ISSN:(O)2320-5407, ISSN(P)3107-4928 Int. J. Adv. Res. 14(09), September-2026, 1150-1166

ISSN (O): 2320-5407
ISSN (P): 3107-4928

Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/24201
DOI URL: http://dx.doi.org/10.21474/IJAR01/24201

RESEARCH ARTICLE

DROUGHT DYNAMICS, VULNERABILITY AND ADAPTATION PRIORITIES IN SIERRA LEONE: AN INTEGRATED ASSESSMENT FOR CLIMATE RESILIENCE AND SUSTAINABLE DEVELOPMENT

Alhaji Brima Gogra[1], Samilia Edden Kamara[2] and Augustine Bob Moseray[3]

1. School of Postgraduate Studies, Ernest Bai Koroma University of Science and Technology, Sierra Leone.
2. Faculty of Geography, Environment, Tourism and Sustainability Studies, Ernest Bai Koroma University of Science and Technology, Sierra Leone.
3. School of Public Health, Bo Campus, Njala University, Sierra Leone.

Manuscript Info

Manuscript History
Received: 12 July 2026
Final Accepted: 14 August 2026
Published: September 2026

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

Abstract

Drought is an important but comparatively under-recognized climate risk in Sierra Leone. Although the country receives relatively high annual rainfall, substantial spatial and temporal variability in precipitati on, prolonged dry spells, increasing temperatures, and dependence on rain fed livelihoods can create significant agricultural, hydrological, en vironmental, and socio - economic consequences. This study presents an integrated evidence assessment of drought dynamics, vulnerability, sectoral impacts, adaptation priorities, and the policy and institutional context in Sierra Leone. Rather than presenting a new national drought-index dataset or a newly calculated vulnerability index, the study synthesizes findings from published research, institutional assessments, climate risk projections, vulnerability assessments, and national policy documents. The assessment is organized around the relationship between drought hazard, exposure, sensitivity, and adaptive capacity. E xisting evidence indicates considerable geographical and temporal variability in drought characteristics, with comparatively lower rainfall and greater dependence on climate-sensitive livelihoods making parts of northern and north-eastern Sierra Leone important areas for targeted drought preparedness. Previous modelling also indicates that drought exposure may increase under higher global warming levels, although such projections require careful interpretation because they are based on global modelling frameworks rather than a country-specific empirical drought-risk model. Agriculture, water resources, health, transport, and energy are interconnected through drought-related changes in water availability and environmental conditions.

The policy review identifies opportunities through Sierra Leone's Nationally Determined Contribution (NDC 3.0), Feed Salone strategy, Climate Resilient Water Investment Programme, community-level initiatives, and climate-

Corresponding Author:-Alhaji Brima Gogra
Address:-School of Postgraduate Studies, Ernest Bai Koroma University of Science and Technology, Sierra Leone.

finance mechanisms, while also identifying institutional, financial, data, and implementation constraints. The study proposes an integrated drought-risk framework and a national drought monitoring and early-warning architecture linking meteorological, agricultural, hydrological, socio-economic, and community information. Priority actions include climate-smart agriculture, water storage and source diversification, improved climate information, geographically targeted adaptation, stronger institutional coordination, and improved access to climate finance. The assessment provides a basis for future district-level quantitative drought and vulnerability analysis and for strengthening proactive drought-risk management in Sierra Leone.

Introduction:-

Climate change is altering the frequency, intensity, duration, and spatial distribution of climate-related hazards worldwide. Drought is among the most persistent of these hazards and can produce substantial environmental, agricultural, economic, and social consequences, particularly in countries where livelihoods and essential services depend strongly on climate-sensitive natural resources.

Drought differs from many rapid-onset hazards because it normally develops gradually. A drought may begin with a precipitation deficit and subsequently affect soil moisture, vegetation, surface water, groundwater, agriculture, ecosystems, and human livelihoods. Its consequences may include reduced agricultural production, water shortages, food insecurity, livestock losses, declining household incomes, ecosystem degradation, and increased pressure on already vulnerable populations.

Sierra Leone is located on the west coast of Africa and has a tropical climate characterized by a pronounced rainy season and dry season. The country is among the wetter countries in West Africa, but rainfall is not distributed uniformly across space or time. Available assessments indicate generally wetter conditions in coastal and south-western areas and comparatively lower rainfall in northern and north-eastern parts of the country. Recent climate assessments also indicate increasing temperatures and changes in precipitation characteristics, creating additional uncertainty for climate-sensitive sectors (IMF, 2026; World Bank, 2026).

High annual rainfall does not eliminate drought risk. Drought is a relative condition determined by water availability in relation to climatic conditions, environmental demand, and societal needs. Prolonged dry spells, delayed rainfall onset, early cessation of rainfall, or precipitation deficits during critical agricultural periods can produce important impacts even in areas with relatively high annual rainfall.

Previous studies have documented substantial rainfall and drought variability in Sierra Leone. Wadsworth et al. (2019), examining rainfall between 1981 and 2018, reported spatially varying changes in rainfall, including evidence of declining annual rainfall in parts of north-western Sierra Leone. Fayiah et al. (2022) examined rainfall and drought dynamics over approximately three decades and identified substantial geographical and temporal variation. Amara and Ullah (2022) quantified precipitation deficits using the Standardized Precipitation Index (SPI) and reported differences in drought characteristics across temporal scales and locations.

These studies provide important evidence on precipitation variability and meteorological drought. However, drought impacts are not determined by climatic hazard alone. The consequences of drought depend on where people, agricultural systems, water infrastructure, ecosystems, and economic activities are located; their sensitivity to water stress; and their capacity to prepare for, cope with, and recover from drought.

There is therefore value in bringing together the physical, environmental, agricultural, socio-economic, and institutional dimensions of drought risk. Such an approach can help connect evidence on drought occurrence with the sectors and populations most likely to experience impacts and with the policies and investments intended to reduce those impacts.

The purpose of this paper is consequently not to present a new national SPI dataset, a new district-level drought map, or a newly calculated composite vulnerability index. Instead, the paper provides an integrated assessment of existing evidence and develops a framework for linking drought hazard with exposure, sensitivity, adaptive capacity, adaptation priorities, and policy implementation.

The specific objectives are to:-
1) synthesize available evidence on the spatial and temporal characteristics of drought in Sierra Leone;
2) examine evidence concerning projected drought exposure under different warming conditions;
3) identify populations, geographical areas, sectors, and livelihood systems that may be particularly sensitive to drought;
4) examine interactions between drought, agriculture, water resources, health, infrastructure, and livelihoods;
5) develop an integrated conceptual framework for drought vulnerability assessment and monitoring;
6) assess the relationship between existing policy initiatives and drought-resilience requirements; and
7) identify adaptation and institutional priorities that can strengthen drought resilience and sustainable development.

The paper therefore contributes primarily through integration and synthesis. Its contribution lies in connecting previously fragmented evidence on drought hazard, exposure, vulnerability, sectoral consequences, adaptation, and policy into a coherent national framework.

Literature Review and Conceptual Framework:-

Understanding drought:-

Drought is a complex phenomenon and no single definition captures all of its dimensions. Four broad categories are particularly relevant to Sierra Leone.

Meteorological drought:-

Meteorological drought occurs when precipitation remains below the expected level for a particular location and period. It is often the initial stage of drought development and can be assessed using precipitation-based indicators such as SPI.

Agricultural drought:-

Agricultural drought occurs when soil moisture and available water become insufficient to meet the requirements of crops, pasture, and livestock. It can result from insufficient precipitation, prolonged dry spells, high temperatures, increased evapotranspiration, or a combination of these conditions.Agricultural drought is particularly important in Sierra Leone because many farming systems depend on seasonal rainfall. The timing of rainfall deficits can be as important as the total magnitude of precipitation deficits.

Hydrological drought:-

Hydrological drought involves reductions in water availability in rivers, reservoirs, lakes, wetlands, and groundwater systems. It may develop after prolonged meteorological or agricultural drought and can continue after rainfall conditions begin to recover because hydrological systems respond more slowly.

Socio-economic drought:-

Socio-economic drought occurs when water shortages affect human activities and economic systems. Consequences may include reduced food production, water-supply constraints, increased food prices, reduced energy generation, health impacts, and loss of household income.These categories are interconnected. A precipitation deficit may initially produce meteorological drought, followed by soil-moisture stress and agricultural impacts. Continued deficits can reduce river flows and groundwater recharge, eventually affecting domestic water supplies, energy production, food security, and livelihoods.

Drought indicators:-

Drought indicators provide different perspectives on drought development and impacts. The Standardized Precipitation Index (SPI) is one of the most widely used precipitation-based indicators because it can be calculated over multiple accumulation periods.SPI transforms precipitation accumulated over a specified period into a standardized index.

Its conventional interpretation includes the following categories:-

Different accumulation periods provide information about different aspects of water stress. SPI-1 and SPI-3 are useful for short-term and seasonal precipitation conditions; SPI-6 can provide information about medium-term deficits; and SPI-12 and longer periods can provide information relevant to longer-term water availability.Previous research in Sierra Leone demonstrates the value of multi-timescale drought analysis.

However, the present assessment does not reproduce those calculations. The SPI findings discussed below (see Table 1) are therefore identified as evidence from previous studies rather than results generated by the present paper.Precipitation-based indices also have limitations under a warming climate. Increasing temperatures can increase atmospheric water demand and potential evapotranspiration. Consequently, a drought monitoring system for Sierra Leone should complement precipitation indicators with temperature-sensitive measures such as the Standardized Precipitation Evapotranspiration Index (SPEI), soil-moisture observations, vegetation indicators, and hydrological information.

Table 1. Interpretations of SPI values

SPI value	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

Conceptual framework for drought vulnerability:-

Drought risk can be represented conceptually as an interaction between hazard, exposure, and vulnerability:

$$\textbf{Drought Risk} = \textbf{Hazard} \times \textbf{Exposure} \times \textbf{Vulnerability} \quad (1)$$

where:

Hazard refers to the occurrence, frequency, duration, severity, and intensity of drought;
Exposure refers to people, agricultural land, ecosystems, infrastructure, water resources, and economic activities located in areas affected by drought; and
Vulnerability refers to the susceptibility of exposed systems to harm and their capacity to cope, adapt, and recover.

For the Sierra Leone context, vulnerability can be considered through three related components:-

Exposure:-
1) frequency of drought;
2) drought severity;
3) duration of dry spells;
4) dependence on rain-fed agriculture;
5) exposure of water resources and infrastructure.

Sensitivity:-
1) crop and livestock dependence on rainfall;
2) soil degradation;
3) water scarcity;
4) ecosystem fragility;
5) livelihood dependence on climate-sensitive activities.

Adaptive capacity:-
1) irrigation availability;
2) access to climate information;
3) availability of drought-tolerant crops;
4) water-storage infrastructure;
5) institutional support;
6) household livelihood diversification;
7) access to financial and technical resources.

The framework therefore links:-
Hazard → Exposure → Sensitivity → Adaptive Capacity → Drought Risk → Impacts → Adaptation

This framework should be understood as a basis for future empirical assessment rather than as a completed district-level vulnerability index. A quantitative vulnerability index would require a defined indicator dataset, normalization procedure, weighting scheme, sensitivity analysis, and validation. Those components are not calculated in the present study.

Materials and Methods:-

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 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 varies geographically, with coastal and south-western areas generally receiving more rainfall than northern and north-eastern areas.Agriculture is an important component of rural livelihoods, and dependence on seasonal rainfall increases the sensitivity of many households and production systems to changes in precipitation timing and availability.

Research design:-
The study adopts an integrated evidence-synthesis and policy-assessment design.

The evidence base comprises:-
1) peer-reviewed research on rainfall and drought in Sierra Leone;
2) climate and drought assessments from national and international institutions;
3) published drought exposure and vulnerability assessments;
4) documentation of adaptation programmes and climate-resilience initiatives;
5) national climate-policy and investment frameworks; and
6) evidence concerning sectoral impacts on agriculture, water, health, transport, energy, and livelihoods.

The approach is designed to distinguish clearly between:-
1) findings generated by previous studies;
2) information reported by institutional sources;
3) synthesis and interpretation undertaken in the present assessment; and
4) analytical methods proposed for future quantitative implementation.

No new national SPI series, district-level SPI maps, composite vulnerability scores, or statistical trend estimates are presented as original results in this paper.

Evidence sources:-
A future full empirical drought assessment would require a combination of climatic, environmental, spatial, and socio-economic datasets.

Climate data:-
Potential climate datasets include:-
1) Climate Hazards Infrared Precipitation with Stations (CHIRPS);
2) Climatic Research Unit (CRU) gridded climate data;
3) ERA5 or comparable reanalysis temperature data; and
4) observations from national meteorological stations.

CHIRPS has previously been applied in rainfall and drought studies because of its long temporal coverage and spatial characteristics (Funk et al., 2015).

Environmental data:-
A comprehensive vulnerability assessment would require:-
1) land-cover and land-use data;
2) vegetation indices such as NDVI;
3) soil characteristics;

4) river networks;
5) groundwater and other water-resource information; and
6) digital elevation data.

Socio-economic data:-
Relevant indicators would include:-
1) population distribution;
2) agricultural land use;
3) dependence on rain-fed agriculture;
4) household access to water;
5) poverty and livelihood indicators;
6) irrigation infrastructure; and
7) household-level adaptive-capacity indicators.

These data are identified as requirements for future quantitative implementation and are not presented here as a completed analytical dataset.

Proposed drought analysis:-
A future national empirical analysis could calculate SPI at multiple timescales, including SPI-1, SPI-3, SPI-6, and SPI-12.

Such an analysis would require:-
1) compilation of monthly precipitation data;
2) quality-control and completeness assessment;
3) treatment of missing observations;
4) selection and fitting of an appropriate probability distribution;
5) transformation of precipitation probabilities into standardized values;
6) identification of drought events using a predefined threshold;
7) calculation of event frequency, duration, severity, and intensity; and
8) spatial analysis of drought characteristics.

Drought severity (DS) could be represented by the cumulative magnitude of negative SPI values during an event:-

$$\mathbf{DS = \Sigma\ |SPI|} \qquad \textbf{(2)}$$

where DS represents drought severity.
Drought duration would be defined as the number of consecutive periods for which SPI remains below the selected drought threshold.

Drought intensity (DI) could subsequently be expressed as:-

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

These equations describe the proposed analytical framework; they do not represent calculations performed in the present assessment.

Proposed trend analysis:-
A future empirical analysis could examine long-term trends using the Mann-Kendall test and Sen's slope estimator. The Mann-Kendall test can assess whether a monotonic trend exists, while Sen's slope can estimate the magnitude of the trend. For hydroclimatic data, appropriate treatment of serial correlation would be required.

A reproducible implementation should report:-
1) test statistic;
2) p-value;
3) Sen's slope;
4) confidence interval;

5) significance threshold;
6) treatment of serial correlation;
7) temporal period analyzed; and
8) spatial aggregation procedure.

Because these calculations were not undertaken for the present assessment, no trend statistic or statistical significance value is reported.

Proposed drought vulnerability assessment:-

A district-level Drought Vulnerability Index could subsequently be developed from normalized indicators representing exposure, sensitivity, and adaptive capacity.

The normalization of a positively oriented indicator could use:-

$$X_i = (X - X_{min}) / (X_{max} - X_{min}) \quad (4)$$

However, selection of indicators and weighting methods can substantially affect composite vulnerability results. Therefore, a future empirical study should explicitly justify:-

1) indicator selection;
2) direction of each indicator;
3) normalization procedure;
4) weighting method;
5) aggregation method;
6) treatment of missing data;
7) sensitivity of results to alternative weights; and
8) validation against observed drought impacts.

The present paper does not assign district-level vulnerability scores or vulnerability classes because the necessary empirical dataset and validation procedure have not been completed.

Policy assessment approach:-

The policy assessment examines major climate, agricultural, water, adaptation, and investment initiatives according to five dimensions:-

1) drought-related objective;
2) target sector;
3) geographical relevance;
4) implementation context; and
5) identified implementation or evidence gap.

This approach moves the policy discussion beyond a purely descriptive listing of programmes and connects policy instruments to the drought-risk pathways identified in the evidence synthesis.

Results and Evidence Synthesis:-

Spatial and temporal drought characteristics:-

Available evidence indicates substantial geographical differences in rainfall across Sierra Leone. Coastal and south-western areas generally receive greater rainfall, while northern and north-eastern areas tend to receive comparatively lower rainfall.

Previous drought studies have also reported geographical and temporal differences in drought characteristics. Fayiah et al. (2022) documented substantial rainfall variability and differences in drought conditions over time and across locations, while Amara and Ullah (2022) demonstrated variation in precipitation deficits across temporal scales.

These findings indicate that drought risk cannot be represented adequately by a single national rainfall average. A national drought monitoring system should account for differences among regions and should operate at sufficiently fine spatial and temporal scales to identify localised water stress.

At the same time, lower annual rainfall does not automatically imply higher drought impacts. Areas with relatively high annual rainfall may also experience agricultural drought if rainfall is poorly distributed during critical crop-development periods.

Temporal variability and drought occurrence:-

The existing evidence demonstrates the importance of considering drought at multiple timescales. Short-term rainfall deficits may affect crop establishment and early growth, while longer deficits can influence soil moisture, groundwater recharge, river flows, and water supplies. Consequently, SPI-1 and SPI-3 can provide useful information for short-term and seasonal monitoring, while SPI-6 and SPI-12 can provide information relevant to longer periods of accumulated water deficit. The existing literature supports the need for such monitoring, but the present study does not generate a new SPI time series. Future quantitative work should therefore produce national and district-level SPI-1, SPI-3, SPI-6, and SPI-12 results and assess drought frequency, duration, severity, intensity, and trends.

Climate change and projected drought exposure:-

Existing global climate and hydrological modelling provides evidence that drought exposure in Sierra Leone may increase under higher levels of global warming.

Lange et al. (2020) estimated that, at approximately 1°C global warming relative to pre-industrial conditions, around 0.07% of Sierra Leone's land area and 0.05% of its population could be exposed to at least one drought per year. Under 2°C warming, the corresponding estimates increase to approximately 0.24% of land area and 0.1% of population.

These figures are reported results from Lange et al. (2020), not calculations undertaken by the present study. They illustrate a projected increase in exposure but should not be interpreted as a country-specific estimate of total future drought risk.

Similarly, the International Center for Biosaline Agriculture (2019) produced vulnerability mapping based on downscaled climate information and classified agricultural exposure into different risk categories under RCP4.5 and RCP8.5 scenarios. These results provide useful spatial context but are likewise secondary evidence.

The interpretation of climate projections requires caution. Global model products may not fully represent Sierra Leone's local hydrology, rainfall processes, groundwater systems, agricultural practices, or socio-economic conditions. Future country-specific analysis should therefore combine climate projections with local observations and vulnerability indicators.

A further consideration is that drought can occur even when annual rainfall totals appear relatively normal. Risk can increase when:-

1) rainfall is concentrated into fewer intense events;
2) prolonged dry spells occur between rainfall events;
3) rainfall onset is delayed;
4) the rainy season ends earlier; or
5) higher temperatures increase atmospheric water demand.

The combination of intense rainfall and intervening dry periods creates a complex climate-risk environment in which flood and drought risks can occur within the same year or in different parts of the country.

Agricultural and food-security vulnerability:-

Agriculture is highly sensitive to rainfall variability in Sierra Leone because many farming systems depend on seasonal precipitation.

Agricultural drought can affect:-

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

The timing of rainfall deficits is therefore important. A relatively short dry period occurring during a critical crop-development stage can have consequences disproportionate to its duration.Available assessments identify rain-fed agriculture as a major pathway through which climate variability can affect food security and livelihoods (UNEP, 2025; Sierra Leone Meteorological Agency, 2026).Rather than characterizing agriculture as categorically "the most vulnerable sector" without a comparative quantitative assessment, it is more appropriate to describe agriculture as a highly drought-sensitive and climate-dependent sector. Its importance arises from the interaction of rainfall dependence, household livelihoods, food production, and limited irrigation in many farming systems.

Climate-resilient agricultural measures identified in the evidence base include:-
1) drought-tolerant crop varieties;
2) improved seed systems;
3) soil-moisture conservation;
4) conservation agriculture;
5) mulching;
6) agroforestry;
7) rainwater harvesting;
8) small-scale irrigation;
9) adjustment of planting calendars; and
10) improved access to seasonal climate information.

The Feed Salone strategy provides an important policy context for these interventions. Its emphasis on agricultural productivity, infrastructure, irrigation, improved seeds, mechanisation, and climate-smart technologies creates opportunities to integrate drought resilience into broader agricultural transformation (Kpaka, 2024).The Technology Needs Assessment (TNA) also identifies drought-tolerant and climate-resilient crops, water storage, rainwater harvesting, and improved water-resource management as relevant adaptation measures (UNEP, 2025).

Water resources and water security:-
Drought risk in Sierra Leone extends beyond agricultural production to water supply and water security. The pressure on water systems is illustrated by the experience of Guma Valley Water Company. IWA Network (2025) reports that the system, established in 1961 to serve approximately 400,000 people, now serves a much larger population, while reported per-capita water availability has declined substantially. Climate-related pressures can compound existing demand and infrastructure challenges. SLMet has identified concerns related to reduced river flows, groundwater recharge, and drying wells during dry periods (Sierra Leone Meteorological Agency, 2026). Earlier adaptation work supported by UNDP also identified water-supply vulnerabilities in drought-sensitive districts. The Water and Climate Change Project supported capacity building, climate-risk planning, rainwater collection demonstrations, spring-water improvements, and household water-storage and treatment systems (UNDP, 2019). Guma Valley Water Company has also pursued adaptation measures including diversification of water sources, development of new sources, monitoring of climatic and reservoir conditions, and water-rationing measures (IWA Network, 2025).

These examples demonstrate that drought resilience in the water sector requires both supply-side and demand-side measures. Relevant measures include:-
1) community water-storage systems;
2) small reservoirs;
3) rainwater harvesting;
4) groundwater monitoring;
5) watershed protection;
6) source diversification;
7) improved rural water infrastructure; and
8) climate-informed planning of major water infrastructure.

The present study does not provide a new hydrological analysis of river flow, groundwater recharge, or reservoir storage. These should be priorities for future empirical drought-risk monitoring.

Public health, transport, and energy:-
Drought impacts can propagate across sectors.

Public health:-
High temperatures and water shortages can increase exposure to heat stress and other health risks. Dry conditions can also increase dust and particulate matter, creating potential respiratory concerns. SLMet has identified heat and dry-condition risks and has expanded temperature-related forecasting and public information (Sierra Leone Meteorological Agency, 2026).Water shortages can also increase risks associated with inadequate sanitation and reduced access to safe water. Health-system resilience is therefore incorporated among the adaptation priorities of NDC 3.0 (Government of Sierra Leone, 2025).These pathways demonstrate that drought preparedness should not be restricted to agricultural agencies. Health institutions, water authorities, local governments, and disaster-risk-management institutions also require drought information.

Transport and energy:-
Dry-season dust and haze can reduce visibility and affect road and aviation operations. Reduced river flows may also affect hydropower generation, with potential implications for electricity availability and economic activity (Sierra Leone Meteorological Agency, 2026).These impacts demonstrate the importance of an integrated drought-monitoring system capable of translating meteorological conditions into sector-specific risk information.

Geographic vulnerability and sectoral interdependencies:-The northern and north-eastern parts of Sierra Leone warrant particular attention in drought preparedness because of comparatively lower rainfall and the importance of climate-sensitive livelihoods.

Potential factors contributing to vulnerability include:-
1) dependence on rain-fed agriculture;
2) seasonal water scarcity;
3) limited irrigation;
4) environmental degradation;
5) limited household resources; and
6) inadequate water-storage infrastructure.

However, geographical targeting should not be interpreted as evidence that drought risk is absent elsewhere. Drought can affect wetter areas when rainfall timing changes, dry spells become prolonged, or atmospheric water demand increases.The evidence also indicates that drought impacts are interconnected across sectors. Agricultural drought can reduce food production and household income. Water scarcity can affect both agricultural and domestic use. Reduced river flows can affect energy production. Health risks can increase when heat, dust, and inadequate water and sanitation occur simultaneously.These interdependencies support a national approach in which drought monitoring is connected to sectoral preparedness rather than treated exclusively as a meteorological issue.

Policy, institutional, and climate-finance context:-
Sierra Leone has developed a number of policy and investment initiatives relevant to climate resilience.

National climate policy:-
The National Climate Change Strategy and Action Plan provides a framework for climate resilience and mainstreaming adaptation.

NDC 3.0, submitted in December 2025, establishes national mitigation and adaptation commitments. The document identifies priorities including:-
1) climate-smart agriculture;
2) water security and coastal resilience;
3) health-system resilience;
4) infrastructure resilience; and

disaster-risk reduction (Government of Sierra Leone, 2025).
These priorities overlap substantially with the drought-risk pathways identified in this assessment.

Climate investment and finance:-
Implementation of adaptation measures requires adequate financial resources as well as institutional capacity The IMF (2026) identifies constraints including limited fiscal space, restricted access to capital markets, data gaps, and limited project-preparation capacity. The Sierra Leone Climate Fund is intended to help consolidate domestic, international, and private climate-finance flows. The Climate Finance Unit and planned monitoring, reporting, and

verification arrangements also provide mechanisms for strengthening climate-finance transparency. The Climate Resilient Water Investment Programme, supported through international partnerships, is intended to address water-sector investment gaps and improve capacity to access climate finance (Global Water Partnership, 2026). These initiatives indicate that the challenge is not simply identifying adaptation measures. It also involves developing bankable projects, improving data systems, clarifying institutional responsibilities, strengthening accountability, and maintaining the capacity required to implement and monitor investments.

International development engagement:-

International development programmes provide additional support for climate resilience. The World Bank-supported activities identified in the available evidence include climate-sensitive public investment and disaster-risk management, urban resilience, water security and WASH, and emergency response mechanisms (IMF, 2026). These programmes are relevant to drought resilience because they address several components of the risk system, including infrastructure, water security, disaster preparedness, and climate-sensitive public investment.

Systematic assessment of policies and programmes:-

The major policy and programme instruments can be summarized according to their drought relevance and implementation context (see Table 2).

Table 2. The assessment of major policy and programme instruments in relation to drought relevance and implementation context

Policy/programme	Drought-related objective or relevance	Target sector	Geographic relevance	Implementation context	Key gap or consideration
NDC 3.0	Strengthens climate adaptation and resilience	Agriculture, water, health, infrastructure, DRR	National	National policy framework	Requires implementation capacity, finance, monitoring and coordination
Feed Salone	Increases agricultural productivity and resilience	Agriculture and food systems	National, with agricultural production areas particularly relevant	Active national development strategy	Drought resilience needs to be integrated into irrigation, seed, soil and climate-information investments
Climate Resilient Water Investment Programme	Strengthens water security and climate-resilient water investment	Water	National with local water-system implications	Under development	Requires project preparation, finance, data and institutional coordination
UNDP Water and Climate Change Project	Builds adaptive capacity of water systems and institutions	Water and local adaptation	Includes Pujehun, Kambia and Kono	Previous project experience	Lessons should inform future district-level water resilience
Restless Development climate-resilience project	Supports vulnerable households through climate-smart agriculture, WASH and livelihood measures	Agriculture, WASH, livelihoods	Kenema, Karene, Pujehun and Tonkolili	Project implementation through 2028	Requires monitoring of outcomes and scalability
Sierra Leone Climate Fund	Supports climate-finance mobilisation	Cross-sectoral	National	Institutional mechanism	Project preparation, transparency and governance remain important

World Bank resilience projects	Supports climate-sensitive infrastructure and disaster resilience	Infrastructure, water, urban resilience, DRR	National/project-specific	Multiple projects	Coordination and integration with drought-risk information are important

This comparison suggests that Sierra Leone's policy architecture already addresses many components relevant to drought resilience. The central implementation issue is therefore to connect existing programmes more systematically to drought-risk information, geographic vulnerability, sectoral preparedness, and measurable outcomes.

Community-level adaptation and the Feed Salone opportunity:-

Community-level programmes provide an important link between national policy and household-level resilience.Restless Development's programme in Kenema, Karene, Pujehun, and Tonkolili focuses on vulnerable households through climate-smart agriculture, capacity building, WASH, livelihood diversification, and participation of women and youth (Restless Development, 2025).The programme also incorporates natural-resource-based livelihood opportunities and aims to improve understanding of resource-poor households affected by climate change.Such approaches are relevant because drought vulnerability is experienced locally. National climate information becomes more useful when it is translated into decisions concerning planting dates, crop selection, water storage, livestock management, food security, and livelihood diversification.Feed Salone provides an opportunity to mainstream these measures within wider agricultural development. Investments in irrigation, improved seeds, infrastructure, agro-processing, and climate-smart technologies can reduce dependence on rainfall while simultaneously supporting food-system transformation (Kpaka, 2024).However, resilience benefits will depend on implementation quality, local accessibility, maintenance of infrastructure, availability of finance, and the capacity of institutions and communities to use climate information.

Proposed National Drought Monitoring and Early-Warning Framework:-

A national drought early-warning system should integrate information from multiple sectors rather than rely on a single indicator.The proposed framework should operate at national, regional, district, and community levels (see Table 3).

Table 3. Proposed national drought monitoring and early-warning framework

Component	Key indicators	Purpose
Meteorological monitoring	Rainfall, SPI, SPEI, temperature, dry-spell duration	Detect precipitation and atmospheric drought
Agricultural monitoring	Soil moisture, NDVI, crop condition, planting dates	Identify agricultural stress
Hydrological monitoring	River flow, groundwater, reservoir levels	Monitor water-resource stress
Socio-economic monitoring	Food prices, water access, crop losses, livelihood indicators	Identify household and economic impacts
Climate forecasting	Seasonal forecasts and climate projections	Support preparedness and planning
Community monitoring	Local rainfall, water-source conditions, crop observations	Provide local impact information
Early warning	Drought classifications, alerts and advisories	Support timely preparedness and response

The operational sequence should be:-
Data collection → Indicator generation → Drought classification → Impact assessment → Alert generation → Communication → Preparedness and response → Evaluation

An effective system should also move toward impact-based drought forecasting. Instead of reporting only that rainfall is below normal, an operational system should communicate the likely implications for agriculture, water supply, health, energy, and livelihoods.For example, a seasonal rainfall deficit combined with high temperatures and declining soil moisture may indicate increased agricultural stress. The same meteorological conditions, when combined with low reservoir levels, may indicate increased water-supply risk.This approach would make drought information more useful to decision-makers and communities.

Adaptation Priorities and Policy Implications:-

Establish an integrated national drought early-warning system:-

Sierra Leone would benefit from an operational drought monitoring and early-warning system that combines precipitation, temperature, vegetation, soil moisture, hydrological, agricultural, and socio-economic information.

The system should integrate:-

1) SPI and temperature-sensitive drought indicators;
2) seasonal forecasts;
3) satellite observations;
4) vegetation monitoring;
5) hydrological information;
6) agricultural observations; and
7) community-based reporting.

The system should also establish clear thresholds for communicating information to national and local decision-makers.

Strengthen climate-resilient agriculture:-

Agricultural adaptation should focus on reducing excessive dependence on seasonal rainfall while improving soil and water management.

Relevant measures include:-

1) drought-tolerant crop varieties;
2) improved seed systems;
3) conservation agriculture;
4) mulching;
5) agroforestry;
6) rainwater harvesting;
7) small-scale irrigation;
8) soil-moisture conservation;
9) improved planting calendars; and
10) seasonal climate information services.

The appropriateness of individual measures will vary geographically. Areas with greater dependence on rain-fed agriculture and limited water storage may require different combinations of interventions from areas with stronger irrigation or alternative livelihood opportunities.

Strengthen water security:-

Water-sector adaptation should address both supply reliability and resource management.

Priority measures include:-

1) community water storage;
2) small reservoirs;
3) rainwater harvesting;
4) groundwater monitoring;
5) watershed protection;
6) source diversification;
7) improved maintenance of rural water infrastructure; and
8) climate-informed design of new water infrastructure.

Urban systems should also incorporate drought conditions into long-term water-resource planning.

Develop geographically targeted adaptation:-

Adaptation investments should reflect spatial differences in rainfall, exposure, livelihood dependence, water availability, infrastructure, and adaptive capacity.Northern and north-eastern areas may warrant particular attention because of comparatively lower rainfall and dependence on climate-sensitive livelihoods. Nevertheless, targeted assessments should also identify vulnerable communities in wetter regions.A future district-level vulnerability assessment should therefore combine climatic indicators with agricultural, environmental, water, infrastructure, and socio-economic indicators rather than using rainfall alone.

Improve climate data and research capacity:-Reliable long-term observations are essential for identifying changing drought conditions.

Priority investments include:-

1) strengthening meteorological monitoring networks;
2) improving climate-data quality and accessibility;
3) integrating satellite and ground observations;
4) developing national drought databases;
5) supporting university-based climate research;
6) improving district-level vulnerability data; and
7) strengthening collaboration among researchers, government institutions, and development partners.

Future research should also conduct the quantitative analyses proposed in this paper, including SPI time-series analysis, spatial drought mapping, trend analysis, and district-level vulnerability assessment.

Strengthen institutional coordination:-

Drought risk crosses institutional boundaries. Agriculture, water, meteorology, health, environment, energy, infrastructure, disaster management, finance, and local-government institutions all have relevant responsibilities.Clear institutional mandates and mechanisms for inter-agency information sharing are therefore important.

Institutional coordination should support:-

1) joint drought-risk assessments;
2) shared climate-data systems;
3) coordinated early warnings;
4) integrated investment planning;
5) common monitoring and evaluation frameworks; and
6) clear responsibilities for preparedness and response.

Strengthen climate-finance readiness:-

Access to climate finance requires more than identifying climate risks. Institutions also need the capacity to develop technically sound projects, demonstrate climate relevance, monitor expenditure, and report results.The evidence reviewed by the IMF identifies fiscal constraints, data gaps, project-preparation limitations, and institutional weaknesses as important challenges (IMF, 2026).

Strengthening climate-finance readiness should therefore include:-

1) project-development capacity;
2) climate-informed public investment planning;
3) improved monitoring and reporting;
4) transparent climate-expenditure tracking;
5) stronger institutional coordination; and
6) improved accessibility and quality of climate data.

Study Limitations:-

This assessment has several limitations.

First, it is an evidence-synthesis and policy-assessment study rather than a new national empirical drought-index analysis. Consequently, it does not provide newly calculated SPI time series, drought-event statistics, district-level drought maps, or statistical trend estimates.

Second, the climate and vulnerability findings summarized in the paper originate from sources with different spatial scales, temporal periods, methods, and purposes. Direct comparison among all sources is therefore not always appropriate.

Third, the drought-exposure estimates reported by Lange et al. (2020) are derived from global climate and impact modelling and should not be interpreted as a country-specific empirical estimate of future drought risk.
Fourth, the vulnerability framework presented here is conceptual. A quantitative vulnerability index would require a consistent district-level dataset, explicit indicator selection, normalization, weighting, uncertainty assessment, and validation.

Fifth, the policy analysis is based primarily on available policy and programme documentation. Documentary evidence may not fully capture implementation conditions at community level.Finally, the paper does not evaluate the effectiveness of individual adaptation interventions using outcome-based indicators.

These limitations define priorities for future research. A subsequent empirical study should develop district-level drought maps, calculate multi-timescale SPI and temperature-sensitive drought indicators, assess long-term trends, construct and validate a vulnerability index, and evaluate adaptation outcomes.

Future Research Priorities:-
Future quantitative research should build on the framework developed here.

National drought-index analysis:-
A consistent national precipitation dataset should be assembled and quality controlled. SPI-1, SPI-3, SPI-6, and SPI-12 should then be calculated and used to identify drought frequency, duration, severity, and intensity.

Temperature-sensitive drought assessment:-
Because increasing temperatures can increase atmospheric water demand, future analysis should incorporate SPEI and related temperature-sensitive indicators.

Spatial drought mapping:-
District-level and gridded analyses should identify geographical differences in drought characteristics and distinguish drought-prone areas from areas where drought impacts are primarily driven by exposure or vulnerability.

Trend and variability analysis:-
Mann-Kendall and Sen's slope methods, with appropriate treatment of serial correlation, can be used to assess changes in precipitation and drought indicators.

District-level vulnerability index:-
A transparent vulnerability index should combine hazard, exposure, sensitivity, and adaptive-capacity indicators. Alternative weighting approaches should be tested through sensitivity analysis.

Validation against observed impacts:-
Quantitative drought indicators should be compared with observed information on crop losses, water shortages, food prices, livestock impacts, health outcomes, and other sectoral indicators.

Evaluation of adaptation effectiveness:-
Future research should examine whether specific interventions reduce drought impacts and under what institutional, environmental, and socio-economic conditions they are effective.

Conclusion:-
Drought represents an important climate risk for Sierra Leone despite the country's relatively high annual rainfall. Existing research demonstrates substantial spatial and temporal variability in rainfall and drought conditions, while climate and institutional assessments identify increasing temperatures, changing precipitation characteristics, and climate-sensitive livelihoods as important considerations for future drought resilience.The evidence reviewed in this study shows that drought should not be assessed solely as a precipitation deficit. The consequences of drought depend on the interaction between climatic hazard, exposure, sensitivity, and adaptive capacity. Rain-fed agriculture, water availability, environmental conditions, household resources, infrastructure, and access to climate

information all influence how drought conditions translate into impacts.Available modelling also indicates that drought exposure may increase under higher global warming levels. However, these projections are drawn from previous modelling studies and should not be interpreted as new calculations from the present assessment. Their limitations further demonstrate the need for country-specific and district-level drought research.Agriculture is a particularly drought-sensitive sector because of its dependence on seasonal rainfall and its importance for food security and livelihoods. Water systems face additional pressures from population growth, infrastructure constraints, and climate variability. Drought can also affect health, transport, energy, and other sectors through interconnected pathways.

Sierra Leone already has a number of policy instruments and programmes relevant to drought resilience, including NDC 3.0, Feed Salone, water-resilience initiatives, community adaptation programmes, and climate-finance mechanisms. The evidence suggests that an important challenge is connecting these initiatives more systematically to drought-risk information, local vulnerability, implementation capacity, and measurable outcomes.An integrated national drought strategy should therefore combine five complementary elements: hazard monitoring, impact-based early warning, sectoral resilience, geographically targeted adaptation, and institutional and financial capacity.The proposed national drought monitoring framework should integrate meteorological, agricultural, hydrological, environmental, socio-economic, and community information. Such a system can move drought management from a predominantly reactive approach toward proactive risk reduction.The present assessment also identifies a clear research agenda. Future empirical work should calculate multi-timescale drought indices, examine temporal trends, develop district-level vulnerability maps, integrate temperature-sensitive indicators, and evaluate adaptation effectiveness. These analyses would provide the quantitative evidence required to complement the integrated framework presented here.Strengthening drought resilience in Sierra Leone is therefore relevant not only to climate adaptation but also to food security, water security, livelihoods, infrastructure resilience, and sustainable development. An evidence-based and coordinated approach can help ensure that drought information is translated into timely decisions at national, district, and community levels.

Acknowledgments:-
The authors acknowledge the contributions of the Sierra Leone Meteorological Agency, the Ministry of Water Resources, the Environmental Protection Agency, UNDP, Global Water Partnership, the World Bank, and the International Center for Biosaline Agriculture for their work on drought monitoring, vulnerability assessment, climate resilience, and adaptation planning in Sierra Leone. The authors also acknowledge the ISIpedia project for providing published drought-exposure projections and the IMF for country-level climate-finance and institutional assessments.

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:-
This study is based on published literature, institutional assessments, policy documents, and other secondary sources. The paper does not present a newly generated national SPI dataset or district-level composite vulnerability dataset. Datasets that could support future empirical implementation, including CHIRPS, CRU, and relevant national climate and environmental datasets, are publicly accessible subject to their respective terms of use and availability.

Ethical Approval:-
This study uses secondary climate, environmental, socio-economic, and policy information and does not involve experimentation involving human participants or animals.

Author Contributions:-
The corresponding author contributed to conceptualization, literature synthesis, methodological design, interpretation, and manuscript preparation. Samilia Edden Kamara (SEK) assisted with analysis, interpretation, and manuscript preparation. Augustine Bob Moseray (ABM) assisted with manuscript preparation.

References:-

1. Amara, D. M. K., & Ullah, K. (2022). Quantification of precipitation deficits on different time scales in Sierra Leone using Standardized Precipitation Index. Theoretical and Applied Climatology, 151, 131–149.
2. Fayiah, M., Tulcan, R. X. S., Bockarie, R., Saccoh, S., Singh, S., &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., & 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. Intergovernmental Panel on Climate Change. (2023). Climate Change 2023: Synthesis Report. Geneva: IPCC.
7. International Center for Biosaline Agriculture. (2019). Vulnerability Map of Sierra Leone.
8. International Monetary Fund. (2024). Sierra Leone: Climate Policy Diagnostic. IMF Technical Assistance Report.
9. International Monetary Fund. (2026). Sierra Leone Country Report on Climate Finance and Institutional Capacity.
10. International Monetary Fund. (2026). Sierra Leone: World Bank Assessment Letter for the Resilience and Sustainability Facility. IMF Staff Country Reports.
11. IWA Network. (2025). Climate Smart Resilience: Sierra Leone's Strategies for Ensuring Supply.
12. Kpaka, H. M. (2024). Paving the way for food systems transformation in Sierra Leone. SDG Knowledge Hub, September 2024.
13. Lange, S., Volkholz, J., Geiger, T., Zhao, F., Vega, I., Veldkamp, T., Reyer, C. P. O., Warszawski, L., Huber, V., Jägermeyr, J., Schewe, J., Bresch, D. N., Büchner, M., Chang, J., Ciais, P., Dury, M., Emanuel, K., Folberth, C., Gerten, D., Gosling, S. N., Grillakis, M., Hanasaki, N., Henrot, A.-J., Hickler, T., Honda, Y., Ito, A., Khabarov, N., Koutroulis, A., Liu, W., Müller, C., Nishina, K., Ostberg, S., Müller Schmied, H., Seneviratne, S. I., Stacke, T., Steinkamp, J., Thiery, W., Wada, Y., Willner, S., Yang, H., Yoshikawa, M., Yue, C., & Frieler, K. (2020). Projecting exposure to extreme climate impact events across six event categories and three spatial scales. Earth's Future, 8.
14. Restless Development. (2025). Improving Food and Nutrition Outcomes of Vulnerable Households Through Strengthening Climate Resilience.
15. Sierra Leone Meteorological Agency (SLMet). (2026). Drought Risks to Agriculture, Water, Health and Transport Sectors.
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.
18. Wadsworth, R., Jalloh, A., & 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.