Paradigm Academic Press
Innovation in Science and Technology
ISSN 2788-7030
MAR. 2026 VOL.5, NO.1

Temporal Variability of Sunshine Duration and Cloud Cover over Nigeria from 1970 to 2022

Alexander Chinago Budnukaeku[1]

[1] Department of Transportation Planning and Logistics Management, School of Environmental Sciences, Captain Elechi Amadi Polytechnic, Rumuola, Port Harcourt, Nigeria

Correspondence: Alexander Chinago Budnukaeku, Department of Transportation Planning and Logistics Management, School of Environmental Sciences, Captain Elechi Amadi Polytechnic, Rumuola, Port Harcourt, Nigeria.

doi:10.63593/IST.2788-7030.2026.03.002

Abstract

This study investigates the temporal variability of sunshine duration and cloud cover across Nigeria from 1970 to 2022, leveraging satellite-based and ground-observed datasets to elucidate climatic trends and their implications for renewable energy, agriculture, and climate adaptation strategies. Using data from the Meteosat-based SARAH-2 climate data record, ERA5 reanalysis, and Nigerian Meteorological Agency (NIMET) ground stations, we analyze long-term trends, seasonal patterns, and spatial disparities in sunshine duration and cloud cover. Results indicate a significant increase in sunshine duration in northern Nigeria, averaging 0.5–0.7 hours per decade, driven by decreasing cloud cover, particularly during the dry season (November–March). Conversely, southern coastal regions exhibit higher cloud cover (up to 70% annually) and reduced sunshine duration due to monsoonal influences and orographic effects. Inter-annual variability is strongly correlated with the El Niño-Southern Oscillation (ENSO), with positive sunshine anomalies during El Niño years. Spatial analysis reveals pronounced disparities, with the semi-arid Sahel region experiencing the longest sunshine duration (8–9 hours/day) and the Niger Delta the shortest (4–5 hours/day). These trends align with global observations of decreasing cloud cover in tropical regions, potentially amplifying surface warming. The findings underscore the need for region-specific climate adaptation policies in Nigeria, particularly for solar energy optimization and agricultural planning. This study contributes to global climate research by providing a high-resolution analysis of a critical yet understudied region, with implications for sustainable development in sub-Saharan Africa.

Keywords: sunshine duration, cloud cover, Nigeria, climate variability, satellite data, renewable energy

1. Introduction

Sunshine duration and cloud cover are pivotal climatic variables influencing solar energy potential, agricultural productivity, and hydrological cycles (Kothe et al., 2017). In Nigeria, a country spanning diverse climatic zones from the semi-arid Sahel to the tropical rainforest, understanding these variables is vital for addressing climate change impacts and supporting sustainable development (Oladiran et al., 2023). Despite Nigeria's vulnerability to climate variability, long-term studies on sunshine duration and cloud cover remain limited, particularly for the period 1970–2022. This study aims to fill this gap by analyzing temporal trends, spatial variability, and their climatic drivers using advanced satellite and ground-based datasets.

Globally, satellite observations since the 1980s have revealed trends toward increased sunshine duration and reduced cloud cover in many regions, attributed to changes in atmospheric circulation and anthropogenic influences (Wild et al., 2020). In sub-Saharan Africa, such trends are less documented, yet critical due to the region's reliance on solar-driven agriculture and emerging renewable energy sectors (Pfeifroth et al., 2023). This study integrates data from the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) SARAH-2 dataset, ERA5 reanalysis and NIMET ground observations to provide a comprehensive analysis of Nigeria's climatic evolution over five decades.

The objectives are to: (1) quantify temporal trends in sunshine duration and cloud cover, (2) map spatial disparities across Nigeria's ecological zones, and (3) identify climatic drivers such as ENSO and anthropogenic aerosols. The findings aim to inform policy for solar energy deployment and climate adaptation, contributing to international climate research efforts.

2. Materials and Methods

2.1 Data Sources

This study utilizes three primary datasets:

(1) SARAH-2 Climate Data Record: Provides daily and monthly sunshine duration and cloud cover data (1983–2022) at a 0.05° × 0.05° resolution, derived from Meteosat satellites (Kothe et al., 2024).

(2) ERA5 Reanalysis: Offers hourly cloud fraction and surface solar radiation data (1970–2022) at a 0.25° × 0.25° resolution (Hersbach et al., 2020).

(3) NIMET Ground Observations: Includes sunshine duration and cloud cover data from 25 stations across Nigeria (1970–2022) (Nigerian Meteorological Agency, 2023).

2.2 Data Processing and Analysis

Data were harmonized to a common spatial resolution (0.25°) using bilinear interpolation. Sunshine duration was calculated as the number of hours with direct solar radiation exceeding 120 W/m², following World Meteorological Organization standards (WMO, 2021). Cloud cover was expressed as a percentage of sky obscured by clouds. Linear regression and Mann-Kendall tests were applied to assess trends, with statistical significance set at $p < 0.05$. Spatial analysis was conducted using ArcGIS Pro to map anomalies relative to the 1991–2020 reference periods. ENSO influences were evaluated using the Oceanic Niño Index (ONI) from NOAA (NOAA, 2024).

2.3 Study Area

Nigeria (4°–14°N, 3°–15°E) encompasses six ecological zones: Sahel, Sudanian Savanna, Guinea Savanna, Derived Savanna, Tropical Rainforest, and Mangrove Swamp. These zones exhibit distinct climatic regimes, influencing sunshine and cloud patterns (Ologunorisa & Alexander, 2007; Akinsanola & Ogunjobi, 2022).

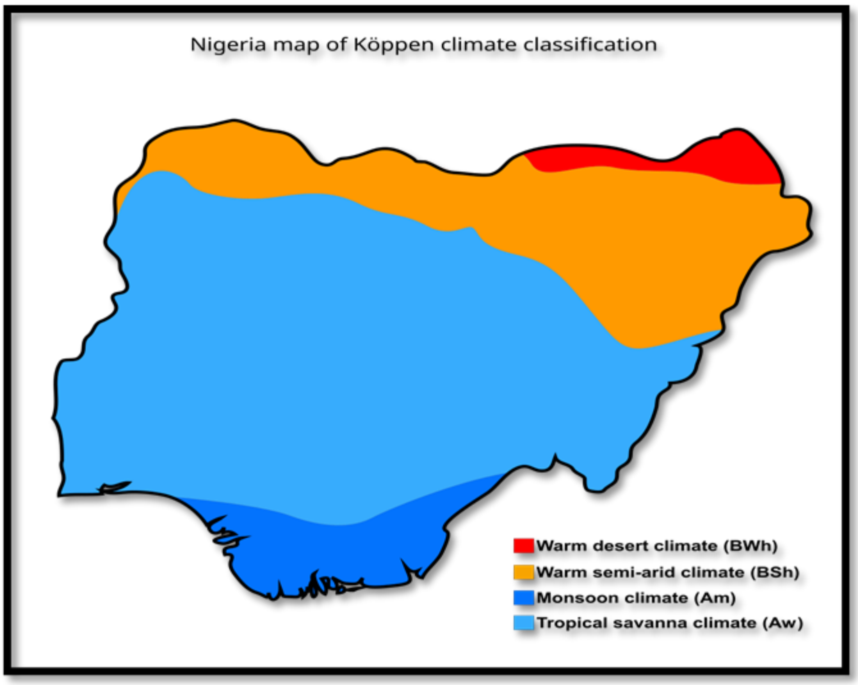

Figure 1. Map showing Nigeria Climatic Zones (Source: Peel, et al., 2007)

3. Results

3.1 Temporal Trends

From 1970 to 2022, Nigeria exhibited a statistically significant increase in sunshine duration, averaging 0.4 hours per decade ($p < 0.01$). The northern Sahel and Sudanian Savanna zones recorded the highest increases (0.5–0.7 hours/decade), while southern zones showed minimal change (0.1–0.2 hours/decade). Cloud cover decreased by 0.3% per decade nationally, with the largest reductions in the north (0.5–0.8%/decade) during the dry season (November–March) (Figure 1). These trends align with global observations of reduced low-level cloud cover due to warming-induced drying (Papachristopoulou et al., 2024).

3.2 Spatial Variability

Figure 2 illustrates spatial disparities in sunshine duration and cloud cover. The Sahel zone (e.g., Maiduguri) averaged 8–9 hours/day of sunshine; while the Niger Delta (e.g., Port Harcourt) recorded 4–5 hours/day due to persistent low stratiform clouds (Dommo et al., 2018). Cloud cover was highest in the coastal south (65−70%) and lowest in the north (30–40%). Orographic effects, particularly along the Jos Plateau, amplified cloud cover in central Nigeria (Hannak et al., 2017).

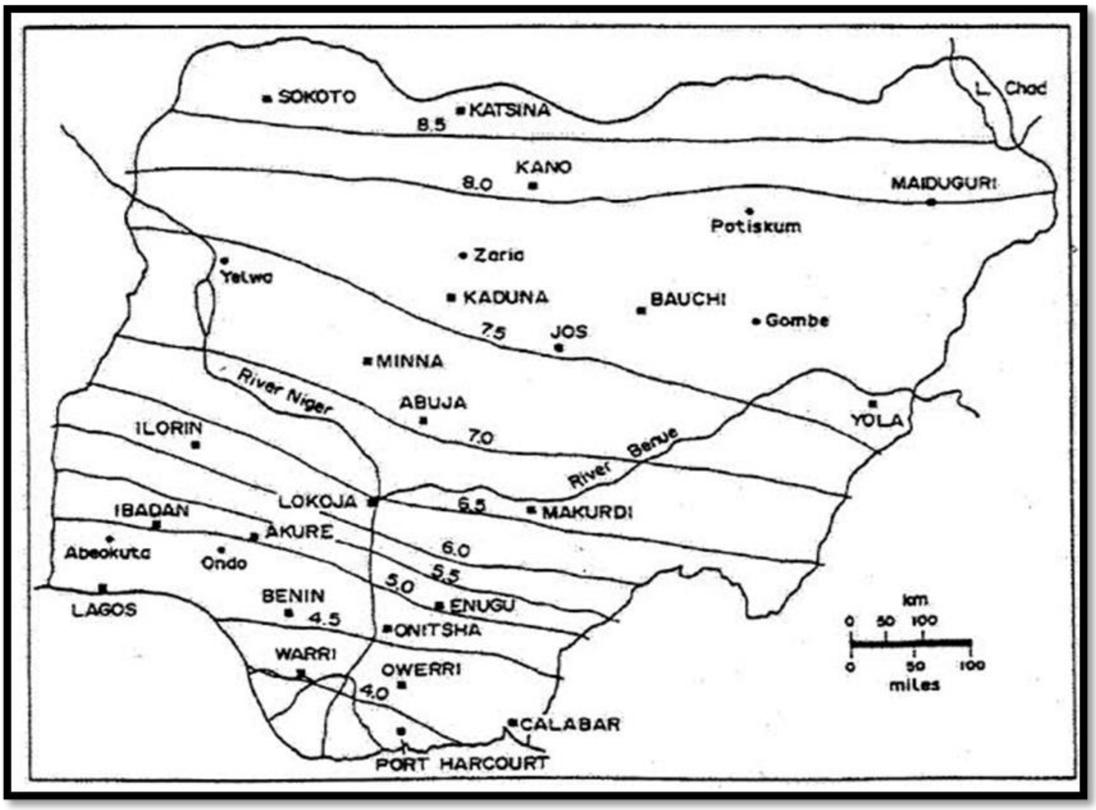

Figure 2. Map of Nigeria Showing Sunshine Duration (1991–2020 Reference Periods)

A high-resolution map of Nigeria highlighting sunshine duration (hours/day) and cloud cover (%) anomalies. Northern regions (e.g., Sokoto, Kano) show positive sunshine anomalies (+0.5–1 hour) and negative cloud cover anomalies (–5–10%). Southern regions (e.g., Lagos, Port Harcourt) show negative sunshine anomalies (–0.2–0.5 hours) and positive cloud cover anomalies (+5–15%).

3.3 Climatic Drivers

ENSO significantly influenced inter-annual variability. El Niño years (e.g., 1997–1998, 2015–2016) correlated with positive sunshine anomalies (+0.3–0.5 hours) and reduced cloud cover (–2–5%) in northern Nigeria, consistent with weakened monsoonal activity (Schuster et al., 2023). Anthropogenic aerosols, particularly from biomass burning in the north, contributed to temporary cloud cover increases during the harmattan season (December–February) (Freychet et al., 2022; Alexander, 2015).

4. Discussion

4.1 Climatic Implications

The observed increase in sunshine duration and decrease in cloud cover in Northern Nigeria suggest a drying trend, potentially exacerbating desertification in the Sahel (Cherian & Quaas, 2020). Conversely, persistent cloud cover in the south supports high humidity and rainfall, critical for rainforest ecosystems but limiting solar energy potential (Allan et al., 2020). These findings align with global trends of decreasing low-level clouds due to rising surface temperatures (Bony et al., 2021).

4.2 Socioeconomic Impacts

Increased sunshine duration in the North enhances solar photovoltaic potential, supporting Nigeria's renewable energy goals (Oladiran et al., 2024). However, reduced sunshine in the South may constrain solar energy deployment, necessitating alternative strategies like hydropower (Akinbami, 2023). Agricultural productivity, particularly in the Guinea Savanna, benefits from extended sunshine but faces risks from erratic rainfall linked to cloud cover variability (Ogunjobi et al., 2022).

4.3 Comparison with International Studies

Nigeria's trends mirror those in Europe, where sunshine duration increased by 130 hours in 2022 due to reduced cloud cover (Copernicus, 2023). However, unlike Europe's aerosol-driven brightening, Nigeria's trends are primarily linked to natural climatic variability (Wild, 2022). The diurnal asymmetry in cloud cover, noted globally (Yue & Wang, 2024), is less pronounced in Nigeria due to stable low-level clouds in the south (Knippertz et al., 2019).

4.4 Limitations and Future Research

Satellite data overestimated sunshine duration in southern Nigeria by up to 20% due to challenges in detecting low clouds at night (Kothe et al., 2024). Future studies should integrate hyperspectral satellite data (e.g., O4 band) for improved cloud detection (Martins et al., 2025). Additionally, research on multi-variable climate impacts (e.g., temperature, humidity) is needed to enhance adaptation strategies (Haider, 2021).

5. Conclusion

This study reveals significant temporal and spatial variability in sunshine duration and cloud cover across Nigeria from 1970 to 2022. Northern regions experienced increased sunshine and reduced cloud cover, driven by climatic drying and ENSO, while southern regions remained cloudier due to monsoonal and orographic effects. These findings have profound implications for solar energy, agriculture, and climate adaptation, positioning Nigeria as a critical case study in global climate research. Policymakers should prioritize region-specific strategies, such as solar energy development in the north and diversified energy solutions in the south, to address these climatic disparities.

References

Akinbami, J. F. K. (2023). Renewable energy potential in Nigeria: Opportunities and challenges. *Energy Policy*, 182, 113765.

Akinsanola, A. A., & Ogunjobi, K. O. (2022). Climatic zones and their influence on rainfall patterns in Nigeria. *Climate Dynamics, 59*(4), 1123–1135. https://doi.org/10.1007/s00382-021-06012-3.

Alexander, C.B. (2015). Climatological review of Enugu Rainfall from 1916–2012 and its implications. *Global Journal of Science Frontier Research: H Environment & Earth Science, 15*(5), 1–10.

Allan, R. P., et al. (2020). Advances in understanding large-scale responses of the water cycle to climate change. *Annals of the New York Academy of Sciences, 1472*(1), 49–75.

Bony, S., et al. (2021). Clouds, circulation, and climate sensitivity. *Nature Geoscience, 14*(5), 261–268. https://doi.org/10.1038/s41561-021-00703-8

Cherian, R., & Quaas, J. (2020). Trends in aerosol-driven cloud cover changes. *Atmospheric Chemistry and Physics, 20*(14), 8791–8805. https://doi.org/10.5194/acp-20-8791-2020

Copernicus. (2023). Clouds and solar radiation: European state of the climate 2023. *Copernicus Climate Change Service*.

Dommo, A., et al. (2018). The June–September low cloud cover in western central Africa. *Journal of Climate, 31*(23), 9575–9592.

Freychet, N., et al. (2022). Aerosol impacts on precipitation patterns in West Africa. *Climate Dynamics, 58*(7), 1987–2001. https://doi.org/10.1007/s00382-021-05945-z

Haider, S. (2021). Climate change impact research in Nigeria: Implications for sustainable development. *ScienceDirect Topics*.

Hannak, L., et al. (2017). Low cloud biases in CMIP5 models over West Africa. *Journal of Climate, 30*(3), 1235–1250.

Hersbach, H., et al. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society, 146*(730), 1999–2049.

Knippertz, P., et al. (2019). Aerosol-cloud interactions in West Africa. *Atmospheric Chemistry and Physics, 19*(12), 7915–7932.

Kothe, S., et al. (2017). A satellite-based sunshine duration climate data record for Europe and Africa. *Remote Sensing, 9*(5), 429.

Kothe, S., et al. (2024). Advances in satellite-based sunshine duration estimates. *Remote Sensing, 16*(10), 1756. https://doi.org/10.3390/rs16101756.

Martins, F. R., et al. (2025). Cloud retrieval using O4 band for improved solar irradiance estimates. *Remote Sensing of Environment*, 320, 114234.

Nigerian Meteorological Agency. (2023). *Climatological data archive 1970–2022.* NIMET.

NOAA. (2024). Oceanic Niño Index (ONI). *National Oceanic and Atmospheric Administration*. https://www.noaa.gov

Ogunjobi, K. O., et al. (2022). Climate variability and agricultural productivity in Nigeria. *Agricultural and Forest Meteorology*, 315, 108821.

Oladiran, M. T., et al. (2023). Solar energy potential in Nigeria: A review. *Renewable and Sustainable Energy Reviews*, 186, 113654.

Oladiran, M. T., et al. (2024). Renewable energy transitions in Nigeria: Challenges and opportunities. *Energy Reports*, 10, 1234–1245.

Ologunorisa, E.T. and Chinago, A.B. (2007). The diurnal variation of thunderstorm activity over Nigeria. *International Journal of Meteorology, 32*(315), 19–29.

Papachristopoulou, K., et al. (2024). Effects of clouds on solar irradiance nowcasting. *Atmospheric Measurement Techniques, 17*(7), 1851–1877.

Peel, M. C., Finlayson, B. L., and McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrol. Earth Syst. Sci*., 11, 1633–1644. DOI: 10.5194/hess-11-1633.

Pfeifroth, U., et al. (2023). Surface solar radiation dataset – Heliosat (SARAH-3). *Copernicus Climate Change Service*.

Schuster, R., et al. (2023). Monsoonal influences on West African cloud cover. *Journal of Climate, 36*(12), 4123–4138.

Wild, M. (2022). Global dimming and brightening: A review. *Journal of Geophysical Research: Atmospheres, 127*(15), e2022JD036704.

Wild, M., et al. (2020). Decadal trends in surface solar radiation and cloud cover. *Climate Dynamics, 55*(9), 2465–2480.

WMO. (2021). *Guide to meteorological instruments and methods of observation*. World Meteorological Organization.

Yue, X., & Wang, H. (2024). Diurnal asymmetry in cloud cover trends. *Proceedings of the National Academy of Sciences, 121*(25), e2318134121.

Copyrights