

Spatio-Temporal Assessment of Precipitation Variability and Meteorological Drought in Northern Nigeria

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Publication Date: 2026/09/25

Abstract: Drought is a recurring environmental hazard in Northern Nigeria, with significant implications for agriculture, water resources, food security and livelihoods. Variations in rainfall patterns and increasing climate variability have heightened the need for effective drought monitoring and assessment. This study assesses the spatial and temporal variability of precipitation and meteorological drought across North Central, North East and North West Nigeria using the Standardized Precipitation Index (SPI). Precipitation data were processed using Google Earth Engine following the SPI approach and further analyzed using Geographic Information System (GIS) techniques. The analysis examined precipitation variability and SPI patterns across the three northern geopolitical regions. Results indicate considerable spatial and temporal variability in both precipitation and drought conditions. The three regions experienced varying patterns of wet and dry conditions, demonstrating that drought characteristics are not spatially uniform across Northern Nigeria. The findings highlight differences in the occurrence and intensity of meteorological drought among the regions and demonstrate the usefulness of SPI and geospatial techniques for monitoring drought dynamics. The study provides useful information for improving drought early warning, agricultural planning, water-resource management and disaster risk reduction. It also emphasizes the need for region-specific drought management strategies that consider local variations in precipitation and drought conditions across Northern Nigeria.

Keywords: Drought, Standardized Precipitation Index, Precipitation Variability, Northern Nigeria, Google Earth Engine, Remote Sensing, GIS, Climate Variability.

How to Cite: Mai Bukar, Adama; Adepoju, Matthew Olumide; James, Godstime Kadiri; Oyewumi, Ademuyiwa; Idris, Halima Ohunene; Salawudeen, Fatima; Odeh, Augustine Abah (2026) Spatio-Temporal Assessment of Precipitation Variability and Meteorological Drought in Northern Nigeria. *International Journal of Innovative Science and Research Technology*, 11(9), 1298-1307. <https://doi.org/10.38124/ijisrt/26sep559>

I. INTRODUCTION

Drought is a significant environmental challenge that compromises food security, water resources and socio-economic stability, particularly in arid and semi-arid regions globally. Climate change has intensified concerns about the frequency and severity of drought, while climate-sensitive livelihoods in the Global South remain particularly exposed.

Northern Nigeria, characterized by Sudano-Sahelian agro-ecological conditions, is highly vulnerable to erratic rainfall, desertification and rising temperatures. Agriculture and livestock production remain important livelihood activities, making changes in precipitation particularly

important for food security and water availability. Historical drought episodes have resulted in crop failures, livestock losses and pressure on natural resources.

Remote sensing and geospatial analysis have expanded drought-monitoring capacity by integrating climate and environmental information over large areas. The Standardized Precipitation Index (SPI) is a widely used precipitation-based indicator for characterizing departures from normal precipitation over selected timescales. The supplied study adopts the UN-SPIDER recommended SPI approach and uses Google Earth Engine (GEE) for processing, followed by GIS visualization and statistical analysis.

Previous studies have emphasized the value of integrating precipitation, vegetation and thermal indicators to characterize drought more comprehensively. AghaKouchak et al. (2015) highlighted the benefits of multi-index approaches, while studies in Nigeria have demonstrated the usefulness of remote-sensing-derived climate and vegetation information for drought monitoring. GEE-based approaches have also demonstrated potential for scalable drought assessment.

Despite these advances, comparative assessments across the three northern geopolitical regions remain useful for understanding spatial differences in drought exposure within a common analytical framework. This study therefore assesses precipitation variability and SPI-derived meteorological drought condition in North Central, North East and North West.

II. STUDY AREA

Northern Nigeria covers approximately two-thirds of the country's landmass and comprises 19 states and the Federal Capital Territory (FCT), grouped into the North Central, North East and North West geopolitical zones. The region extends approximately between latitudes 7°N and 14°N and longitudes 3°E and 14°E. It experiences a tropical continental climate characterized by distinct wet and dry seasons. Rainfall varies considerably from wetter southern areas to drier northern areas. Agriculture and livestock rearing are important livelihood activities, while climate variability, desertification and land degradation pose continuing risks to food security and natural-resource management.

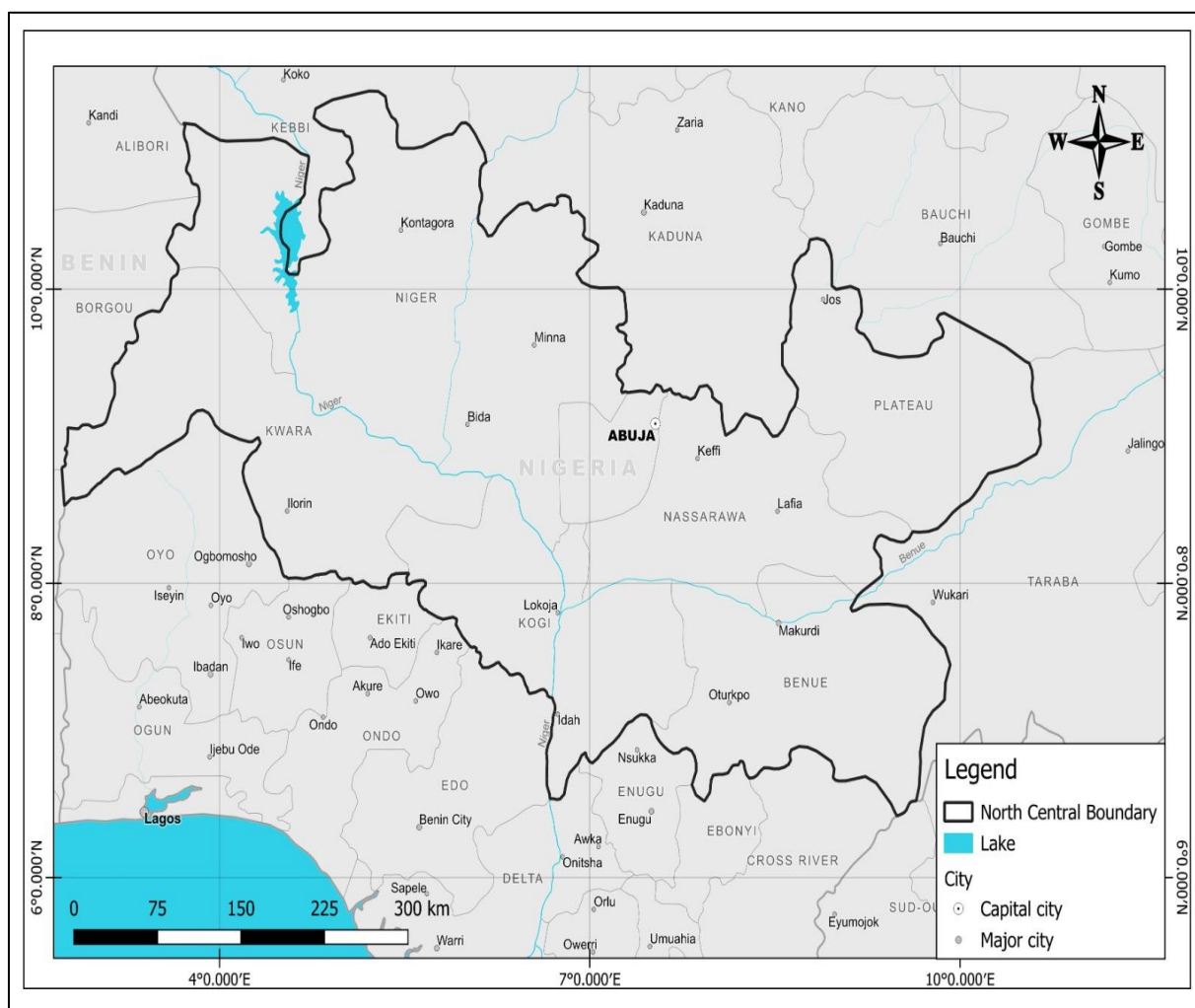


Fig 1 North Central Nigeria.

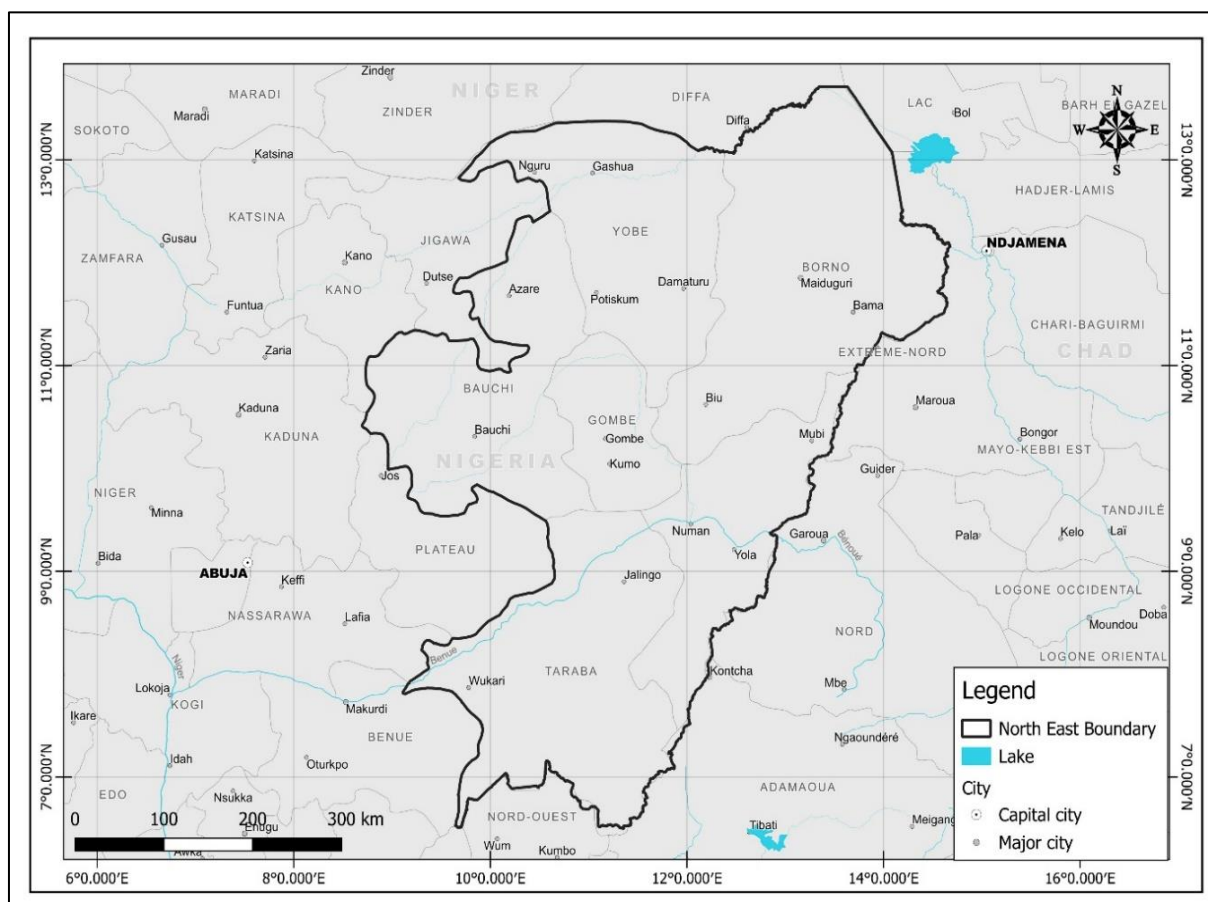


Fig 2 North East Nigeria.

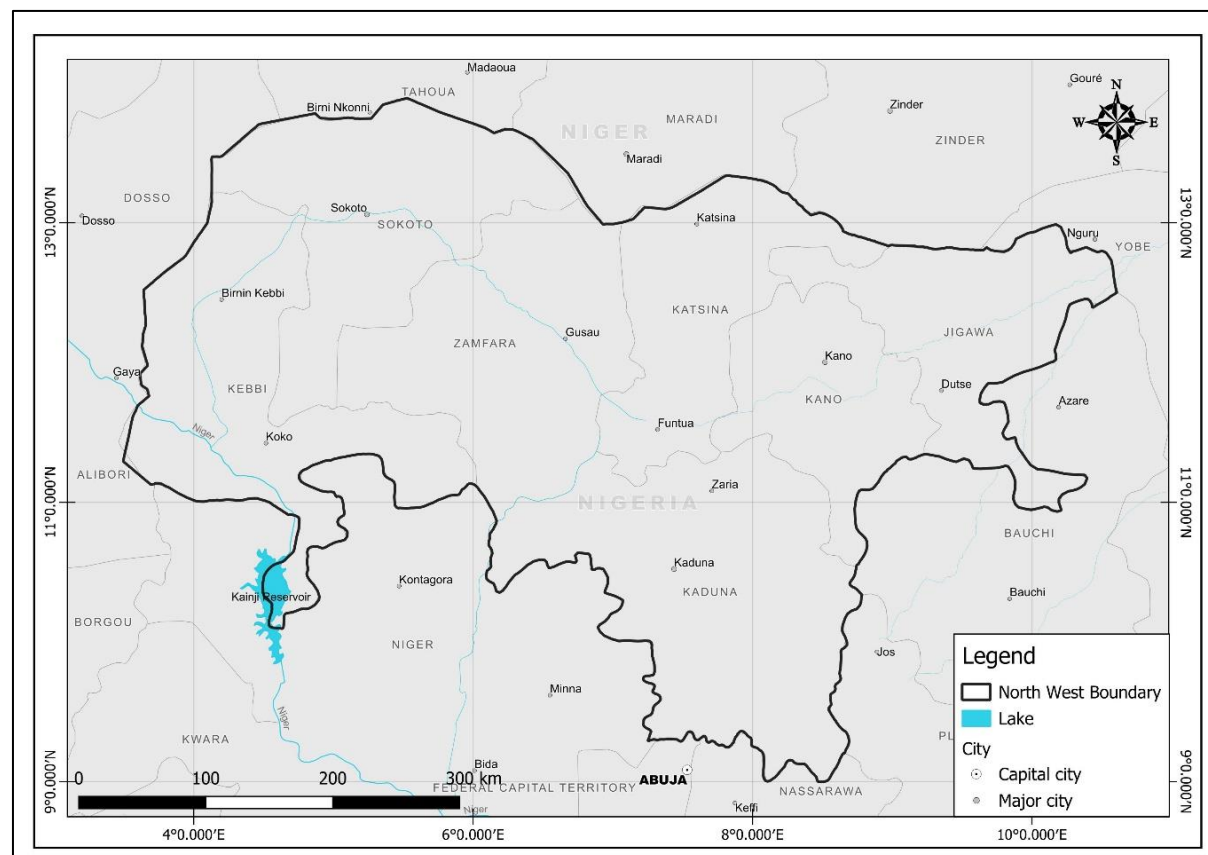


Fig 3 North West Nigeria.

➤ Statement of Problem

Drought remains one of the pressing environmental challenges in Northern Nigeria, disrupting water availability, threatening food security and undermining livelihoods. Increasing climate variability has contributed to erratic rainfall and prolonged dry spells, creating risks for communities dependent on rain-fed agriculture and natural water resources.

Many drought assessments rely on fragmented observations or approaches that do not fully capture spatial differences across the region. Without timely and spatially detailed information, policymakers and stakeholders may face difficulties in targeting drought mitigation and adaptation measures.

This study addresses this need by applying geospatial processing to precipitation data across North Central, North

East and North West. The resulting SPI maps and temporal analyses provide a comparative picture of drought and wetness variability.

III. METHODOLOGY

The study adopted the UN-SPIDER recommended practice for drought monitoring using the SPI. The GEE script for implementing SPI was utilized to achieve the objectives of the research. The GEE script was imported and ran on the GEE platform, the output was downloaded and taken to a GIS environment for maps production and also for further statistical analysis on Microsoft Excel so as to enhance the interpretation of spatial and temporal trends of both precipitation and drought in the three geopolitical zones. Figure 4 shows the flow chart adopted from UN-SPIDER.

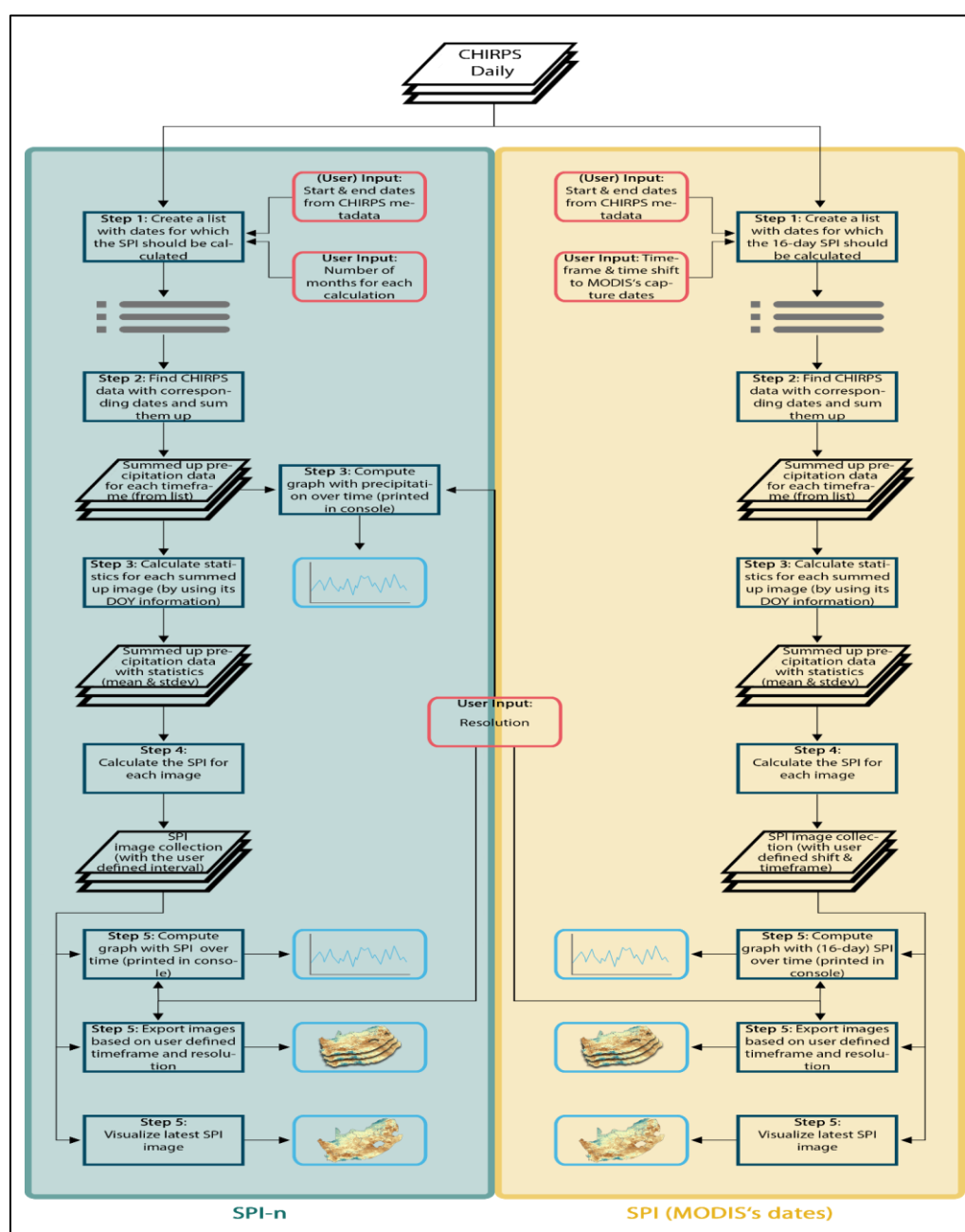


Fig 4 Flow Chart

IV. RESULTS AND DISCUSSION

➤ North Central

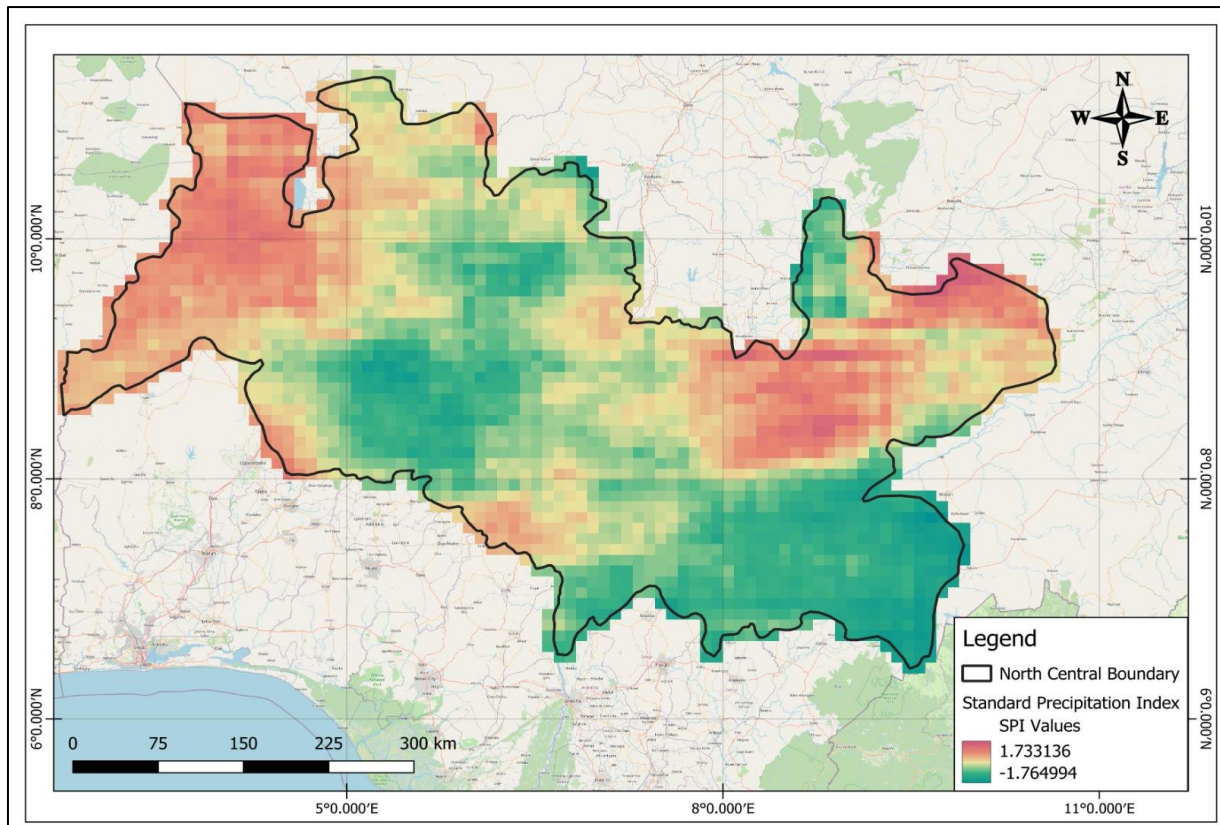


Fig 5 North Central SPI Map.

The North Central SPI map shows substantial spatial variability. Positive SPI values, reaching approximately 1.73 in the western and eastern parts, indicate a wetter-than-normal conditions. Central and southern parts however record

negative SPI values down to approximately -1.76, indicating below-normal precipitation and conditions ranging from moderately to severely dry condition.

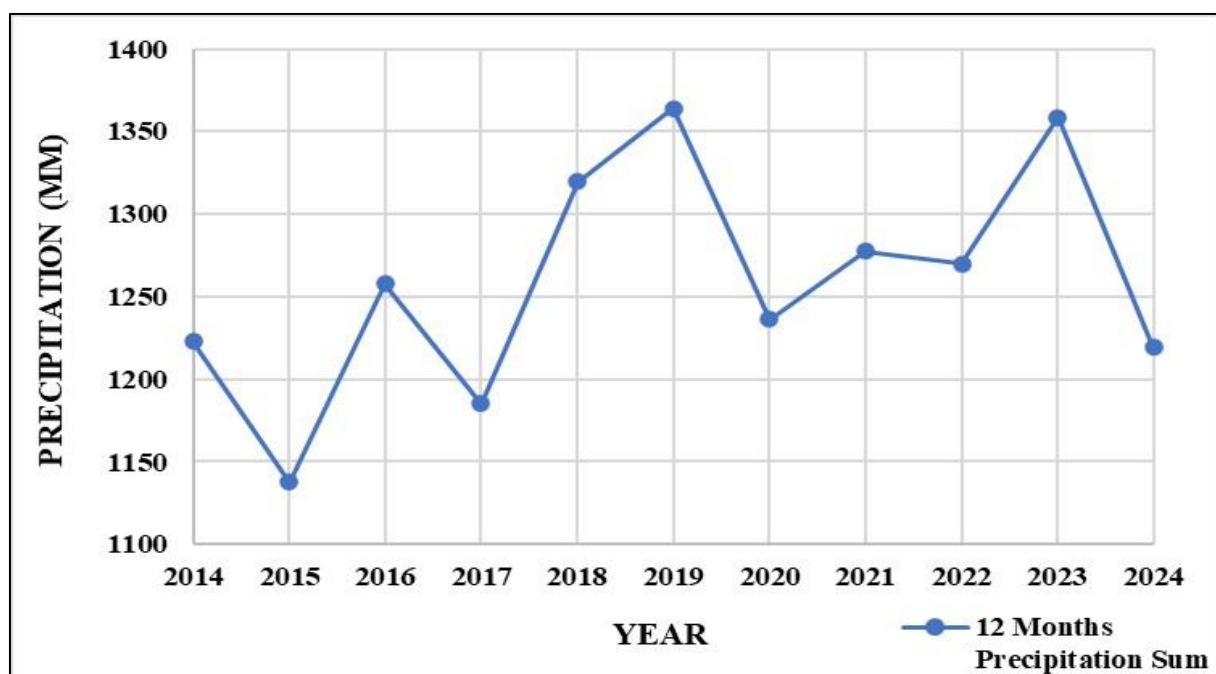


Fig 6 Annual Precipitation Trend in North Central

Annual precipitation fluctuated considerably. The lowest precipitation occurred in 2015, while 2019 and 2023 recorded the highest precipitation levels, exceeding 1,350 mm according to the supplied analysis. Precipitation generally

increased from 2015 to 2019, declined in 2020, remained comparatively stable through 2022, peaked again in 2023 and declined sharply in 2024.

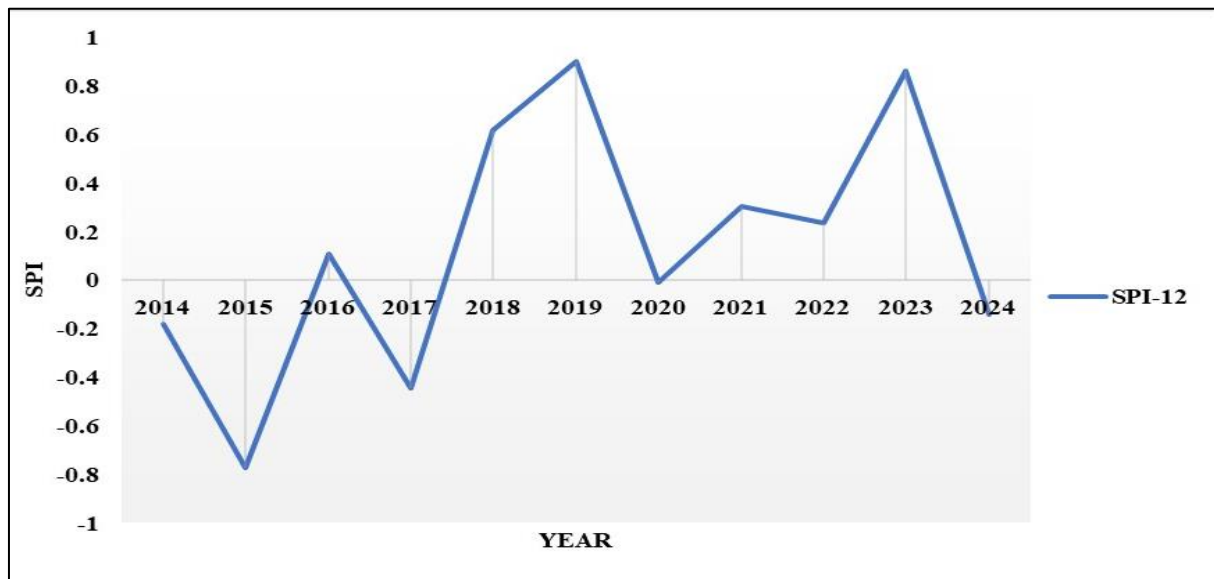


Fig 7 SPI-12 Variation in North Central

The SPI-12 series indicates alternating wet and dry conditions. The most pronounced drought occurred in 2015, while positive SPI conditions were strongest in 2018 and 2019.

Conditions were comparatively moderate from 2020 to 2022, followed by a positive peak in 2023 and a decline in 2024.

➤ North East

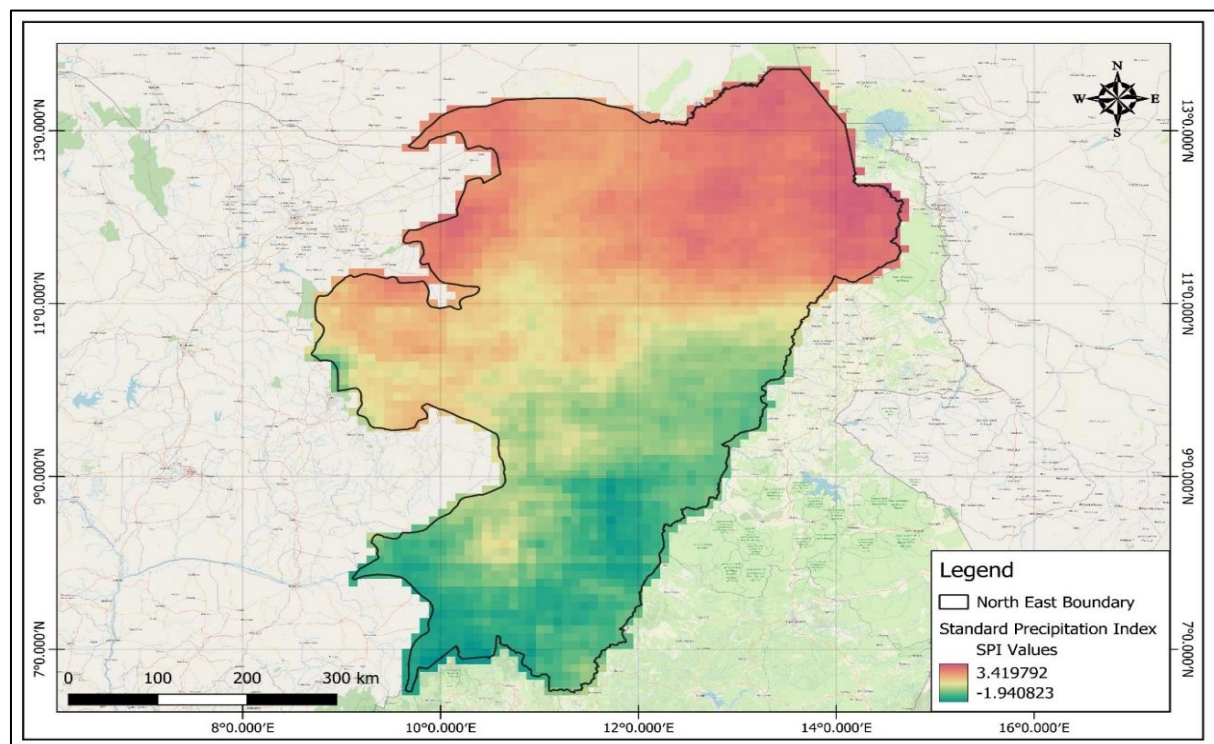


Fig 8 North East SPI Map.

The North East SPI map shows pronounced spatial variability, with SPI values ranging approximately from -1.94 to 3.42. Higher values occur in the northern parts of the region, indicating wetter conditions, whereas lower values occur

toward the southern parts, indicating drier conditions. The pattern suggests exposure to both drought and excessive-rainfall conditions.

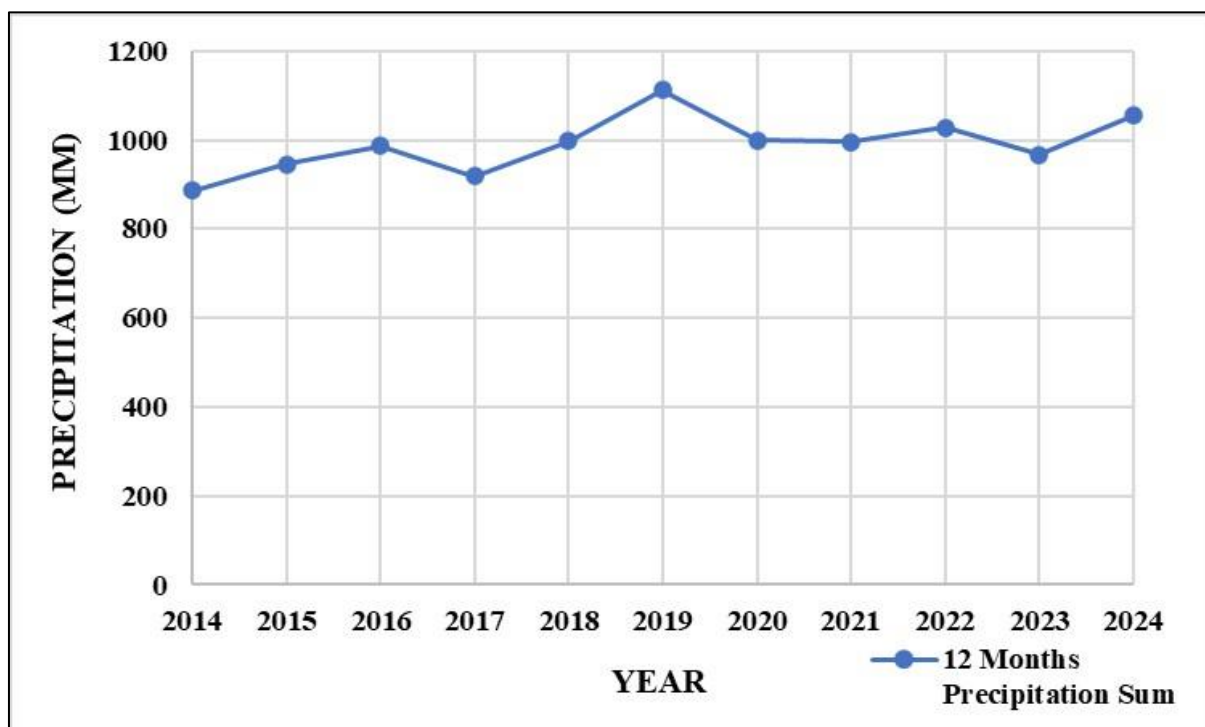


Fig 9 Annual Precipitation Trend in North East

Annual precipitation fluctuated during the study period. The highest rainfall occurred in 2019, with another notable increase in 2024. Lower precipitation was observed in 2017

and 2023. The series therefore reflects interannual variability rather than a consistently increasing or decreasing pattern.

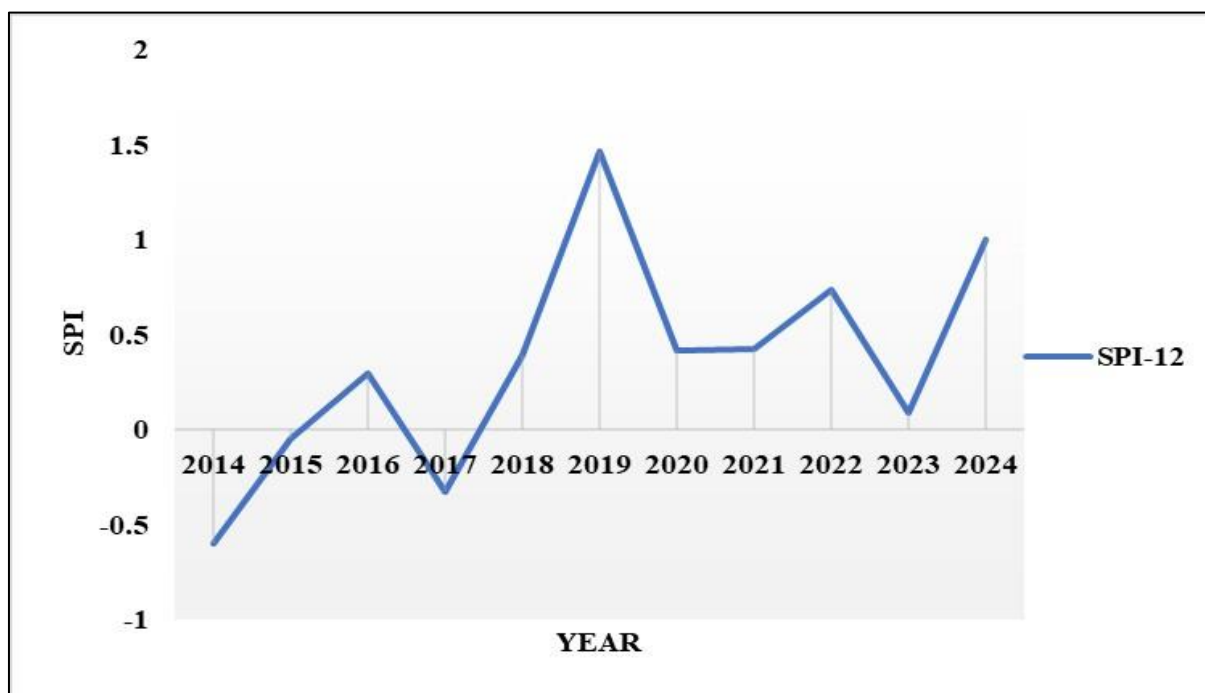


Fig 10 SPI-12 Variation in North East

Negative SPI values in 2014 and 2017 indicate below average precipitation and potential drought conditions. The highest SPI value occurred in 2019, indicating a markedly wet

year. Moderately wet conditions were observed in 2020, 2021, 2022 and 2024, while 2023 recorded a decline.

➤ North West

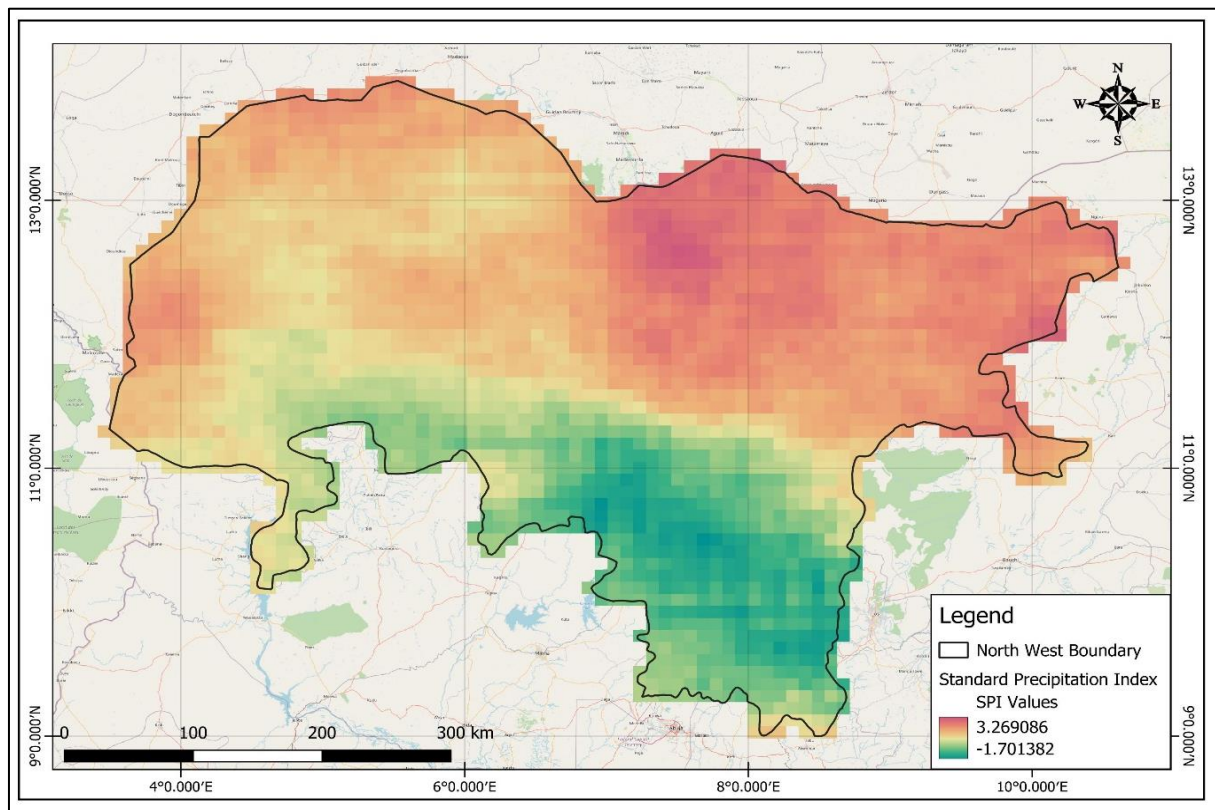


Fig 11 North West SPI Map.

The North West SPI map indicates significant spatial differences in wetness and dryness. Higher SPI values occur particularly toward northern and border areas, while negative

values are more evident in southern parts. This indicates that drought exposure is spatially concentrated rather than uniform.

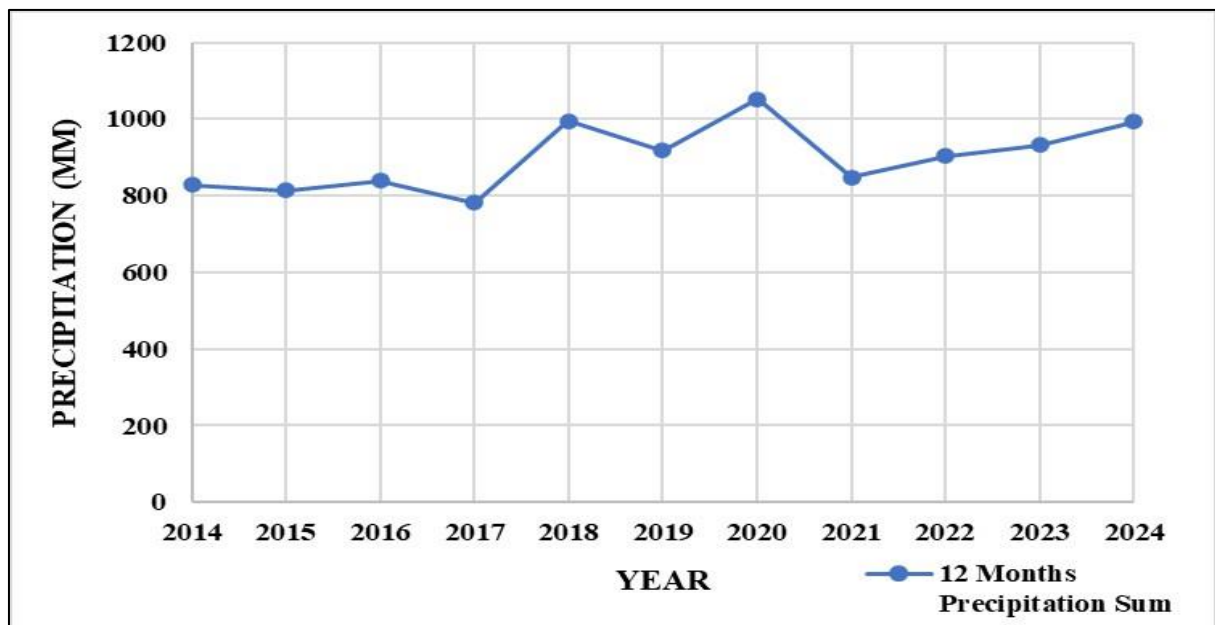


Fig 12 Annual Precipitation Trend in North West

Precipitation remained relatively stable from 2014 to 2017 before increasing substantially in 2018. A slight decline occurred in 2019, followed by the highest recorded

precipitation in 2020. Precipitation decreased sharply in 2021 and then increased gradually from 2022 through 2024.

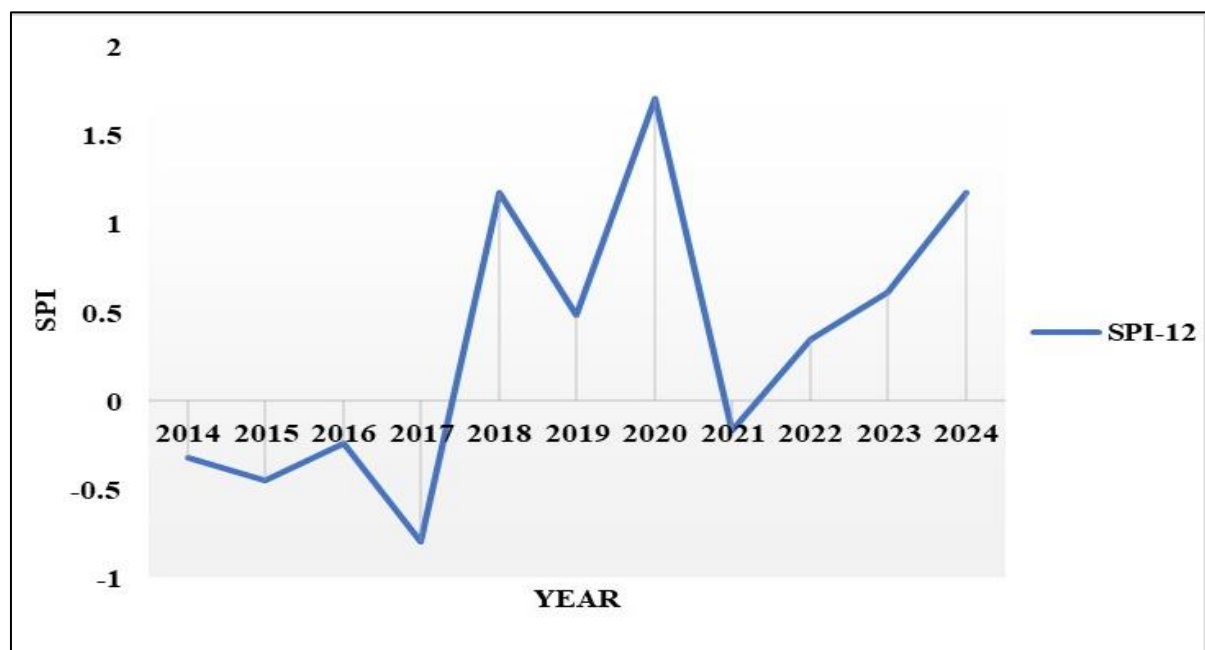


Fig 13 SPI-12 Variation in North West

The SPI series remained slightly negative from 2014 to 2016, while a more pronounced decline occurred in 2017. It increased sharply in 2018 and reached a peak in 2020. A decline in 2021 brought conditions toward near normal, followed by a generally increasing tendency from 2022 to 2024.

➤ Comparative Regional Assessment

Comparison of the three regions shows that drought and wetness conditions vary both spatially and temporally. North Central displays alternating dry and wet conditions, with a pronounced dry period in 2015 and wet peaks around 2018-2019 and 2023. North East shows the widest reported SPI range and marked alternation between negative and positive conditions. North West however exhibited a pronounced dry phase around 2017 followed by wetter conditions, particularly around 2018-2020, and a recovery after 2021.

These results indicate that drought risk should not be treated as spatially homogeneous across Northern Nigeria. Regional and sub-regional differences in precipitation distribution require geographically targeted monitoring and adaptation measures.

V. CONCLUSION

This study assessed precipitation variability and meteorological drought across North Central, North East and North West Nigeria using SPI and geospatial processing. The results demonstrated substantial spatial and temporal variability in rainfall and drought conditions across the three geopolitical zones.

North Central experienced a notable dry condition in 2015 and wetter conditions in 2018, 2019 and 2023. North East exhibited pronounced variability, including negative SPI conditions in 2014 and 2017 and strongly positive conditions in 2019 and subsequent years. North West experienced a

marked dry phase around 2017, followed by wetter conditions and a gradual recovery after 2021. Overall, drought management in Northern Nigeria requires spatially differentiated monitoring and intervention. SPI-based monitoring implemented through Google Earth Engine provides a useful framework for generating timely information for agricultural planning, water-resource management and climate adaptation. Future work should integrate SPI with vegetation, thermal and soil-moisture indicators and validate satellite-derived results with ground observations and impact data.

RECOMMENDATIONS

- Strengthen operational drought early-warning systems using regularly updated SPI products and spatially explicit drought maps.
- Develop region-specific drought preparedness and water-resource management strategies because drought exposure varies across the three geopolitical zones.
- Integrate precipitation-based SPI with vegetation, land-surface-temperature and soil-moisture indicators to support agricultural drought assessment.
- Improve validation of satellite- and GEE-derived drought products using meteorological observations, agricultural production data and ground-based impact information.
- Use geospatial drought information to support agricultural advisories, water allocation, livelihood planning and disaster-risk reduction.

REFERENCES

- [1]. Adamu, I., & Mohammed, A. (2022). Climate variability and drought management in the Sahel. *Journal of Environmental Management*, 250(3), 45–58.
- [2]. Adepoju, A. (2020). *Climate change and regional vulnerability in Nigeria*. Green Press.

- [3]. AghaKouchak, A., Farahmand, A., Melton, F. S., Teixeira, J., Anderson, M. C., Wardlow, B. D., & Hain, C. R. (2015). Remote sensing of drought: Progress, challenges, and opportunities. *Reviews of Geophysics*, 53(2), 452–480.
- [4]. Akande, A., Costa, A. C., Mateu, J., & Henriques, R. (2021). Drought monitoring in Nigeria using MODIS NDVI time-series data. *Remote Sensing Applications: Society and Environment*, 23, 100565.
- [5]. Bayissa, Y., Tadesse, T., Demisse, G., & Shiferaw, A. (2018). Evaluation of satellite-based rainfall estimates and application to monitor meteorological drought for the Upper Blue Nile Basin, Ethiopia. *Remote Sensing*, 10(10), 1562.
- [6]. Bello, O. W., Abdulrahman, S., & Suleiman, M. T. (2021). Climate change and drought dynamics in Northern Nigeria. *Journal of Arid Environments*, 184, 104329.
- [7]. Buba, A., Hassan, M., & Shehu, T. (2019). Desertification and food security in Northern Nigeria: An assessment of climate trends. *Journal of Environmental Studies*, 15(3), 45–60.
- [8]. Enaruvbe, G. O., & Ukhurebor, K. E. (2021). Monitoring rainfall and drought trends using remote sensing-derived climate data and vegetation indices in semi-arid eco-zone, Nigeria.
- [9]. Eze, J. N., Uwizeyimana, D., & Nwachukwu, M. U. (2018). Challenges of drought monitoring in Sub-Saharan Africa: A case study of Nigeria. *Environmental Management*, 62(5), 911–925.
- [10]. FAO. (2020). The impact of disasters on agriculture and food security. Food and Agriculture Organization.
- [11]. IPCC. (2021). *Climate Change 2021: The Physical Science Basis*. Cambridge University Press.
- [12]. Kumar, S., Dutta, S., Islam, A. S., & Hu, Z. (2022). Leveraging Google Earth Engine for drought risk assessment in semi-arid India. *Remote Sensing*, 14(3), 544.
- [13]. Mortimore, M. (2010). Adapting to drought in the Sahel: Lessons for climate change. *Wiley Interdisciplinary Reviews: Climate Change*, 1(1), 134–143.
- [14]. Nandgude, N., Singh, T. P., Nandgude, S., & Tiwari, M. (2023). Drought prediction: A comprehensive review of different drought prediction models and adopted technologies. *Sustainability*, 15(15), 11684.
- [15]. Nigerian Meteorological Agency. (2021). Seasonal rainfall prediction and climate review for Nigeria. Abuja, Nigeria: NIMET.
- [16]. Nigerian Meteorological Agency. (2021). Annual climate report. Nigerian Meteorological Agency.
- [17]. Oladipo, E. (2022). Understanding precipitation variability in the Sahel: Implications for Northern Nigeria. *Climate Research Journal*, 18(2), 78–92.
- [18]. Umar, S., Bello, R., & Musa, J. (2023). Resource conflicts and climate change in Nigeria: The case of farmer-herder clashes. *African Journal of Conflict Studies*, 12(1), 33–50.
- [19]. United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER). (n.d.). Recommended Practice: Drought monitoring using the Standardized Precipitation Index (SPI).
- [20]. World Meteorological Organization. (2022). State of climate services: Drought. World Meteorological Organization.