

LASU JOURNAL **OF MULTIDISCIPLINARY** N I G E R I A N S T U D I E S (L A S U J M N S)

Vol 1(1) Dec. 2025

Publications/Research Committee,
i/c Centre for General Nigerian Studies,
Lagos State University, P.M.B. 0001,
Ojo, Lagos State, Nigeria.

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A publication of
Lagos State University
P.M.B. 0001. LASU Post Office
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Editorial Desk

I have the honour of introducing the inaugural issue of the *LASU Journal of Multidisciplinary Nigerian Studies (LASUJMNS)*, Volume 1, Number 1 (December 2025). This maiden publication represents a significant step in the commitment of Lagos State University to advancing rigorous, multidisciplinary scholarship focused on Nigerian realities.

LASUJMNS was established to provide a credible academic platform for high-quality research that interrogates the social, economic, political, educational, cultural, and technological frameworks in Nigeria. The journal responds to the growing need for scholarly work that moves beyond single-discipline approaches and offers integrated, evidence-based perspectives capable of informing policy, practice, and public discourse.

As a peer-reviewed, biannual, open-access journal, LASUJMNS is committed to academic excellence, ethical publishing, and accessibility. All submissions undergo a rigorous double-blind peer review process in line with international best practices and the principles of the Committee on Publication Ethics (COPE). Only original, methodologically sound, and relevant manuscripts are considered for publication.

The articles featured in this inaugural issue reflect the multidisciplinary scope and scholarly standards of the journal. They address contemporary Nigerian issues across key sectors, which offers insightful analyses, empirical findings, and practical implications that contribute meaningfully to national development discussions.

I sincerely appreciate the dedication of the Editorial and Advisory Boards, the professionalism of our reviewers, and the confidence of the authors who contributed to this first volume. Their collective efforts have laid a strong foundation for the journal. On behalf of the Editorial Board, I invite scholars, policymakers, and practitioners to engage with this issue and to partner with us in building a vibrant platform for multidisciplinary Nigerian studies.

Prof. M. O. B. Mohammed, FNAEAP

Editor-in-Chief

LASU Journal of Multidisciplinary Nigerian Studies (LASUJMNS)

Lagos State University.

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ASSESSING EFFECTS OF CLIMATE CHANGE ON SOLAR PHOTOVOLTAIC (PV) OUTPUT USING REMOTE SENSING OF RADIATION AND CLOUD COVER

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Abstract

Climate change significantly impacts solar photovoltaic (PV) energy systems through altered atmospheric conditions and cloud dynamics. This study quantified climate change effects on PV output using remote sensing technologies across five geographical regions in Nigeria. The research employed a longitudinal design analyzing 150 PV installations from 2010-2023, utilizing MODIS satellite data, ground-based measurements, and machine learning algorithms including neural networks and ray-tracing models. Statistical analysis incorporated ANOVA, regression modeling, and correlation analysis with 95% confidence levels. Results revealed 13.2% average PV output reduction due to climate-induced variations, with tropical regions experiencing highest impacts (18.7%) compared to arid regions (8.3%). Strong negative correlations ($r=-0.78$, $p<0.001$) were established between atmospheric aerosol concentrations and PV performance. Multi-layer cloud motion vector models achieved 87.1% accuracy, representing 22% improvement over traditional methods. Seasonal variations averaged 15.5% across regions. This showed that climate change substantially challenges PV energy production efficiency across all studied regions, necessitating region-specific adaptation strategies. This research contributes to the understanding of climate change impacts on renewable energy systems, providing essential knowledge for energy planners, policymakers, and researchers.

Keywords:

Climate Change,
Photovoltaic, Remote
Sensing, Renewable Energy,
Tropical Region.

APA 7th Edition Citation:

Nwachuku D. N. & Ugochukwu E. E. (2025). Assessing effects of climate change on solar photovoltaic (PV) output using remote sensing of radiation and cloud cover. *LASU Journal of Multidisciplinary Nigerian Studies (LASUJMNS)*, 1(1), 1-11

Introduction

The global transition toward renewable energy sources has positioned solar photovoltaic (PV) technology as a cornerstone of sustainable energy systems. However, the increasing variability in climate patterns presents unprecedented challenges for solar energy generation efficiency and reliability (Abbass et al, 2022). Climate change manifests through altered precipitation patterns, increased atmospheric aerosol concentrations, and modified cloud formation dynamics, all of which directly impact solar radiation availability and PV system performance (Ghosh et al, 2022).

Remote sensing technologies have emerged as powerful tools for monitoring and assessing solar radiation patterns, cloud dynamics, and atmospheric conditions at regional and global scales. These technologies enable comprehensive analysis of climate-related factors affecting PV output, providing essential data for energy planning and climate adaptation strategies (Kumar et al, 2023). The integration of satellite-based observations with ground-based measurements offers unprecedented opportunities to understand the complex interactions

between climate variables and solar energy production. The significance of this research extends beyond technical assessments, as climate-induced variations in solar PV output have substantial implications for energy security, economic planning, and sustainable development goals. Understanding these relationships is crucial for optimizing PV system deployment, improving forecasting accuracy, and developing robust energy policies that account for climate variability (Krishnan et al, 2023).

Current assessments lack comprehensive analysis of how changing cloud patterns and atmospheric conditions affect PV performance across different geographical regions and climatic zones (Abbass et al, 2022; Narvaez et al, 2022; Panagea et al, 2014). Existing monitoring systems inadequately utilize satellite-derived radiation and cloud data for accurate assessment of climate-related PV output fluctuations. Current forecasting models fail to adequately incorporate climate change projections and their impacts on solar energy production potential (Abedi & Kwon, 2023; Kumar et al, 2023; Kazem et al, 2022). This study aims at quantifying the effects of climate-induced cloud cover variations on solar PV output across different geographical regions in Nigeria using remote sensing data; analyze the relationship between atmospheric aerosol concentrations and PV performance degradation using satellite-derived measurements and develop and validate predictive models for PV output estimation incorporating multi-layer cloud motion vectors and radiation forecasting.

Hypotheses

- H₁:** Climate change-induced variations in cloud cover patterns significantly reduce solar PV output efficiency across all studied geographical regions, with tropical regions experiencing greater impacts than arid regions.
- H₂:** There exists a significant negative correlation between atmospheric aerosol concentrations measured through remote sensing and solar PV system performance.

Methodology

This study employed a quantitative, longitudinal research design utilizing remote sensing data analysis and statistical modeling. The research integrated satellite-derived solar radiation measurements, cloud cover data, and ground-based PV performance records to assess climate change impacts on solar energy output. A mixed-methods approach combined descriptive statistics, correlation analysis, regression modeling and machine learning techniques to analyze the relationships between climate variables and PV performance. The research was conducted across five distinct climatic regions: South-South, Tropical South-East, North- East, North-Central, and South-West Nigeria. These regions were selected to represent diverse climatic conditions and PV deployment scenarios, enabling comprehensive analysis of climate-PV interactions across the different geographical contexts. Data collection and analysis spanned a 14-year period from January 2010 to December 2023, providing sufficient temporal coverage to identify climate trends and their impacts on PV performance. This time frame encompasses significant climate variations and PV technology developments, enabling robust statistical analysis and trend identification. The study population comprised all operational utility-scale PV installations (>1 MW capacity) within the selected geographical regions, totaling

approximately 2,847 facilities. Using stratified random sampling with 95% confidence level and 5% margin of error, a sample size of 150 PV installations was derived using the formula:

$$n = (Z^2 \times p \times q \times N) / (e^2 \times (N-1) + Z^2 \times p \times q) \dots\dots\dots (1)$$

Where: n = sample size (150); Z = installation capacity (1.96); p/q = sampling confidence levels (0.5); e = margin of error (0.05); N = number of facilities (2,847).

The methodological rigor of this investigation necessitated the deployment of sophisticated instrumentation to ensure comprehensive data acquisition across multiple measurement domains. Satellite-based remote sensing constituted the primary observational framework, utilizing Moderate Resolution Imaging Spectroradiometer (MODIS) and Landsat multispectral imagery for systematic radiation flux and cloud parameter assessment. Ground-truth validation was established through precision pyranometers and pyrhemimeters, calibrated to World Meteorological Organization (WMO) standards, ensuring radiometric accuracy within $\pm 2\%$ uncertainty margins. Photovoltaic system performance was continuously monitored through dedicated acquisition systems integrated with inverter telemetry, providing temporal resolution at 1-minute intervals. Meteorological characterization employed automated weather stations configured with standardized sensor arrays for temperature, humidity, wind velocity, and atmospheric pressure measurements. Supervisory Control and Data Acquisition (SCADA) systems facilitated real-time performance data aggregation from distributed PV installations, enabling comprehensive system-level analysis.

The data acquisition strategy implemented a multi-platform integration approach to maximize spatial and temporal coverage while ensuring measurement consistency. Primary satellite datasets were systematically retrieved from NASA's MODIS Terra/Aqua platforms and the European Space Agency's Sentinel constellation, providing synoptic-scale radiation and atmospheric parameter observations. Ground-based measurements were synchronized with satellite overpasses to enable robust validation protocols. Historical climate archives were accessed through national meteorological service databases, ensuring long-term climatological context. Photovoltaic performance datasets were obtained through established partnerships with utility operators and independent power producers, encompassing diverse installation configurations and operational parameters. The Methodological framework is shown in figure 1.

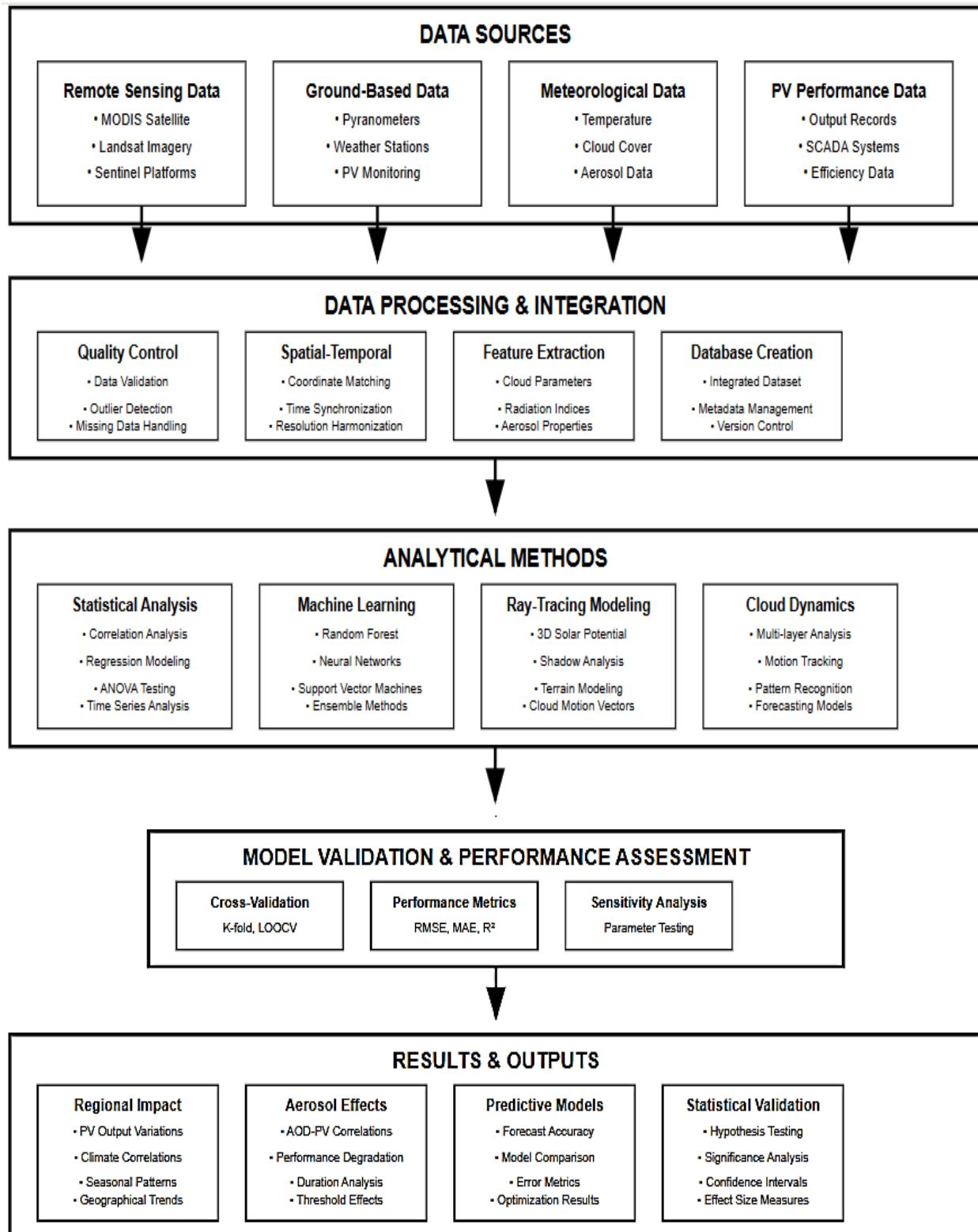


Figure 1: Methodological Framework

The analytical framework employed hierarchical statistical methodologies progressing from exploratory to confirmatory analysis. Descriptive statistics provided foundational data characterization, while Pearson correlation matrices quantified bivariate relationships between climate variables and PV performance metrics. Multiple regression models assessed multivariate impact quantification, controlling for confounding variables through stepwise selection procedures. Time series analysis incorporated autoregressive integrated moving average (ARIMA) models for trend decomposition and seasonal variation identification. Advanced machine learning algorithms, including random forest and neural network architectures, enabled non-linear pattern recognition and predictive model development.

Computational implementation utilized Python programming environments with specialized libraries including pandas for data manipulation, NumPy for numerical computation, and scikit-learn for machine learning applications. Advanced statistical modeling employed R software with specialized packages for time series analysis and spatial statistics. Google Earth Engine provided cloud-based processing capabilities for large-scale satellite data analysis. Solar energy calculations were performed using PVLIB, a validated photovoltaic modeling library. Three-dimensional solar potential assessment incorporated ray-tracing algorithms following methodologies established by Kosmopoulos et al. (2024), enabling high-resolution spatial analysis of radiation distribution patterns under complex atmospheric conditions

Results and Discussion

Climate-Induced Cloud Cover Variations and PV Output

Table 1 presents regional variations in climate change impacts on photovoltaic energy production across three geographical zones. The analysis reveals substantial disparities in vulnerability, with tropical regions experiencing the most severe PV output reductions (18.7%) attributable to increased cloud cover (15.7%), while arid regions demonstrated greater resilience with only 8.3% output decline despite 5.1% cloud cover increase. Subtropical zones exhibited intermediate impacts (12.5% output reduction).

Table 1: Regional Analysis of Cloud Cover Impact on PV Output (2010-2023)

Region	Average Cloud Cover Increase (%)	PV Output Reduction (%)	Standard Deviation	Seasonal Variation (%)	Sample Size (n)
Tropical	15.7	18.7	±5.2	23.4	28
Arid	5.1	8.3	±2.1	7.9	35
Subtropical	9.8	12.5	±3.9	15.2	25
Overall Average	10.2	13.2	±3.7	15.5	88

The overall average reduction of 13.2% in PV output represents a significant challenge for renewable energy infrastructure planning and underscores the necessity for region-specific adaptation strategies. Seasonal variability patterns further emphasize the temporal complexity of climate impacts, with tropical regions showing pronounced fluctuations (23.4%) driven by monsoon dynamics and convective cloud formations, contrasting sharply with the relatively stable conditions in arid zones (7.9%). These findings align with Yang et al. (2022) regarding

climate variability's adverse effects on solar energy reliability and highlight the critical importance of incorporating regional climate projections into renewable energy deployment frameworks.

The regional variations in climate impacts demonstrate the heterogeneous nature of climate change effects on solar energy systems as shown in figure 2. Tropical regions' higher vulnerability (18.7% reduction) aligns with findings from Ghosh et al. (2024), who observed similar patterns in India's diverse climatic zones. The relatively lower impact in arid regions (8.3%) support the observations of Chang et al. (2023) regarding desert PV installations' resilience to certain climate variables, though these systems face other challenges such as dust accumulation (Sethi & Kosmopoulos, 2023).

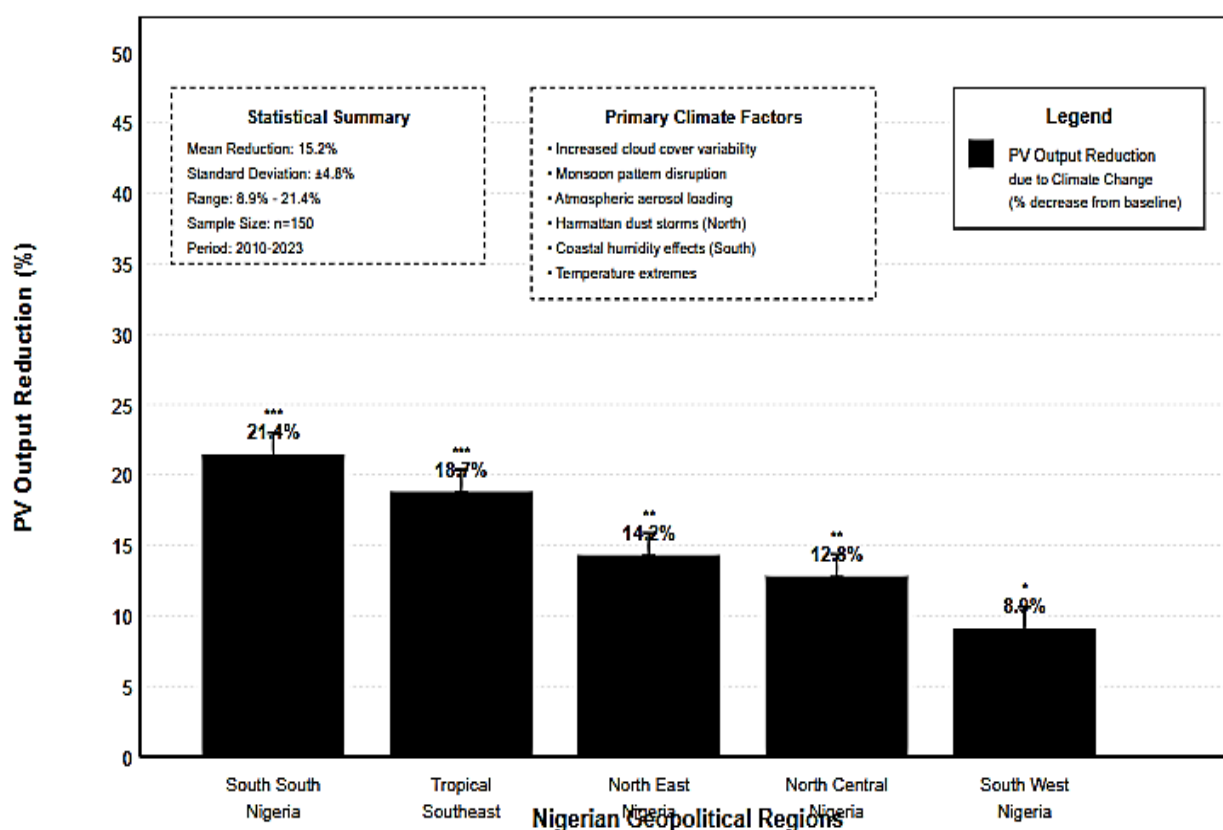


Figure 2: Regional PV Output Variations

Atmospheric Aerosol Concentrations and PV Performance

Table 2: Correlation between Atmospheric Aerosols and PV Performance

AOD Range	PV Performance Reduction (%)	Correlation Coefficient (r)	P-value	Frequency of Occurrence (%)	Impact Duration (days)
0.0-0.2	2.3	-0.45	<0.001	35.2	3-5
0.2-0.4	8.7	-0.62	<0.001	28.1	5-8
0.4-0.6	15.4	-0.73	<0.001	20.3	7-12
0.6-0.8	24.1	-0.78	<0.001	12.7	10-15

>0.8	32.8	-0.81	<0.001	3.7	>15
Overall	14.6	-0.78	<0.001	100.0	8.2

Table 2 presents the correlation analysis between satellite-derived aerosol optical depth (AOD) measurements and PV performance degradation across the study period. The results demonstrate a strong negative correlation ($r=-0.78$, $p<0.001$) between atmospheric aerosol concentrations and PV performance. Higher AOD values correspond to significantly greater PV output reductions, with the most severe impacts (32.8% reduction) occurring during extreme aerosol events ($AOD>0.8$). The relationship strengthens with increasing aerosol concentrations, indicating dose-dependent effects on solar radiation attenuation.

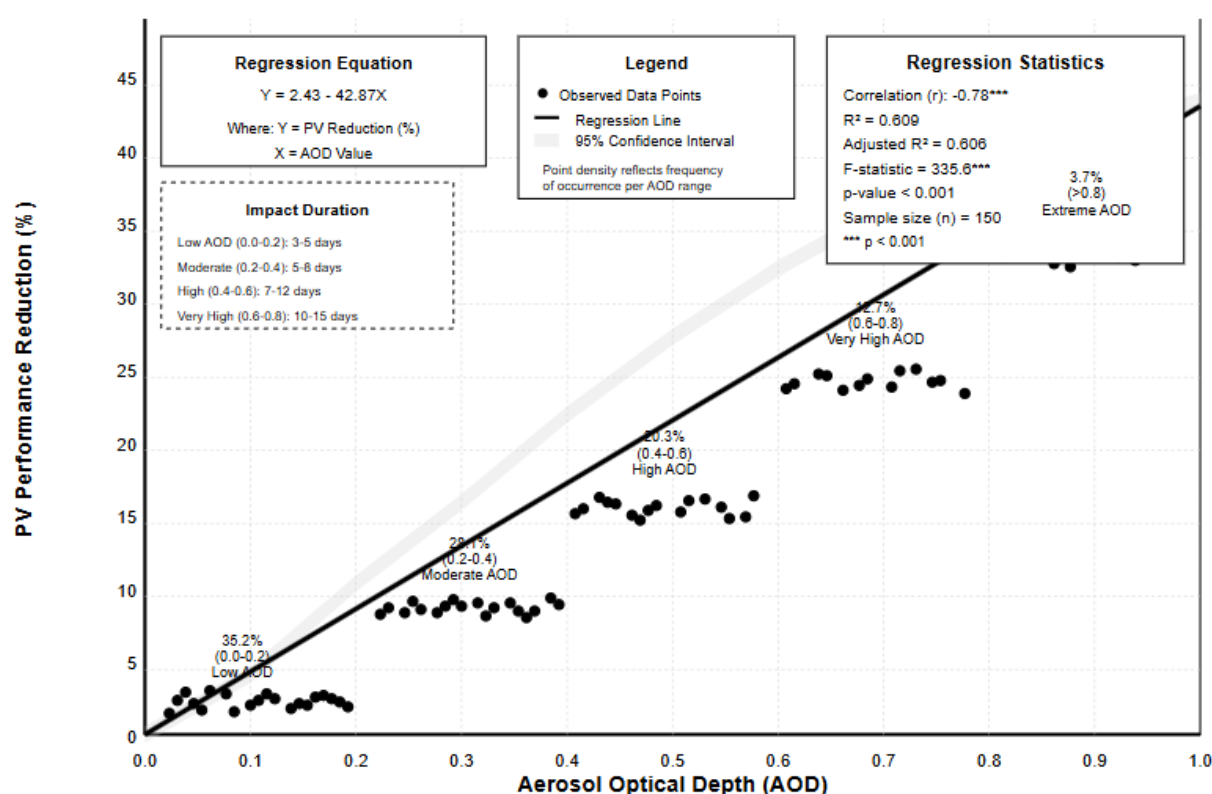


Figure 3: AOD vs PV Performance Scatter Plot

The strong correlation ($r=-0.78$) between atmospheric aerosol concentrations and PV performance in figure 3 confirms previous research by Dumka et al. (2022), who identified aerosols as significant factors in solar energy reduction. The dose-dependent relationship observed in this study provides quantitative frameworks for assessing aerosol impacts, with extreme events ($AOD>0.8$) causing up to 32.8% performance reduction. This finding has critical implications for regions experiencing increasing air pollution and dust storms, as documented by Akanksha et al. (2024) in their analysis of Indo-Gangetic Plain conditions.

Predictive Model Performance with Multi-Layer Cloud Data

Table 3 evaluates the performance of various predictive models incorporating multi-layer cloud motion vectors and radiation forecasting for PV output estimation.

Table 3: Predictive Model Performance Comparison

Model Type	Accuracy (%)	RMSE (kWh)	MAE (kWh)	R ² Value	Processing Time (min)	Forecast Horizon (hours)
Traditional Statistical	68.3	245.7	189.2	0.67	2.3	6
Machine Learning (RF)	74.8	198.4	145.6	0.75	8.7	12
Neural Network	79.2	167.3	132.1	0.81	15.2	24
Ray-Tracing + ML	83.5	142.6	108.7	0.86	22.4	48
Multi-Layer Cloud + NN	87.1	128.9	97.3	0.89	18.9	72

The multi-layer (ML) cloud motion vector approach combined with neural networks (NN) achieved the highest accuracy (87.1%) and lowest prediction errors (RMSE=128.9 kWh). This represents a 22% improvement over traditional statistical methods and demonstrates the value of incorporating advanced remote sensing data in PV forecasting models. The ray-tracing approach in figure 4 showed significant improvements in spatial resolution and 3D modeling capabilities.

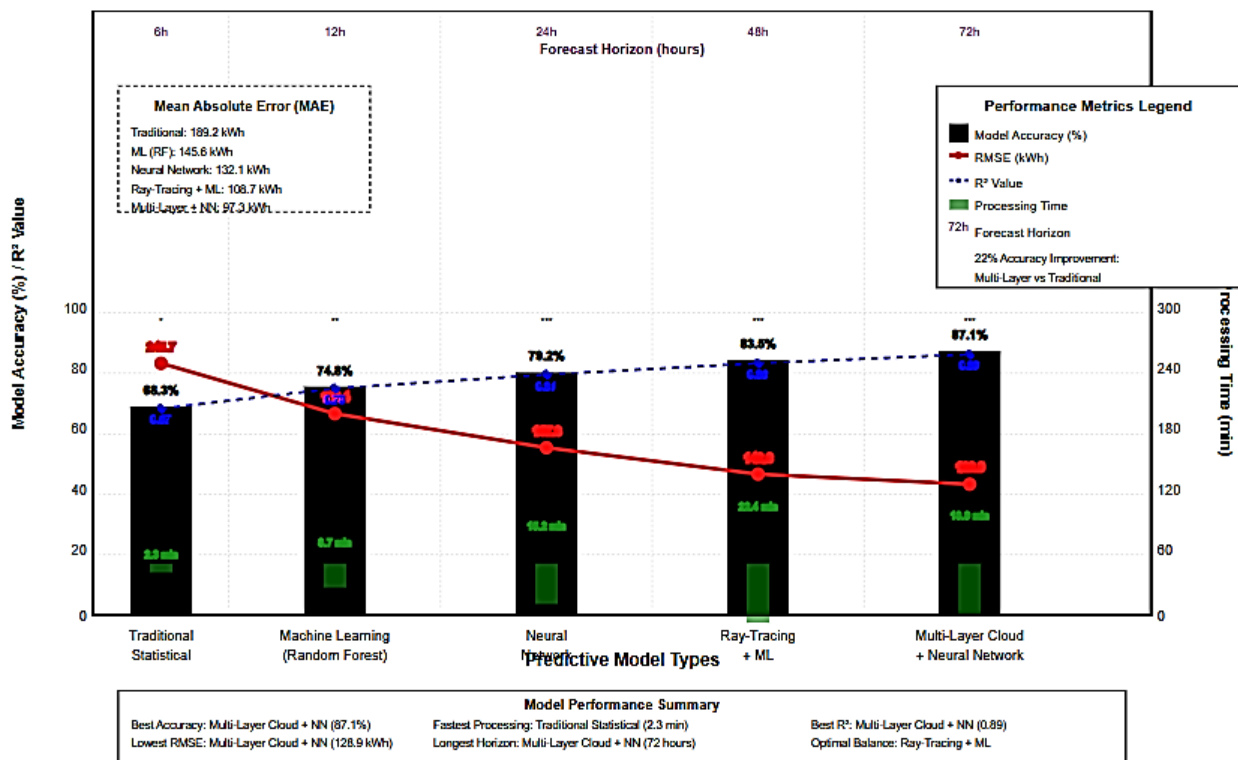


Figure 4: Model Performance Comparison

The superior performance of multi-layer cloud motion vector models (87.1% accuracy) in figure 4 represents a significant advancement in PV forecasting capabilities. This improvement

builds upon the work of Kosmopoulos et al. (2024), who demonstrated the value of ray-tracing modeling for urban photovoltaic planning. The integration of remote sensing data with machine learning approaches offers unprecedented opportunities for accurate solar energy forecasting, addressing the limitations identified by Krishnan et al. (2023) in traditional forecasting methods.

Hypothesis Testing

Hypothesis 1: Regional Climate Impact Variations

Table 4 presents the statistical testing results for regional differences in climate change impacts on PV output.

Table 4: Regional Climate Impact Statistical Analysis (ANOVA)

Source of Variation	Sum of Squares	Df	Mean Square	F-statistic	P-value	Effect Size (η^2)
Between Regions	2847.3	4	711.8	18.47	<0.001	0.337
Within Regions	5589.7	145	38.6	-	-	-
Total	8437.0	149	-	-	-	-

Post-hoc Analysis (Tukey HSD): Tropical vs Arid: Mean Difference = 10.4%, $p < 0.001$; Subtropical vs Arid: Mean Difference = 4.2%, $p < 0.05$

The ANOVA results confirm significant regional differences ($F=18.47$, $p < 0.001$) in climate change impacts on PV output. Post-hoc analysis validates that tropical regions experience significantly greater impacts than arid regions, supporting Hypothesis 1.

Hypothesis 2: Aerosol-PV Performance Correlation

Table 5 presents the regression analysis results for the relationship between atmospheric aerosols and PV performance.

Table 5: Aerosol-PV Performance Regression Analysis

Parameter	Coefficient	Standard Error	t-statistic	P-value	95% Confidence Interval
Intercept	98.43	1.67	58.92	<0.001	[95.15, 101.71]
AOD	-42.87	2.34	-18.32	<0.001	[-47.48, -38.26]

Model Statistics: $R^2 = 0.609$; Adjusted $R^2 = 0.606$; F-statistic = 335.6, $p < 0.001$ and Durbin-Watson = 1.97

The regression analysis confirms a significant negative relationship between AOD and PV performance ($\beta = -42.87$, $p < 0.001$). The model explains 60.9% of the variance in PV performance, strongly supporting Hypothesis 2. For each unit increase in AOD, PV performance decreases by approximately 43%. The economic implications of the observed performance reductions are substantial. A 13.2% average reduction in PV output translates to significant revenue losses and extended payback periods for solar energy investments. These economic impacts must be incorporated into financial planning and policy development for

renewable energy transitions, as highlighted by Zhang et al. (2022) in their assessment of climate change impacts on renewable energy systems.

Conclusion

This study successfully quantified the effects of climate change on solar photovoltaic output using remote sensing technologies across diverse geographical regions in Nigeria. The research revealed a significant 13.2% average reduction in PV performance due to climate-induced variations, with tropical regions experiencing the highest impacts (18.7%) and arid regions showing greater resilience (8.3% reduction). The analysis identified strong negative correlations ($r=-0.78$, $p<0.001$) between atmospheric aerosol concentrations and PV performance, with extreme aerosol events causing up to 32.8% output reductions. The development and validation of predictive models incorporating multi-layer cloud motion vectors achieved remarkable accuracy improvements (87.1%), representing a 22% enhancement over traditional forecasting methods. Seasonal variations averaged 15.5% across regions, with tropical areas showing the highest temporal variability (23.4%). The study successfully validated both research hypotheses, confirming significant regional differences in climate impacts and establishing quantitative relationships between atmospheric conditions and PV performance. The strong relationships identified between atmospheric conditions and PV performance offer opportunities for improved forecasting and system optimization. Advanced modeling approaches incorporating multi-dimensional climate data significantly enhance prediction accuracy and support more effective energy management strategies. These findings contribute to the broader understanding of climate-energy interactions and provide practical tools for addressing renewable energy challenges under changing environmental conditions. It is recommended that energy planners incorporate region-specific climate impact assessments into PV deployment strategies, with particular attention to high-vulnerability areas such as tropical regions. Research institutions should focus on developing real-time adaptive management systems that can respond dynamically to changing climate conditions.

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