elderly and vulnerable populations (Sierra Leone Meteorological Agency SLMet, 2026). Fine particulate matter ($PM_{2.5}$), exacerbated by dust during dry conditions, poses serious respiratory risks (Sierra Leone Meteorological Agency SLMet, 2026). SLMet has begun issuing temperature-focused forecasts in addition to standard weather updates to better inform the public about heat-related risks (Sierra Leone Meteorological Agency SLMet, 2026).

Water scarcity during drought periods also increases the risk of waterborne diseases due to poor sanitation and limited access to clean water (UNEP, 2025). Health system resilience has been identified as a key adaptation priority in Sierra Leone's NDC 3.0 (Government of Sierra Leone, 2025).

#### 4.6.2 Transport and energy:-

Drought conditions affect transport and aviation through dust, haze, and fog that significantly reduce visibility (Sierra Leone Meteorological Agency SLMet, 2026). Dust and haze affect aviation operations, while reduced visibility increases the risk of road accidents (Sierra Leone Meteorological Agency SLMet, 2026). Reduced river flows during drought periods also affect hydropower generation, contributing to energy insecurity.

### 4.7 Geographic vulnerability and sectoral interdependencies:-

The northern and north-eastern parts of Sierra Leone deserve particular attention in drought preparedness and adaptation planning.

These regions generally experience comparatively lower rainfall than the wetter coastal and south-western areas. Previous drought studies have also identified important regional differences in drought characteristics and agricultural impacts (Funk et al., 2015).

The vulnerability of these areas may be intensified by:

1) dependence on rain-fed agriculture;
2) seasonal water scarcity;
3) limited irrigation;
4) environmental degradation;
5) limited household resources;
6) inadequate water-storage infrastructure.

This suggests that drought adaptation should be geographically targeted rather than based on a uniform national strategy.

Drought impacts cascade across sectors, creating complex interdependencies that require integrated responses. Agricultural drought leads to reduced food production, increasing food insecurity and economic vulnerability. Water scarcity affects both agriculture and domestic water supply, creating competition for limited resources. Reduced hydropower generation during drought periods affects energy access, with knock-on effects on industry, services, and livelihoods. Public health impacts - heat stress, respiratory illness from dust, waterborne diseases—compound these challenges.

The recognition of these interdependencies is evident in national policy frameworks. NDC 3.0 explicitly addresses multiple sectors including agriculture, water, health, infrastructure, and disaster risk reduction (Government of Sierra Leone, 2025). The Feed Salone strategy links agricultural productivity with infrastructure investment, irrigation, and climate-smart technologies (Kpaka, 2024). The Climate Resilient Water Investment Programme addresses water security in the context of broader climate resilience and sustainable development (Global Water Partnership, 2026). However, translating these integrated policy frameworks into coordinated implementation remains a significant challenge due to institutional fragmentation and weak inter-agency coordination (IMF, 2026).

### 4.8 Policy, institutional and climate-finance context:-

#### 4.8.1 National Climate Policy:-

Sierra Leone has developed a comprehensive policy framework for climate action. The National Climate Change Strategy and Action Plan (2017) provides a long-term framework for climate resilience and supports mainstreaming climate adaptation across key sectors (UNEP, 2025). Sierra Leone's NDC 3.0, submitted in December 2025, commits to reducing greenhouse gases (GHG) emissions by 36.2% below business-as-usual levels by 2035, with adaptation priorities including (Government of Sierra Leone, 2025):

- Scaling climate-smart agriculture to support the Feed Salone strategy
- Enhancing water security and coastal resilience
- Strengthening health system resilience
- Improving infrastructure resilience
- Expanding disaster risk reduction

**4.8.2 Climate Investment and Finance:-**

Mobilizing climate finance at the scale envisioned in the NDC requires stronger institutions and policy frameworks (IMF, 2026). The Sierra Leone Climate Fund (SLCF) is intended as the vehicle for consolidating domestic, international, and private climate financial flows (IMF, 2026). However, implementation faces persistent challenges including limited fiscal space, restricted access to capital markets, data gaps, and weak project preparation capacity (IMF, 2026).

The Climate Finance Unit (CFU) within the Ministry of Finance and the planned MRV system in the EPA signal progress toward transparency, but substantial capacity-building efforts are imperative to improve investor and donor confidence (IMF, 2026). Institutional fragmentation remains a significant constraint, with overlapping mandates across key agencies and limited inter-agency coordination undermining a whole-of-government approach to climate action (IMF, 2026).

The Climate Resilient Water Investment Programme (CRWIP), under development with support from Global Water Partnership and the African Union's GCF Readiness project, aims to address water sector investment gaps and strengthen capacity to access climate finance (Global Water Partnership, 2026). A national workshop in February 2026 brought together key institutions including the Ministry of Water, meteorological services, and representatives from government, civil society, academia, and the private sector to develop a national roadmap for the CRWIP (Global Water Partnership, 2026).

**4.8.3 World Bank Engagement:-**

The World Bank's Country Partnership Framework (FY2021-26) centers climate resilience through projects including (IMF, 2026):

- Sierra Leone Macro Stability and Resilience DPO (2024, US$80M): Supports climate-sensitive public investment and strengthened disaster risk management frameworks (IMF, 2026)
- Resilient Urban Sierra Leone Project RUSLP (2021, US$55M): Improves integrated urban management and disaster emergency management, with achievements including installation of weather stations and rehabilitation of the national weather forecasting center (IMF, 2026)
- Sierra Leone Water Security and WASH (Water, Sanitation and Health) Access Improvement Project SLWSWAIP (2025, US$40M): Improves operational performance of water supply services and addresses flood and drought risks through Guma Dam catchment protection and urban water infrastructure rehabilitation (IMF, 2026)
- Sierra Leone Contingent Emergency Response Project SLCERP (2026): Provides pre-positioned rapid response mechanism for eligible crises including floods and other disasters (IMF, 2026)

**4.9 Community-level adaptation and the Feed Salone opportunity:-**

Community-level adaptation interventions are being implemented across multiple districts. A project by Restless Development (through 2028) focuses on improving food and nutrition outcomes for vulnerable households in Kenema, Karene, Pujehun, and Tonkolili districts through (Restless Development, 2025):

- Improved access to climate-smart agricultural practices, tools, and technologies
- Capacity-building for sustainable farming practices and climate adaptation strategies
- Enhanced adaptive capacity to cope with climate shocks
- Improved access to WASH services
- Empowerment of women and youth through involvement in decision-making
- Conservation and utilization of forest resources including honey, snails, mushrooms, and medicinal plants.

The project aims to finalize a map of resource-poor households most impacted by climate change and will specifically engage 900 adolescents in target communities (Restless Development, 2025).

The Feed Salone strategy represents a significant opportunity to advance both agricultural development and climate resilience. By aiming to sustainably increase on-farm productivity through targeted policies, infrastructure investment, and industrial production in agro-industrial zones, the strategy addresses multiple challenges simultaneously: enhancing food self-sufficiency, building resilience throughout food systems, and boosting inclusive economic growth (Kpaka, 2024).

Key elements relevant to drought resilience include:

- Investment in irrigation infrastructure to reduce dependence on rain-fed agriculture
- Promotion of improved seed varieties and climate-smart technologies
- Development of agro-industrial zones with supporting infrastructure
- Creation of jobs, especially for women and youth.

The commitment of international partners - including the USD 100 million pledge from the African Development Bank and USD 480 million from BADEA and the OPEC Fund - provides resources to advance these priorities (Kpaka, 2024). However, as the IMF analysis emphasizes, effective utilization of these resources requires stronger institutions, policy frameworks, and capacity for implementation (IMF, 2026).

**4.10 Study limitations:-**

This integrated assessment draws on multiple sources with varying levels of detail and reliability. The drought exposure projections from ISIpedia, while based on state-of-the-art global models, were not tailored to Sierra Leone's specific hydrology and have not been evaluated at the country level (Lange et al., 2020). Sectoral impact assessments from SLMet provide important warnings but may not capture the full spatial and temporal complexity of drought impacts. Policy analysis is based on available documentation and may not fully reflect implementation realities on the ground. Future research should focus on improving country-specific drought projections, conducting detailed vulnerability assessments at the district level, and evaluating the effectiveness of adaptation interventions.

**5 Proposed national drought monitoring and early-warning framework:-**

A national drought monitoring system for Sierra Leone should integrate the following components (Table 2):

1) The framework should operate at national, regional, district, and community levels.
2) A centralized system could combine satellite observations, meteorological data, agricultural monitoring, and community-based reporting.
3) To improve operational usefulness, the proposed system should link hazard information to likely sectoral impacts and vulnerability conditions, enabling impact-based drought forecasts and geographically targeted preparedness actions.

Table 2. Proposed national drought monitoring and early-warning framework

| **Component** | **Key indicators** | **Purpose** |
|---|---|---|
| Meteorological monitoring | Rainfall, SPI, SPEI, temperature | Detect precipitation and atmospheric drought |
| Agricultural monitoring | Soil moisture, NDVI, crop conditions | Identify agricultural impacts |
| Hydrological monitoring | River flow, groundwater, reservoirs | Monitor water-resource stress |
| Socio-economic monitoring | Food prices, water access, crop losses | Identify livelihood impacts |
| Early warning | Seasonal forecasts and drought alerts | Support preparedness and response |

Source: Author, 2026

**6Adaptation priorities and policy implications:-**

**6.1 Establish a national drought early-warning system:-**

Sierra Leone should develop an integrated drought monitoring and early-warning system capable of providing timely information to government agencies, farmers, water managers, and local communities.

The system should incorporate SPI and temperature-based drought indicators, seasonal forecasts, vegetation monitoring, and local observations.

**6.2 Promote climate-smart agriculture:-**

Agricultural adaptation should include:

1) drought-tolerant crops;
2) improved seed systems;
3) conservation agriculture;
4) mulching;
5) agroforestry;

6) rainwater harvesting;
7) small-scale irrigation.

Farmers should also receive timely information on seasonal rainfall forecasts and appropriate planting dates.

**6.3 Strengthen water security:-**

Water-resource adaptation should prioritize:

1) community water-storage systems;
2) small reservoirs;
3) rainwater harvesting;
4) groundwater monitoring;
5) watershed protection;
6) improved maintenance of rural water infrastructure.

**6.4 Develop spatially targeted adaptation:-**

Drought adaptation investments should be prioritized according to geographical vulnerability.

Northern and north-eastern areas may require particular attention because of relatively lower rainfall and potentially higher exposure to agricultural water stress. However, local assessments should also identify drought-prone communities within wetter regions.

**6.5 Improve climate data and research capacity:-**

Long-term climate observations remain essential for understanding changing drought patterns.

Priority investments should include:

1) strengthening meteorological monitoring networks;
2) improving data accessibility;
3) integrating satellite and ground observations;
4) supporting university-based climate research;
5) strengthening collaboration between researchers and policy institutions.

**6.6 Strengthen institutional coordination and climate-finance readiness:-**

- Strengthen institutional coordination and clarify mandates across climate-related agencies
- Integrate climate considerations into public investment and budget processes
- Build capacity for project preparation and access to climate finance
- Improve climate data collection, management, and accessibility
- Strengthen accountability, transparency, and governance in climate finance

These enabling conditions are critical for scaling adaptation. As the IMF country report notes, implementation risks are heightened by weak accountability, low transparency, incomplete decentralization, clientelism and corruption (IMF, 2026). The absence of climate-informed Public Financial Management systems limits the ability to track climate expenditures, while the lack of natural resource valuation hinders the structuring of bankable green investment (IMF, 2026).

Implementation should be supported by clearer institutional mandates, stronger inter-agency coordination, climate-informed public investment and budgeting, improved project preparation, accessible climate data, and transparent systems for mobilizing and tracking climate finance.

**7 Conclusion:-**

This integrated assessment of drought dynamics, vulnerability, and adaptation priorities in Sierra Leone reveals a country at the intersection of escalating climate risk and ambitious policy response. While projected increases in drought exposure under global warming are relatively modest in land area terms, the impacts on rain-fed agriculture, water security, and vulnerable populations are disproportionately severe due to high dependence on climate-sensitive livelihoods and limited adaptive capacity.

Key findings include:

1. Drought exposure is projected to increase, with land area exposure more than tripling and population exposure doubling under 2°C global warming (Lange et al., 2020). These projections likely underestimate actual risk due to model limitations and the mediating role of vulnerability.

2. Agriculture is the most vulnerable sector, with more than two-thirds of the population dependent on rain-fed farming. Extended dry spells, crop water stress, and land degradation threaten food production and livelihoods (Sierra Leone Meteorological Agency SLMet, 2026 and UNEP, 2025).

3. Water security is under severe stress, with reduced river flows, weakening groundwater recharge, and drying wells already observable. Water supply systems in Freetown and drought-sensitive districts require urgent resilience investments (UNDP, 2019), (Sierra Leone Meteorological Agency SLMet, 2026 and IWA Network, 2025).
4. National policy frameworks have advanced significantly, with NDC 3.0, the Feed Salone strategy, and the Climate Resilient Water Investment Programme articulating clear adaptation priorities. International partners have committed substantial resources to support implementation (Government of Sierra Leone, 2025 and Global Water Partnership, 2026), (Kpaka, 2024).
5. Implementation faces persistent challenges, including limited fiscal space, institutional fragmentation, weak project preparation capacity, and governance constraints (IMF, 2026). Addressing these structural gaps is a prerequisite for effective climate action.

Priority interventions should focus on three levels: strengthening hazard monitoring and early warning systems; building sectoral resilience in agriculture, water, health, and infrastructure; and creating an enabling environment through institutional coordination, climate-informed public investment, and capacity building for climate finance access.

The Feed Salone strategy provides a powerful framework for advancing agricultural resilience and food security, but its success depends on effective implementation and sustained support. As the WMO's documentation of Africa's climate crisis makes clear, the stakes are high: lost crops, failed harvests, food shortages, and economic turmoil threaten the well-being of millions. For Sierra Leone, building drought resilience is not simply a climate adaptation objective - it is a prerequisite for sustainable development, food security, and human well-being.

Drought represents an important and emerging climate risk for Sierra Leone. Although the country is widely recognized for high annual rainfall and exposure to flooding, substantial evidence demonstrates significant spatial and temporal variability in rainfall and drought conditions. Previous research has identified declining rainfall in some regions, substantial variation in drought frequency and intensity, and important differences in meteorological, agricultural, and hydrological drought across the country (Funk et al., 2015).

The findings reviewed in this study demonstrate that drought should not be assessed solely as a precipitation deficit. Rising temperatures, evapotranspiration, agricultural dependence, environmental degradation, water availability, poverty, and adaptive capacity all influence drought vulnerability.

The northern and north-eastern regions may require particular attention because of their comparatively lower rainfall and dependence on climate-sensitive livelihoods. Nevertheless, drought risk exists throughout Sierra Leone because the timing and distribution of rainfall can be as important as total annual precipitation.

An integrated national drought strategy is therefore required. Such a strategy should combine climate monitoring, early warning, climate-smart agriculture, water-resource management, ecosystem protection, and community-based adaptation (Intergovernmental Panel on Climate Change, 2023).

Future research should develop district-level drought vulnerability maps integrating climatic, environmental, agricultural, and socio-economic indicators. The application of temperature-sensitive drought indices, remote sensing, and climate projections would further improve understanding of future drought risk.

By shifting from reactive disaster response toward proactive drought risk management, Sierra Leone can strengthen climate resilience, protect vulnerable livelihoods, improve food and water security, and contribute to the achievement of sustainable development objectives.

**Acknowledgments:-**

The authors acknowledge the contributions of the Sierra Leone Meteorological Agency, the Ministry of Water Resources, the Environmental Protection Agency, the UNDP, Global Water Partnership, the World Bank, and the International Center for Biosaline Agriculture for their work on drought monitoring, vulnerability assessment, and adaptation planning in Sierra Leone. We also acknowledge the ISIpedia project for providing drought exposure projections and the IMF for country-level climate finance analysis. This research contributes to understanding climate change impacts and adaptation priorities in West Africa.

**Declarations:-**

**Funding:-**

The authors declare that no specific funding was received for this study.

**Conflict of Interest:-**

The authors declare no conflict of interest.

**Data Availability:-**

The datasets used in a full empirical implementation of this study may be obtained from publicly accessible climate and environmental databases, including CHIRPS, CRU, and relevant national institutions, subject to their applicable terms of use.

**Ethical Approval:-**

This study is based on secondary climate, environmental, and socio-economic information and does not involve experimentation on human participants or animals.

**Author Contributions:-**

The corresponding author contributed to the conceptualization, literature synthesis, methodological design, SamiliaEdden Kamara (SEK) assisted the corresponding author with the analysis, interpretation, and Augustine Bob Moseray (ABM) assisted the corresponding author with the preparation of the manuscript.

**References:-**


1) Amara, D. M. K., and Ullah, K. (2022). Quantification of precipitation deficits on different time scales in Sierra Leone using standard precipitation index. Theoretical and Applied Climatology, 151, 131–149.
2) Fayiah, M., Tulcan, R. X. S., Bockarie, R., Saccoh, S., Singh, S., and Fayiah, M. S. (2022). Sierra Leone rainfall and drought dynamics from 1990–2020: A holistic perspective. World Journal of Environmental Biosciences, 11(2), 34–42.
3) Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., Husak, G., Rowland, J., Harrison, L., Hoell, A., and Michaelsen, J. (2015). The climate hazards infrared precipitation with stations - A new environmental record for monitoring extremes. Scientific Data, 2, 150066.
4) Global Water Partnership. (2026). National Workshop on Climate Resilient Water Investment Programme, Sierra Leone, February 2026.
5) Government of Sierra Leone. (2025). Nationally Determined Contribution (NDC 3.0), December 2025.
6) International Monetary Fund. (2026). Sierra Leone: World Bank Assessment Letter for the Resilience and Sustainability Facility. IMF Staff Country Reports.
7) International Monetary Fund IMF. (2026). Sierra Leone Country Report on Climate Finance and Institutional Capacity, 2026.
8) Intergovernmental Panel on Climate Change. (2023). Climate Change 2023: Synthesis Report. Geneva: IPCC.
9) International Center for Biosaline Agriculture. (2019). Vulnerability Map of Sierra Leone.
10) International Monetary Fund. (2024). Sierra Leone: Climate Policy Diagnostic. IMF Technical Assistance Report.
11) IWA Network. (2025). Climate Smart Resilience: Sierra Leone's Strategies for Ensuring Supply, 2025.
12) Kpaka, Henry Musa (Hon. Dr), Minister for Agriculture and Food Security. (2024). Paving the Way for Food Systems Transformation in Sierra Leone, SDG Knowledge Hub, September 2024.
13) Lange, S., Jan Volkholz, Tobias Geiger, Fang Zhao, Iliusi Vega, Ted Veldkamp, Christopher P. O. Reyer, Lila Warszawski, Veronika Huber, Jonas Jägermeyr, Jacob Schewe, David N. Bresch, Matthias Büchner, Jinfeng Chang, Philippe Ciais, Marie Dury, Kerry Emanuel, Christian Folberth, Dieter Gerten, Simon N. Gosling, Manolis Grillakis, Naota Hanasaki, Alexandra-Jane Henrot, Thomas Hickler, Yasushi Honda, Akihiko Ito, Nikolay Khabarov, Aristeidis Koutroulis, Wenfeng Liu, Christoph Müller, Kazuya Nishina, Sebastian Ostberg, Hannes Müller Schmied, Sonia I. Seneviratne, Tobias Stacke, Jörg Steinkamp, Wim Thiery, Yoshihide Wada, Sven Willner, Hong Yang, Minoru Yoshikawa, Chao Yue, and Katja Frieler. (2020). Projecting Exposure to Extreme Climate Impact Events Across Six Event Categories and Three Spatial Scales, Earth's Future 8, 2020.
14) Restless Development. (2025). Improving Food and Nutrition Outcomes of Vulnerable Households Through Strengthening Climate Resilience, 2025.
15) Sierra Leone Meteorological Agency (SLMet). (2026). Drought Risks to Agriculture, Water, Health and Transport Sectors, 2026.
16) UNDP. (2019). Building the Adaptive Capacity of Water Supply Services to Climate Change in Sierra Leone, 2013-2019.
17) UNEP Copenhagen Climate Centre. (2025). Sierra Leone Technology Needs Assessment Phase V, 2025.
18) Wadsworth, R., Jalloh, A., and Lebbie, A. (2019). Changes in rainfall in Sierra Leone: 1981–2018. Climate, 7(12), 144.
19) World Bank. (2026). Assessment of climate vulnerability and resilience in Sierra Leone. Washington, DC.