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Modelling the Interrelationship of Solar Irradiance and Temperature Patterns across the Climatic Zones of Nigeria Using Regression Analysis

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Abstract

This study investigates the interrelationship between solar irradiance and air temperature across the major climatic zones of Nigeria using data from ten representative meteorological stations over a 15-year period (2001–2015). Monthly observations of solar irradiance and temperature from Calabar, Benin, Oshogbo, Lokoja, Minna, Yola, Yelwa, Jos, Maiduguri, and Sokoto were obtained from the Nigerian Meteorological Agency (NiMET) through WASCAL at FUT Minna. Descriptive analysis showed distinct seasonal peaks in both irradiance and temperature across climatic zones, with coastal and rainforest zones peaking earlier in the year than savannah and Sahelian zones. In addition to correlation analysis, this study employed multiple linear regression models—both station-specific and a combined national model—to better understand the strength and dynamics of the irradiance–temperature relationship while accounting for elevation, latitude, and longitude. Coastal stations (Calabar and Benin) recorded peak irradiance and temperature in February–March, while tropical rainforest stations (Oshogbo and Lokoja) peaked between January and early April. In the Guinea savannah (Minna and Jos), peaks occurred in February to early May. Sudan savannah stations (Yelwa and Yola) peaked in February and May, with Yelwa recording the highest irradiance (40.25 W/m²). Sahel savannah locations (Sokoto and Maiduguri) also peaked in February and May. Across all zones, a direct proportionality between solar irradiance and temperature was observed. Station-level regression revealed significant relationships in all zones, with R^2 values ranging from 0.33 (Maiduguri) to 0.50 (Jos), and solar irradiance consistently emerging as a statistically significant predictor of temperature ($p < 0.0001$). A combined centered

multiple regression model across all stations achieved an R^2 of 0.52 and a Root Mean Squared Error (RMSE) of 0.988°C, indicating strong predictive performance. Elevation showed a negative effect on temperature, while latitude and longitude were not statistically significant. The model accurately predicted monthly temperature variations and demonstrated broad applicability across Nigeria's diverse climatic regions. These findings provide valuable insights for solar energy system design and agricultural thermal forecasting. Future research using longer data records is recommended to capture long-term climate trends.

Keywords: Solar irradiance, Air temperature, Climatic zones, Multiple linear regression, Elevation, Nigeria

Introduction

The sun is the source of most of the energy on earth, the power source for plants, the cause of flow of atmosphere and of water, and the source of the warmth which makes life possible (Ezenwora *et al*., 2011). Solar irradiance is Earth's dominant energy source and the only external agent of change of its surface and atmosphere. Consequently, the reliable specification of solar irradiance variability on multiple time scales informs a wide range of research and applications, the most obvious and controversial of which is the detection and attribution of the Sun's natural influence on climate (Gray *et al*., 2010; Lean, 2017; Matthes *et al*., 2017).

Solar Irradiance is the measure of energy density of sunlight and is measured in kWh/m^2. It is the integral of irradiance since the energy is integrated over time. It is often expressed as Peak Sun Hours (PSH). The PSH is simply the length of time in hours at an irradiance level of ($1kW/m^2$) needed to produce the daily irradiation obtained from the integration of irradiance over all daylight hours. Most solar energy technologies rely on it to provide energy, as well as modelling and design related device or system like Photovoltaic (PV) system.

Photovoltaic systems have been increasingly used in the generation of electrical energy, either as a means of providing electricity in areas where there is no grid connection (stand-alone systems), or by providing electricity to the grid or grid connected systems (Ibrahim *et al*., 2019).

Temperature differences from day to night and from season to season are the consequences of the intensity of sunlight falling to the surface and into the earth's atmosphere.

When Solar radiation is greater than 3 kWh/m^2 it indicates that the sky is clear, its intensity is very high and very good for PV application. Temperature is an important consideration in the operation of PV module system. At lower temperatures, PV module systems produce more power. For higher temperature, optimum operation requires modification of electrical load and removal of excess heat. The efficiency losses for PV systems can be minimized in the presence of temperature variations. (Daut *et al*., 2012).

Study Area

The study area comprises of some selected locations (Yelwa, Oshogbo, Lokoja, Sokoto, Yola, Jos Calabar, Maiduguri, Benin and Minna) within the five climatic zones of Nigeria as shown in Figure 1.

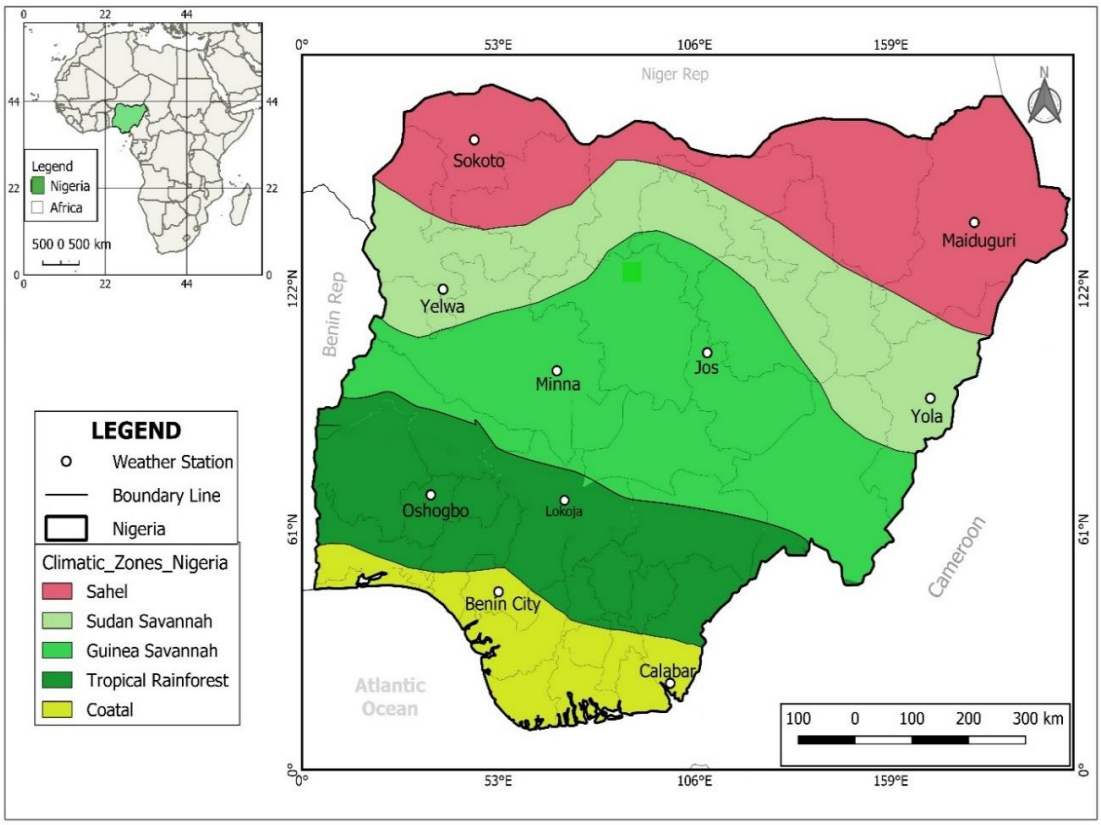


Figure 1.: The study locations within the five climatic zones of Nigeria.
(Researcher Design, 2023)

Nigeria is located at the extreme inner corner of the Gulf of Guinea on the West coast of Africa, occupies an area of 923,768 km². 910,768 km² of the area is land, while water takes up the remaining 13,000 km². Nigeria's total boundaries are 4,047 km in length. The border with Benin Republic is 773 km with Cameroon is 1,690 km, Chad is 87 km, and Niger is 1,497 km. Nigeria's coast line is 853 km. She lies within the tropical zone. There are wide climatic variations in the different regions of the country. Near the coast, the seasons are not sharply defined. Temperatures rarely exceed 32° C (90° F), but humidity is very high and nights are hot. Basically, there are two distinct seasons: a wet season from April to October, with generally lower temperatures, influenced by an air mass originating from the south Atlantic Ocean, locally known as the south west wind, or by its main name, The Tropical Maritime air mass and a dry season from November to March, which blows from the Sahara Desert, locally known as, Harmattan.

Nigeria can be divided into five climatic zones as shown in Table 1. namely Sahel, Tropical rainforest, Guinea Savannah, Sudan Savannah and Coastal zones (Olaniran and Summer, 2001). The weather stations, their respective geographical locations and elevations are shown in Table 1.

Table 1: List of stations showing their latitude, longitude and elevation

Climatic zones	Station	Latitude (°N)	Longitude (°E)	Elevation(m)
Coastal	Calabar	4.97	8.35	63
	Benin	6.33	5.62	200
Tropical rainforest	Oshogbo	7.78	4.54	340
	Lokoja	7.81	6.74	44
Guinea savannh	Minna	9.60	6.55	260
	Jos	9.56	9.00	1220
Sudan savannah	Yelwa	10.88	4.75	243
	Yola	9.23	12.47	174
Sahel savannah	Maiduguri	11.83	13.15	351
	Sokoto	13.02	5.25	302

Methodology

Data Acquisition

Atmospheric data of solar irradiance and temperature from the Nigerian Metrological Agency (NIMET), Abuja, was acquired from the data bank of the West Africa Service Centre on Climate Change and Adapted Land use (WASCAL), Federal University of Technology, Minna, for a 15-year period (2001-2015). Ten weather stations across the climatic zones of Nigeria (Lokoja, Calabar, Oshogbo, Sokoto, Yola, Jos, Benin, Yelwa, Maiduguri and Minna) were used.

The data of solar irradiance, rainfall and temperature were acquired using Aviation Weather Observing and Display System (AWODS). The system provides a truly integrated presentation for all meteorological data, and it also supports multiple sensor sites as required. This powerful microprocessor-based computer systems collects and processes the data from the sensor arrays and passes it to the central data processing (CDP) computer via wired or wireless connection. The CDP receives the data from the various field sensor stations, processes and archives the data and then distributes it to the displays located in the base station. The system also has a dual processing system, with automatic switch over in the case of failure. The system archive data for future use. The CDP computer has an integral watch dog timer that will ensure automatic restart of the system in the event of a power failure. The AWOS CDP also has an optional uninterruptible power supply that provide backup power in the event of power failure.

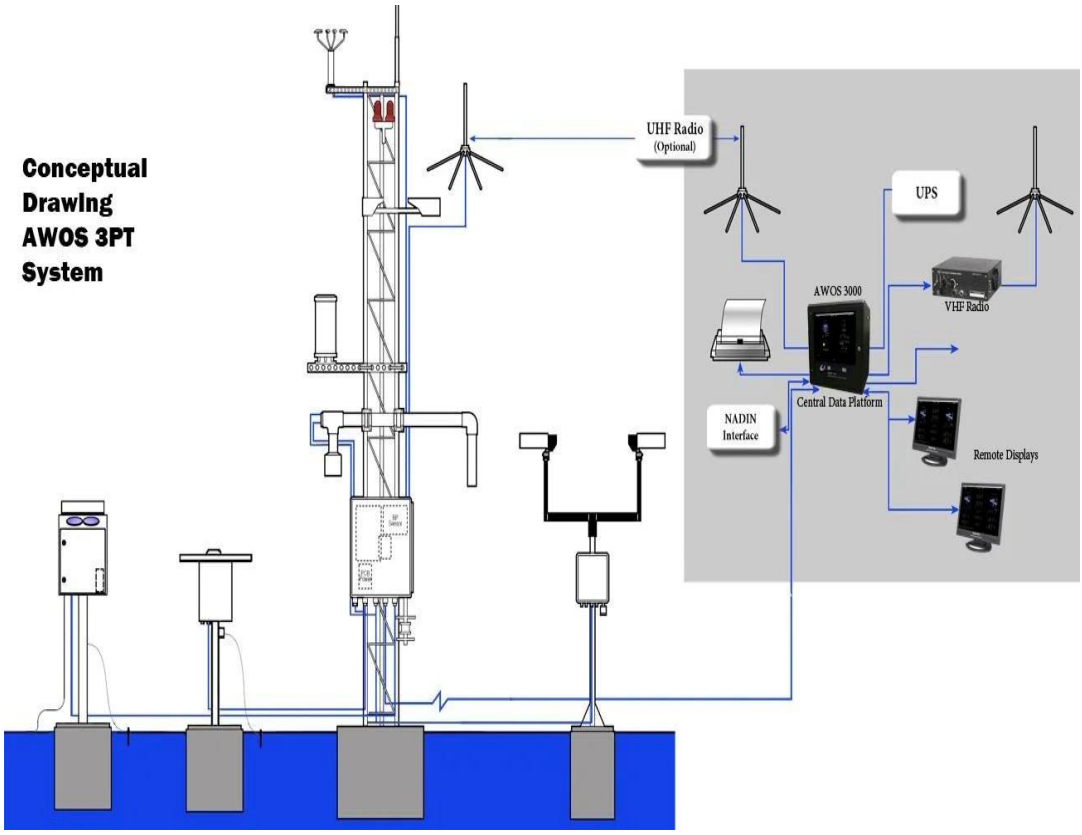


Figure 2: Aviation Weather Observing and Display System (Michael *et al*., 2023)

Data Analysis

The acquired data of solar irradiance and temperature were sorted, filtered and also the mean monthly and annual values were computed using Microsoft excel package. Afterwards, analysis of the data was carried out.

Metric measure was used to: compute the interrelationship of solar irradiance with and atmospheric temperature for each of the climatic zones.

Statistical Modelling Approach

To investigate the relationship between solar irradiance and temperature, multiple linear regression (MLR) models were developed using the statsmodels and scikit-learn Python libraries. The general MLR model specification was:

$$T = \beta_0 + \beta_1 \cdot Solar\ Irradiance + \beta_2 \cdot Elevation + \varepsilon$$

Where:

T = temperature (dependent variable)

Solar Irradiance and Elevation = independent variables

$\beta_0, \beta_1, \beta_2$ = model coefficients

ε = error term

Station-by-Station Model Development

To capture localized climatic behaviour, separate regressions were fitted for each of the ten stations. This station-specific modelling accounts for microclimatic differences and allows for comparison of model performance and parameter sensitivity across ecological zones.

For each station:

- Independent variables were solar irradiance and elevation
- Latitude and longitude were excluded as regressors because they remained constant per station

Model performance was evaluated using R-squared (R^2) and adjusted R-squared, while statistical significance was assessed via p-values for each coefficient. This method highlighted how each location uniquely responds to solar energy input, influenced by elevation and ecological factors.

Combined Model

In addition to localized regressions, a combined national-level model was developed to generalize temperature prediction across all stations. This pooled model included spatial coordinates as explanatory variables:

T=β0+β1·Solar Irradiance+β2·Elevation+β3·Latitude+β4·Longitude+

$$T = \beta_0 + \beta_1 \cdot Solar\ Irradiance + \beta_2 \cdot Elevation + \beta_3 \cdot Latitude + \beta_4 \cdot Longitude + \varepsilon$$

This approach:

- Treated the entire dataset as one unified population
- Enabled assessment of spatial gradients (latitude, longitude) in temperature variation
- Served as a control model for validating regional regressions

Model Evaluation and Visualization

Both sets of models were evaluated using:

- **R^2 and Adjusted R^2** (to assess goodness-of-fit)
- **Root Mean Squared Error (RMSE)** and **residual analysis** (to assess prediction accuracy)
- **Actual vs Predicted plots**, All visualizations and statistical computations were conducted using Python (version 3.10) with key libraries including pandas, statsmodels, matplotlib, and seaborn.

Results and Discussion

Interrelationship of Solar irradiance and temperature pattern across the climatic zones of Nigeria are presented in Figure 2 below:

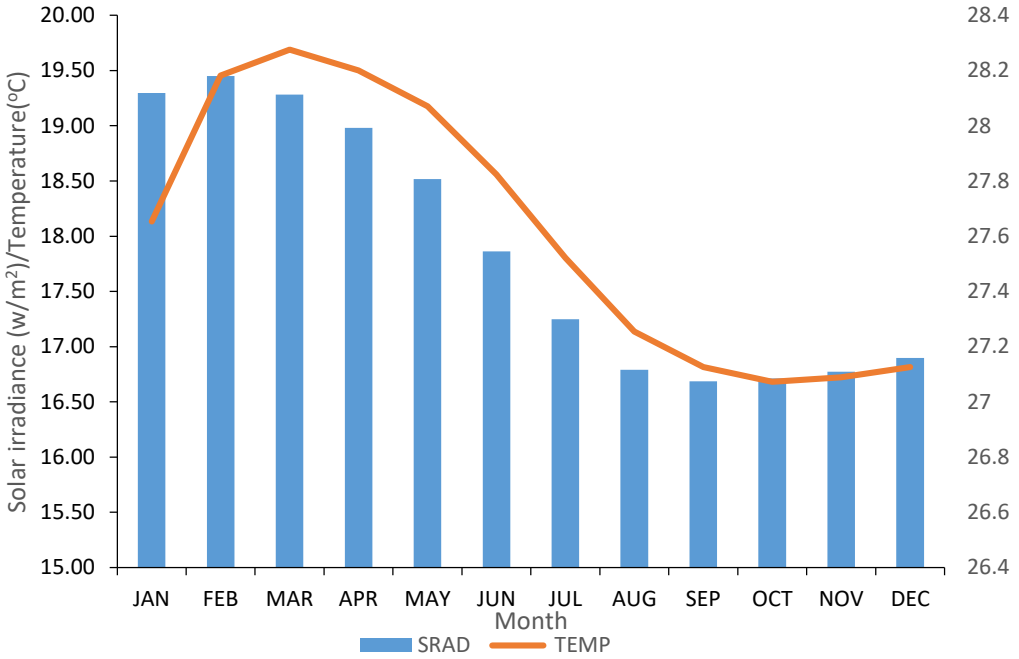


Figure 2a: Interrelationship of Mean Monthly Solar Irradiance with Mean Monthly Atmospheric Temperature in Calabar (2001-2015)

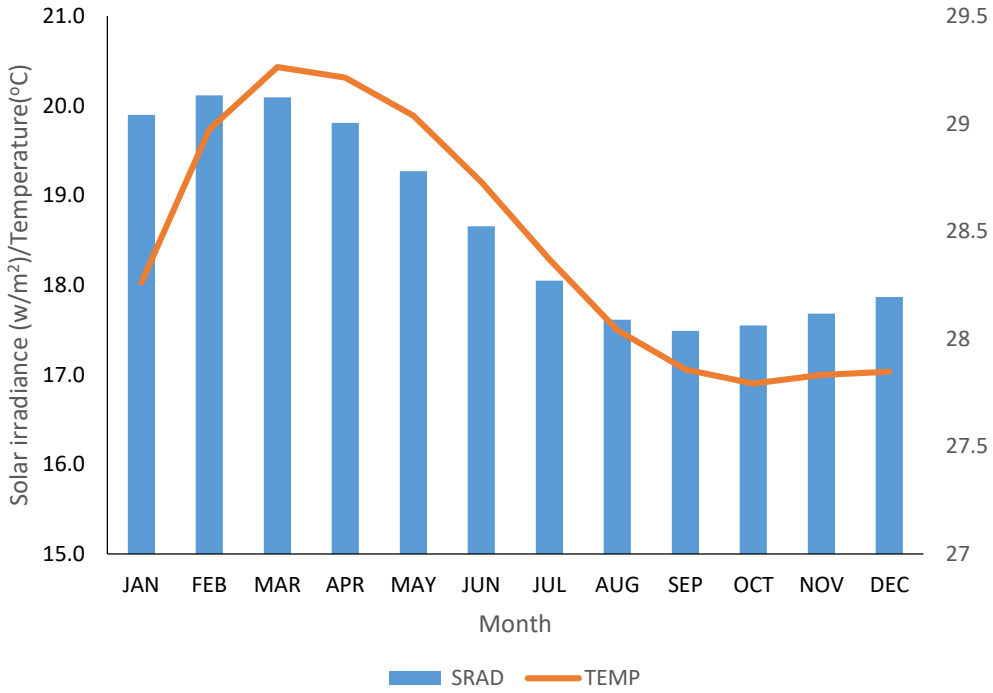


Figure 2b: Interrelationship of Mean Monthly Solar Irradiance with Mean Monthly Atmospheric Temperature in Benin (2001-2015)

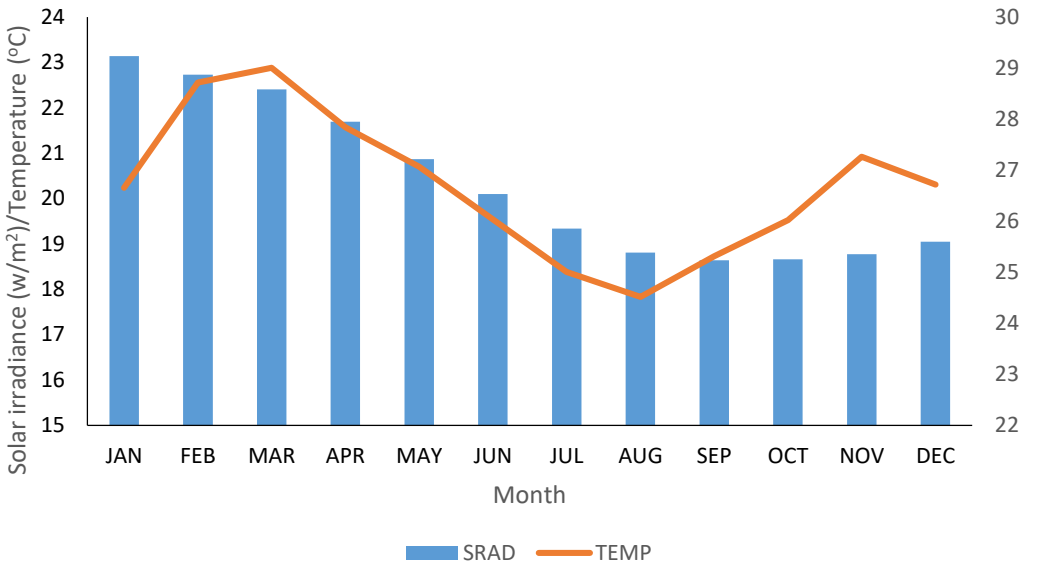


Figure 2c: Interrelationship of Mean Monthly Solar Irradiance with Mean Monthly Atmospheric Temperature in Oshogbo (2001-2015)

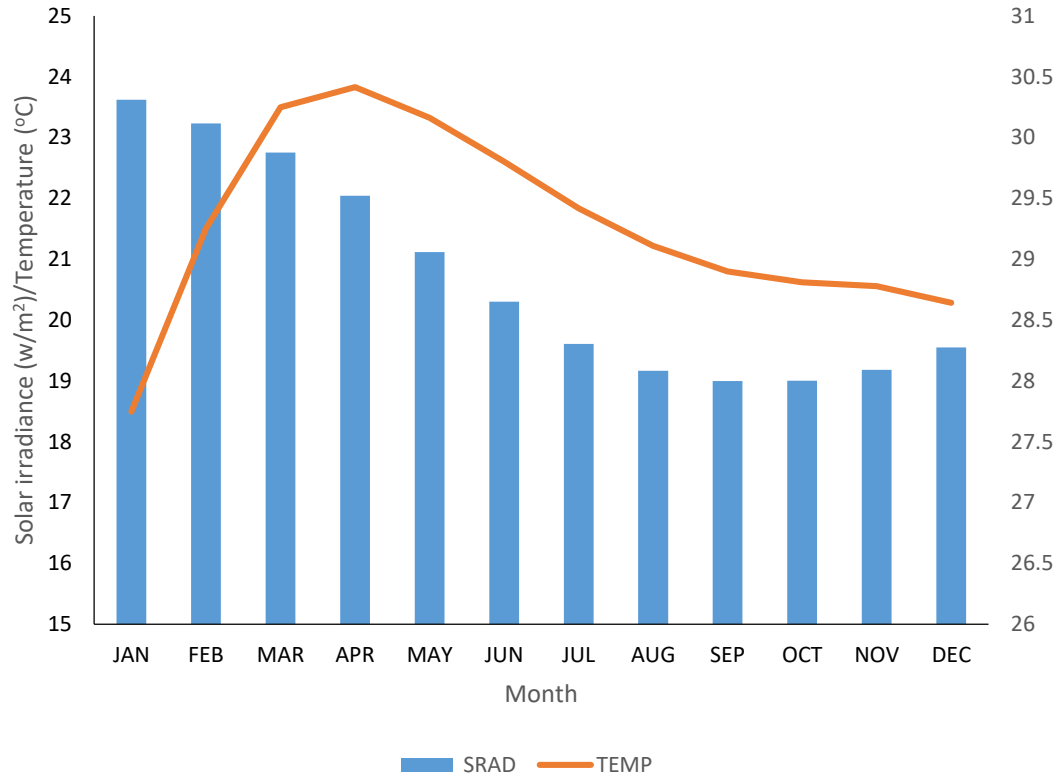


Figure 2d: Interrelationship of Mean Monthly Solar Irradiance with Mean Monthly Atmospheric Temperature in Lokoja (2001-2015)

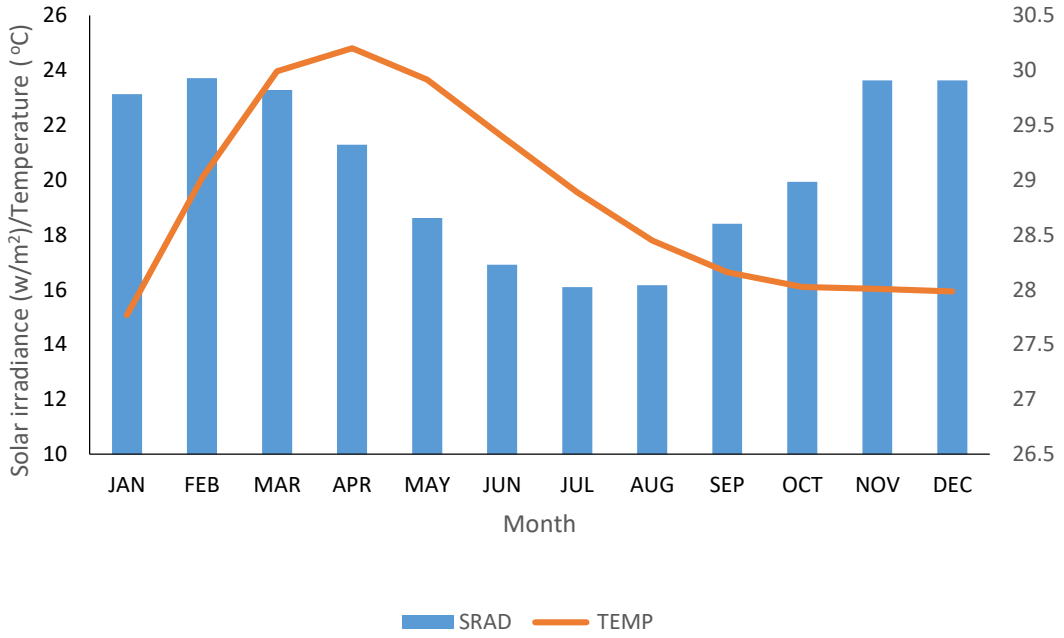


Figure 2e: Interrelationship of Mean Monthly Solar Irradiance with Mean Monthly Atmospheric Temperature in Minna (2001-2015)

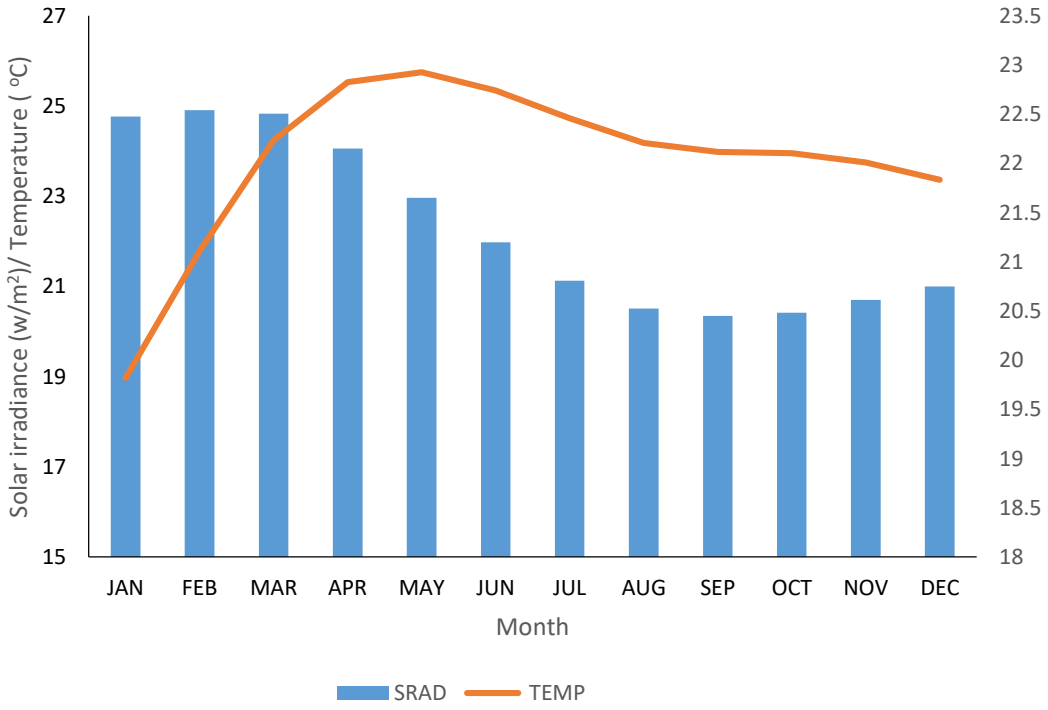


Figure 2f: Interrelationship of Mean Monthly Solar Irradiance with Mean Monthly Atmospheric Temperature in Jos (2001-2015)

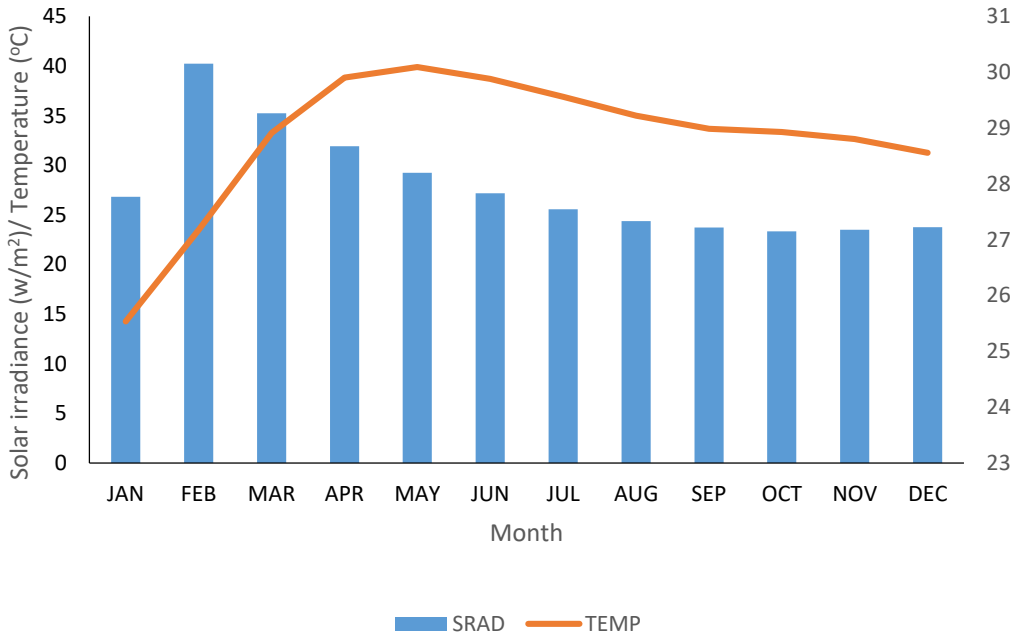


Figure 2g: Interrelationship of Mean Monthly Solar Irradiance with Mean Monthly Atmospheric Temperature in Yelwa (2001-2015)

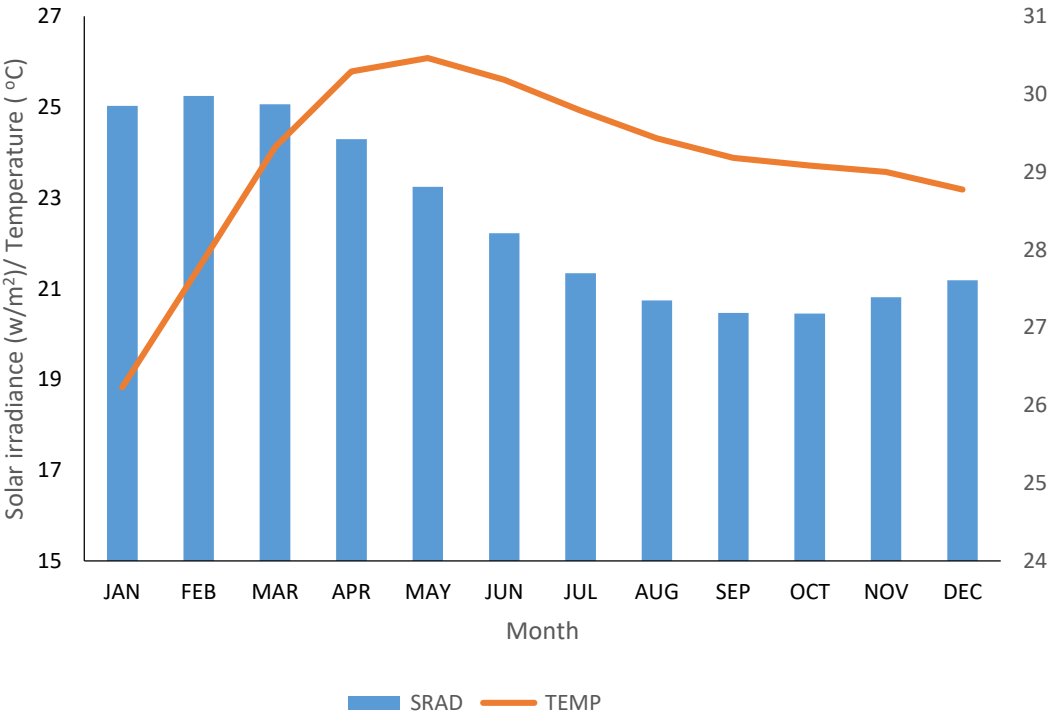


Figure 2h: Interrelationship of Mean Monthly Solar Irradiance with Mean Monthly Atmospheric Temperature in Yola (2001-2015)

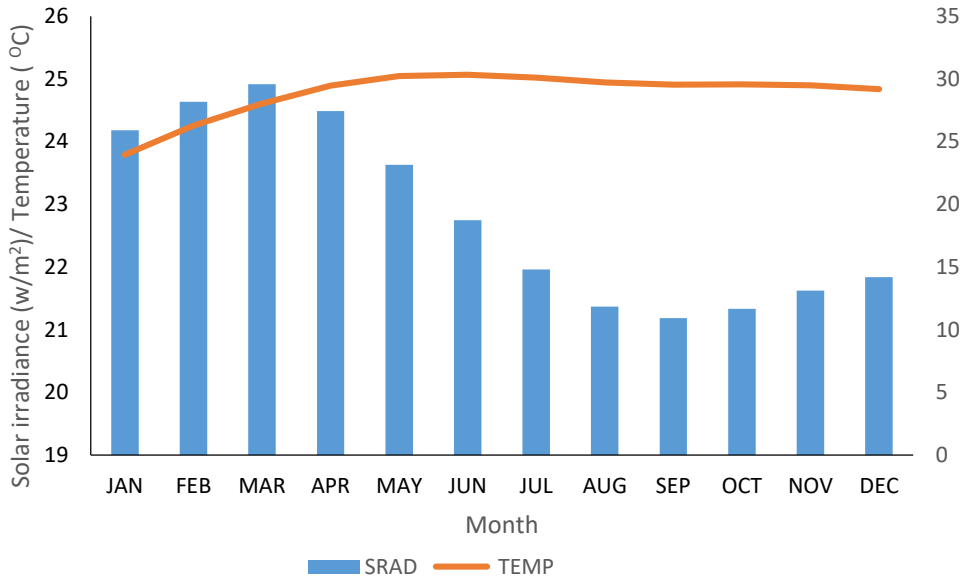


Figure 2i: Interrelationship of Mean Monthly Solar Irradiance with Mean Monthly Atmospheric Temperature in Sokoto (2001-2015)

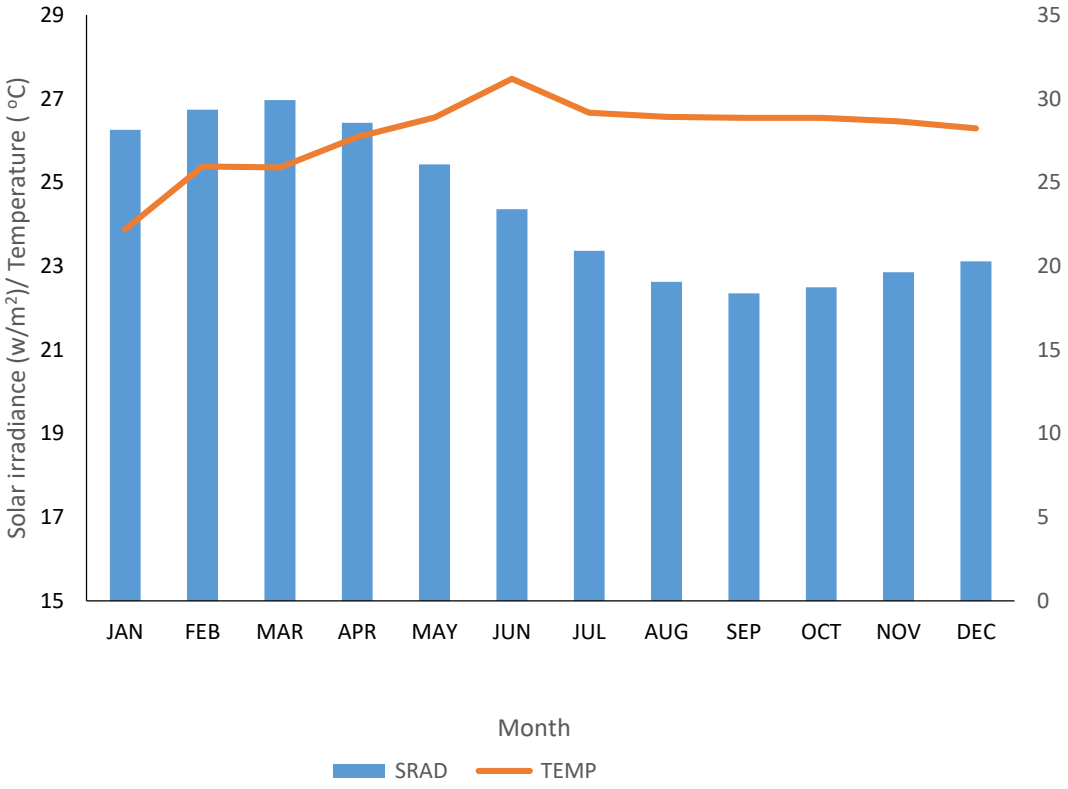


Figure 2j: Interrelationship of Mean Monthly Solar Irradiance with Mean Monthly Atmospheric Temperature in Maiduguri (2001-2015)

Figure 2a shows the peak solar irradiance and atmospheric temperature values of 19.44 w/m^2 and 28.27 ^{o}C respectively in Calabar in the months of February and March (dry season months). The correlation coefficient value of 0.599 signifies positive correlation between solar irradiance and atmospheric temperature, which is in accordance with (Solomon and Hyacinth, 2020). solar irradiance was at its peak in the month of February and a month later (March) atmospheric temperature was at its peak too. In the dry season months, with minimum or zero rainfall, the atmosphere experiences prevalence of low smog low relative humidity, low cloud cover, low reflections, scattering and low absorption of diffuse solar radiation. Thus, minimum rainfall with time lead to peak solar irradiance because of the above-mentioned atmospheric experiences (Solomon and Hyacinth, 2020). Figure 2b shows the maximum values of 20.11 w/m^2 and 29.26 ^{o}C of solar irradiance and atmospheric temperature respectively, observed in Benin in the month of Feb and March (dry season months). Positive correlation coefficient value of 0.512 was obtained for the relationship between solar irradiance and atmospheric temperature.

Figure 2c shows the peak solar irradiance and atmospheric temperature values of 23.13 w/m^2 and 29.01 ^{o}C respectively observed in Oshogbo in the months of January and March (dry season months). The correlation coefficient value of 0.374 signifies positive correlation between solar irradiance and atmospheric temperature. Figure 2d shows the maximum values of 23.62 w/m^2 and 30.41 ^{o}C of solar irradiance and atmospheric temperature respectively, observed in Lokoja in the month of January and April (dry season months). Positive correlation coefficient value of 0.815 was obtained for the relationship between solar irradiance and atmospheric temperature.

Figure 2e shows the peak solar irradiance and atmospheric temperature values of 23.71 w/m^2 and 30.20 ^{o}C respectively, observed in Minna in the months of February and April (dry season months). The correlation coefficient value of 0.513 signifies positive correlation between solar irradiance and atmospheric temperature. Figure 2f shows the maximum values of 24.90 w/m^2 and 22.92 ^{o}C of solar irradiance and atmospheric temperature respectively, observed in Jos in the month of February and May (dry season months). Positive correlation coefficient value of 0.116 was obtained for the relationship between solar irradiance and atmospheric temperature.

Figure 2g shows the peak solar irradiance and atmospheric temperature values of 40.25 w/m^2 and 30.09 ^{o}C respectively, observed in Yelwa in the months of February and May (dry season months). The correlation coefficient value of -0.046 signifies negative correlation between solar irradiance and atmospheric temperature. Figure 2h shows the maximum values of 25.24 w/m^2 and 30.46 ^{o}C of solar irradiance and atmospheric temperature respectively, observed in Yola in the month of February and May (dry season months). Positive correlation coefficient value of 0.182 was obtained for the relationship between solar irradiance and atmospheric temperature. Figure 2i shows the maximum values of 24.91 w/m^2 and 30.34 ^{o}C of solar irradiance and atmospheric temperature respectively, observed in Sokoto in the month of March and June (dry season months). Positive correlation coefficient value of 0.033 was obtained for the relationship between solar irradiance and atmospheric temperature.

Figure 2j shows the Peak solar irradiance and atmospheric temperature values of 26.96 w/m^2 and 31.19 ^{o}C respectively, were observed in Maiduguri in the months of March and June (dry season months). The correlation coefficient value of -0.215 signifies negative correlation between solar irradiance and atmospheric temperature.

Regression Model Result

Table 1 presents the results of station-specific multiple linear regression analyses conducted to examine the relationship between solar irradiance and air temperature across ten meteorological stations in Nigeria

Table 1: Station-by-Station Multiple Linear Regression Results for Temperature Prediction Based on Solar Irradiance and Elevation (2001–2015)

Station	R^2	Adj. R^2	β_1 (Solar Irradiance)	p-value (SI)	β_2 (Elevation)	p-value (Elev)	Model Equation
Jos	0.498	0.495	0.323	2.01×10^{-28}	0.01553	2.02×10^{-79}	T = 0.40 + 0.323·SI + 0.01553·Elev
Oshogbo	0.492	0.490	0.309	5.25×10^{-28}	0.06157	9.87×10^{-85}	T = 0.071 + 0.309·SI + 0.06157·Elev
Sokoto	0.480	0.477	0.308	4.44×10^{-27}	0.06345	1.55×10^{-80}	T = 0.020 + 0.308·SI + 0.06345·Elev
Calabar	0.464	0.461	0.294	7.38×10^{-26}	0.62848	1.48×10^{-86}	T = 0.02 + 0.294·SI + 0.62848·Elev
Lokoja	0.426	0.423	0.331	3.16×10^{-23}	0.35228	8.29×10^{-70}	T = 0.01 + 0.331·SI + 0.35228·Elev
Benin	0.416	0.412	0.290	1.59×10^{-22}	0.26231	1.49×10^{-80}	T = 0.10 + 0.290·SI + 0.26231·Elev
Yelwa	0.398	0.395	0.302	2.17×10^{-21}	0.09494	1.83×10^{-74}	T = 0.32 + 0.302·SI + 0.09494·Elev

Station	R^2	Adj. R^2	β_1 (Solar Irradiance)	p-value (SI)	β_2 (Elevation)	p-value (Elev)	Model Equation
Minna	0.392	0.388	0.311	5.71×10^{-21}	0.07571	1.20×10^{-69}	$T = 0.01 + 0.311 \cdot SI + 0.07571 \cdot Elev$
Yola	0.353	0.349	0.281	1.57×10^{-18}	0.10996	1.29×10^{-72}	$T = 0.060 + 0.281 \cdot SI + 0.10996 \cdot Elev$
Maiduguri	0.333	0.329	0.270	2.34×10^{-17}	0.06437	2.43×10^{-72}	$T = 0.02 + 0.270 \cdot SI + 0.06437 \cdot Elev$

The regression results presented in Table 4.1 show the strength and nature of the relationship between solar irradiance and temperature for each station, while accounting for elevation. The coefficient of determination (R^2) varies from 0.333 in Maiduguri to 0.498 in Jos, indicating that up to 49.8% of the variation in temperature in Jos can be explained by solar irradiance and elevation. This suggests that Jos, with its elevated terrain, shows the strongest temperature response to the independent variables.

The solar irradiance coefficient (β_1) ranges from 0.270 in Maiduguri to 0.331 in Lokoja, meaning that for every unit increase in solar irradiance (W/m^2), temperature rises by approximately 0.27°C to 0.33°C, depending on location. These effects are statistically significant across all stations, with p-values far below 0.05, confirming the robustness of solar irradiance as a predictor.

The elevation coefficient (β_2) is also statistically significant at all stations, though its magnitude varies. For instance, Calabar exhibits a high β_2 value of 0.62848, showing a strong elevation influence, while Jos has a relatively modest β_2 of 0.01553, likely due to its already high baseline elevation. This variation indicates elevation's moderating effect on temperature differs by geography, with coastal or lower altitude areas showing steeper elevation-temperature gradients. Interestingly, even in arid stations like Sokoto and Maiduguri, the models still capture significant relationships (R^2 of 0.48 and 0.33 respectively), highlighting the consistency of the irradiance-temperature link across climatic zones. Overall, the models confirm that solar irradiance is a reliable predictor of air temperature, with elevation further refining the predictive capacity, particularly in areas with significant altitude variations. This supports the viability of using irradiance-based models to guide solar energy planning and agricultural thermal forecasting in Nigeria.

Figure 3 illustrates the performance of the multiple linear regression model in predicting monthly air temperatures based on solar irradiance and elevation across ten meteorological stations in Nigeria. Each coloured dot represents a data point from one of the ten stations,

plotted by its predicted temperature on the x-axis and observed (actual) temperature on the y-axis. The black dashed line denotes the line of perfect prediction (where predicted = actual).

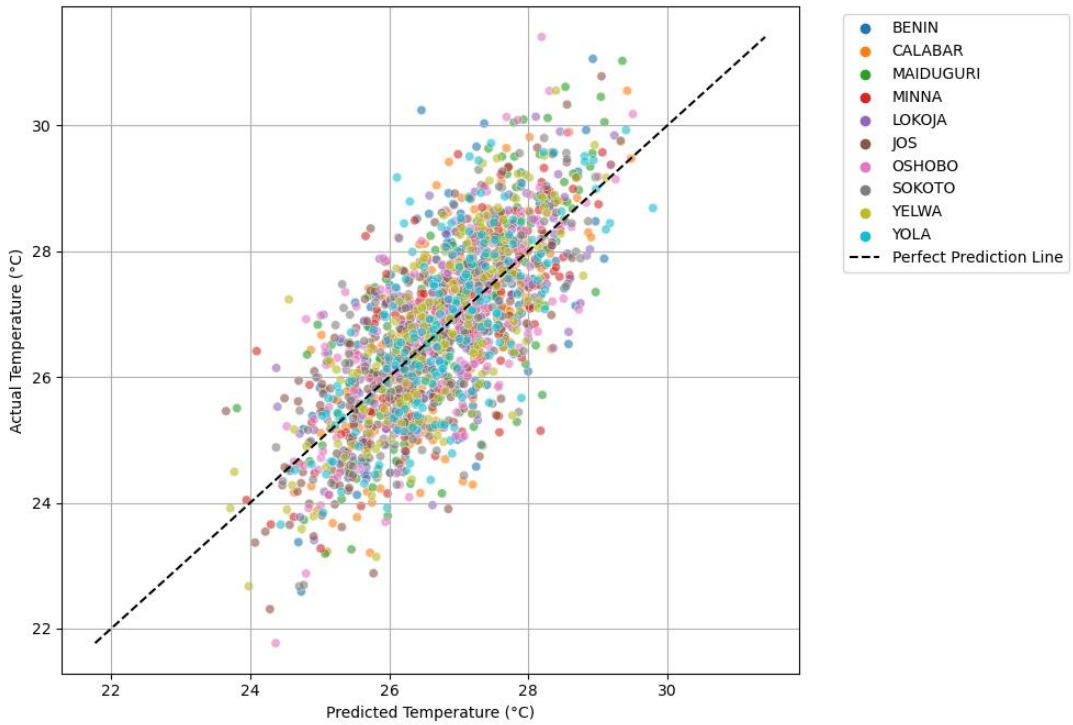


Figure 3: Actual vs Predicted Air Temperatures by Station (2001–2015)

The figure 3 reveals a generally strong linear alignment between predicted and actual temperatures across stations, with most points clustering closely around the perfect prediction line. This confirms the validity of the model structure, especially its ability to generalize across Nigeria's climatic zones.

Most data points fall within a ±2°C range of error, with the majority of predictions between 24°C and 30°C aligning well with observed values. Outliers, which fall further from the line, may reflect local microclimatic anomalies, seasonal lags, or residual noise not captured by solar irradiance and elevation alone. Notably, the spread is relatively symmetrical across stations, indicating no major systematic bias toward over- or under-prediction in any particular location. This suggests the model maintained a balanced predictive capacity across diverse regions—from coastal Benin and Calabar to the arid Sahelian zones like Sokoto and Maiduguri. Overall, the plot supports the conclusion that solar irradiance and elevation are strong predictors of temperature in Nigeria. Table 2 summarizes the output of a multiple linear regression model developed to explain variations in monthly air temperature across ten climatic zones in Nigeria from 2001 to 2015. The model uses centered predictors—solar irradiance, elevation, latitude, and longitude—so that the intercept reflects the mean temperature at average environmental conditions.

Table 2: Centred Multiple Linear Regression Model Predicting Temperature from Solar Irradiance, Elevation, Latitude, and Longitude (2001–2015)

Variable	Coefficient	Std. Error	t-value	p-value	95% CI Lower	95% CI Upper
Intercept	26.755	0.0233	1147.56	< 0.0001	26.709	26.800
Solar Irradiance[c]	0.2941	0.0067	43.58	< 0.0001	0.2809	0.3073
Latitude[c]	-0.0077	0.0107	-0.72	0.471	-0.0286	0.0132
Longitude[c]	-0.0009	0.0081	-0.11	0.910	-0.0169	0.0150
Elevation[c]	-0.0005	0.0001	-6.26	< 0.0001	-0.0006	-0.0003

RMSE = 0.988°C

The intercept value of 26.755°C represents the predicted mean temperature when all independent variables—solar irradiance, elevation, latitude, and longitude—are at their respective average values across Nigeria. This centered formulation provides a practical and realistic baseline for interpreting deviations due to environmental and spatial factors. The coefficient for solar irradiance[c] is 0.2941 ($p < 0.0001$), indicating a statistically significant and positive relationship. Specifically, for every 1 W/m² increase in solar irradiance above the national mean, the model predicts a temperature increase of approximately 0.29°C. This highlights the critical influence of solar energy input on surface air temperature and reinforces its dominant role in thermal dynamics across the country's climatic zones.

Conversely, the elevation[c] coefficient is -0.0005 ($p < 0.0001$), which is also statistically significant and consistent with physical expectations. This suggests that for every 100-meter increase in elevation, the temperature is expected to decrease by approximately 0.05°C, reaffirming the well-documented effect of altitude on atmospheric cooling. Meanwhile, latitude[c] (-0.0077, $p = 0.471$) and longitude[c] (-0.0009, $p = 0.910$) were found to be statistically insignificant in the model. These results imply that once solar irradiance and elevation are accounted for, geographic position alone does not significantly enhance the model's predictive capability for temperature within the Nigerian context.

The centered regression model equation is expressed as:

$$Temperature = 26.76 + 0.2941(SI_n) - 0.0005(Elev_n) - 0.0077(Lat_n) - 0.0009(Lon_v)$$

where SI_n, $Elev_n$, Lat_n, and Lon_n represent the deviations of solar irradiance, elevation, latitude, and longitude from their respective mean values. With an RMSE of 0.988°C, the centered multiple linear regression model demonstrates strong predictive performance, offering both statistical significance and real-world applicability for understanding the interrelationship between solar irradiance, elevation, and temperature across Nigeria. Figure 4 presents a scatter plot of predicted temperatures (x-axis) versus actual observed temperatures (y-axis) across various Nigerian climatic zones from 2001 to 2015.

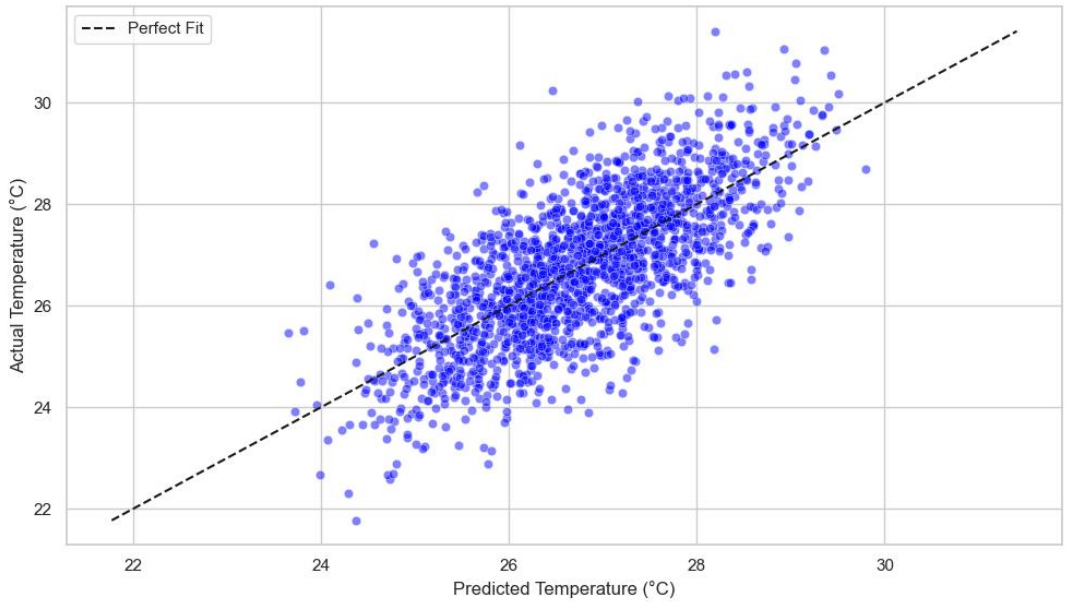


Figure 4: Actual vs Predicted Temperatures (Combined Centered Model)

Figure 4 illustrates the relationship between actual and predicted temperatures as estimated by the combined centered linear regression model across Nigeria's ten climatic zones from 2001 to 2015. Each point on the scatter plot represents a monthly observation, and the black dashed line denotes perfect agreement between predicted and actual values. The tight clustering of data points around this line indicates a strong positive correlation, suggesting that the model predicts temperature with high accuracy under typical environmental conditions. Most predictions fall within a narrow band around the actual temperatures, particularly in the central range of 26°C to 28°C, where data density is highest. Although some scatter is evident at the lower and upper extremes—implying slightly reduced precision for unusually low or high temperatures—there is no visible pattern of systematic overestimation or underestimation. This symmetric spread confirms the reliability of the model's structure and its centered predictors, which help reduce bias and enhance interpretability. Overall, the figure demonstrates that the model captures the spatial and temporal variability of air temperature in Nigeria effectively, validating its suitability for climatological analysis and environmental decision-making.

Conclusion

The findings showed that across the climatic zones in Nigeria, solar irradiance and temperature were interrelated with perfect positive correlation in the following locations; Calabar, Benin, Lokoja and Minna while they showed no interrelationship in the following locations; Oshogbo, Jos, Yelwa, Yola, Sokoto and Maiduguri. The study confirms a strong and statistically significant interrelationship between solar irradiance and air temperature across Nigeria's climatic zones. Initial correlation analysis showed positive but location-dependent

relationships, with perfect correlations observed in Calabar, Benin, Lokoja, and Minna, and weaker or inconsistent correlations in Oshogbo, Jos, Yelwa, Yola, Sokoto, and Maiduguri. However, the more robust multiple linear regression models revealed that solar irradiance remains a consistent and significant predictor of temperature across all stations, irrespective of the strength of linear correlation alone. In the station-by-station regression analysis, Jos exhibited the highest model explanatory power ($R^2 = 0.498$), while Maiduguri had the lowest ($R^2 = 0.333$), likely due to local microclimatic factors or elevation effects. The combined regression model, which included centered values of solar irradiance, elevation, latitude, and longitude, showed high statistical significance and a low RMSE (0.988°C), indicating excellent model fit and prediction accuracy. Elevation was found to exert a consistent cooling effect on temperature, while geographic coordinates (latitude and longitude) contributed minimally once irradiance and elevation were accounted for.

Overall, the regression-based approach reveals a more nuanced and reliable understanding of temperature dynamics than correlation analysis alone. The findings reinforce the potential for using solar irradiance-based models to inform energy system design, thermal forecasting, and climate adaptation strategies across Nigeria. For enhanced climate modelling and energy planning, extending the data range to 30 years or more is recommended.

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