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ESTIMATION OF THE RELATIONSHIP BETWEEN SOLAR RADIATION, RELATIVE HUMIDITY, AND TEMPERATURE IN UGWOLAWO USING LINEAR REGRESSION ANALYSIS

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ABSTRACT

The radiation of the sun has a critical climatic influence on solar energy generation, ecology and crop production. Consequently, it is important to know how solar radiation interacts with other climate variables such as temperature and relative humidity towards developing better designs of solar arrays and mitigate the impact of climate variability. In this study, we have explored the impacts of relative humidity and temperature on the sun's radiation. The statistical data for this work was collected from the trustworthy National Aeronautics and Space Administration (NASA) power archive. Shortwave solar radiation, relative humidity and temperature readings from January 1991 to December 2020 were retrieved and evaluated to establish average values. The results showed that the annual relative humidity ranged from 77.25% to 83.94%, while the annual temperature fluctuated between 24.86°C and 26.58°C, and the radiation from sun varied from 4.72 to 5.40 kW-hr/m². Both graphical and statistical analyses using a simple regression model indicated a slightly direct correlation between solar radiation and relative humidity while data regarding temperatures and solar radiation during the analysis period demonstrated an inverse relationship.

Keywords: Solar radiation, Relative humidity, Temperature, Simple regression method

INTRODUCTION

Over the years, techniques for monitoring and forecasting climatic events have improved. As a result, a wealth of information and understanding has been gained that contributes to the interpretation and prediction of climate. Climate change has been reported to have profound effect on human life and the environment (Ukhurebor, et al., 2017). Factors such as the latitude of a region, its elevation, the closeness to water bodies, and the landscape are reported to affect climate characteristics (Yazdani, et al., 2016). One of the key elements that these factors influence is the solar radiation. Solar radiation is the energy emitted by the Sun which is sent in all directions through space as electromagnetic waves that influences atmospheric and climatological processes (Odejobi, et al., 2024).

A precise understanding of the distribution of solar radiation at a specific location is crucial for assessing and forecasting climate change, environmental pollution, crop and food production, hydrology, and astronomy. It's also vital for designing and assessing solar energy devices and estimating their photovoltaic performance (Abdullahi et al., 2017). This interdisciplinary nature of solar radiation's influence is what makes the understanding of climate factors such as temperature, winds, pressure, precipitation, and relative humidity so important. It's these factors that ultimately determine how much sunlight reaches a specific location at a specific time of year (Ayoade, 1993). Therefore, the capacity to forecast periods of reduced solar radiation or solar energy will assist in effective planning, such as arranging alternative power sources like wind or hydroelectric power to compensate for the shortfall of the installed solar power system. As solar radiation travels through the atmosphere, it undergoes various changes. It is partly reflected, absorbed, and scattered by molecules, aerosols, water vapor, and clouds. Relative humidity and temperature are noted to be among the weather parameters that highly influence the amount of solar radiation in an area (Swartman & Ogunlade, 1967). Relative humidity, the ratio of water vapor in the air to the maximum water vapor the air can hold at a particular temperature. The air's capacity to hold water vapor is primarily a function of temperature, with warmer air having a greater capacity for holding water vapor than cooler air. Humidity, however, is not just a passive influencer. It actively creates hurdles for the energy received at the top of the atmosphere and affects device consumption in many aspects.

The primary objective of this research is to examine how temperature, relative humidity, and solar radiation correlate with one another in the region of Ugwolawo, Kogi State, Nigeria. Using historical climate data from the NASA power archive and statistical and graphical techniques, we aim to assess the impact of temperature and relative humidity on the intensity of solar radiation.

MATERIALS AND METHODS

Study Area

Ugwolawo is a town located in the Ofu Local Government Area of Kogi State, Nigeria. It is situated between latitudes 7°14'N and longitudes 6°55'E. The mean altitude of the town above sea level is 385 meters, and it covers a total land area of 420 square kilometers.

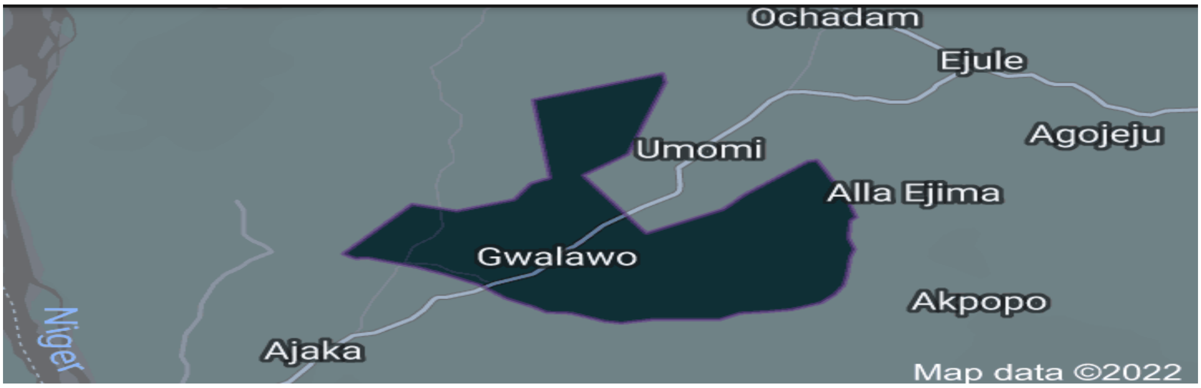

Figure 1: Map of Ugwolawo, Kogi State

Data Collection

The data collection process was thorough. Mean monthly data of incoming shortwave solar radiation, temperature and relative humidity of Ugwolawo from 1991 to 2020 were obtained from the power archives of the National Aeronautics and Space Administration on 15th June, 2024.

Method of Data Analysis

Graphical and statistical analyses were utilised to determine the possible relationship between the study area's solar radiation, relative humidity, and temperature. The relationship between solar radiation, relative humidity, and temperature in Ugwolawo was also deduced using simple linear regression models (Rawlings et al., 1998). The simple regression model is an effective statistical tool for studying the relationship between variables. The simple linear regression formula for analyzing the independent and dependent variables follows.

$$R = B_o + B_1 T \quad (1)$$

Where B_o and B_1 are constants

T = Dependent variable (relative humidity or temperature)

R = Independent variable (solar radiation)

From equation (1), the anonymous of B_o and B_1 can be determined from a calculation using the following steps:

$$B_1 = \sum[(T - T_i)(R - R_i)]/\sum[(T - T_i)^2] \quad (2)$$

Where: T_i = Dependent variable

R_i = Independent variable

From equation (1), B_o can be derived using equation (3);

$$B_o = R_i - B_1 T_i \quad (3)$$

RESULTS AND DISCUSSION

Data on solar radiation and relative humidity were carefully organized to present the mean annual values from 1991 to 2020. As shown in figure 2 (a and b), a scatter plot effectively depicts the relationship between solar radiation and relative humidity and temperature values. This visual representation allows a clearer understanding of how these environmental factors interact over the designated time frame.

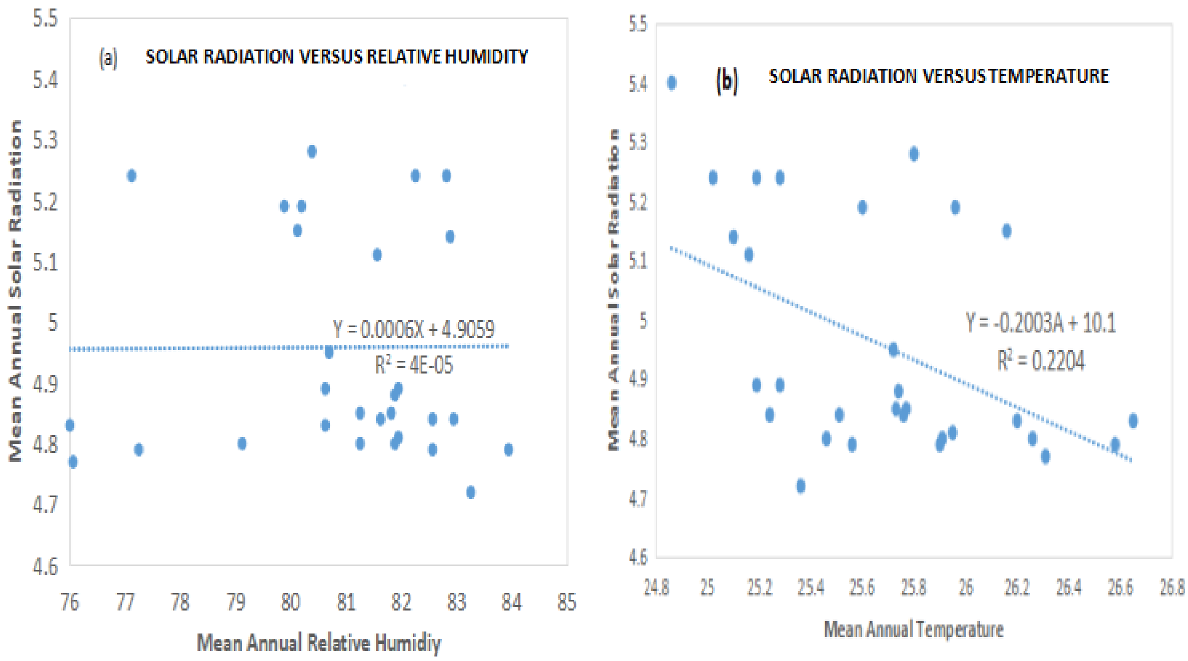

Figure 2: Relationship between solar radiation, relative humidity, and temperature

Figure 2(a) depicts a scatter plot showing solar radiation with relative humidity. The scattering of the points represents a large amount of data between these two variables and thus demonstrates how complex the interaction is. A line of best fit is drawn into the plot, showing an equivocal but identifiable direct correlation between solar radiation and relative humidity in the study region. The relationship is also represented in the fitted graphical equation below, highlighting their dependency.

$$Y = 0.0006X + 4.905 \quad (4)$$

Where X represents the relative humidity and Y denotes the radiation. This somewhat straightforward connection indicates that solar radiation rises as relative humidity increases. However, the low variance (R^2 = 0.00004) implies that the relative humidity for the specific period does not highly influence the solar radiation. Figure 2(b): Scatter plot showing solar radiation with temperature. The scattering of the points represents a large amount of data between these two variables and thus demonstrates how complex the interaction is. A regression line is drawn into the plot, showing an uncertain but identifiable slightly direct correlation between solar radiation and relative humidity in the study region. The relationship is also represented in the fitted graphic equation, highlighting their dependency.

$$Y = -0.2003A + 10.1 \quad (5)$$

where Y represents solar radiation, and A represents temperature. The graph signifies that increasing temperature negatively affected solar radiation over the chosen period of study, as seen in the works of Tasie et al., 2018, and Ibrahim et al., 2012.

Simple Regression Model

Tables 1 and 2 show the regression analysis results for Ugwalawo, calculated using the evaluated data and the simple regression formula for analyzing solar radiation, relative humidity, and temperature.

Table 1: Calculated Regression analysis of solar radiation and relative humidity from 1991 - 2020

Region	Equation	Constant (B_o)	Constant (B_1)
Ugwolawo	R = 4.9061 + 0.00064T	4.9061	0.00064

Table 2: Calculated Regression analysis of solar radiation and temperature from 1991 - 2020

Region	Equation	Constant (B_o)	Constant (B_1)
Ugwolawo	R = 10.300 - 0.20015T	10.300	0.20015

The analysis of the variables indicated a slight direct correlation between solar radiation and relative humidity. The study of solar radiation and relative humidity in Ugwalawo suggests that an increase of 1.0 % in relative humidity leads to 4.90674 kW-hr/m² in solar radiation. Given that Bo = 4.9061 kW-hr/m² and is a positive value, the average solar radiation is 4.9061 kW-hr/m² when relative humidity is zero. However, since relative humidity of '0' is not feasible, it cannot be considered a realistic value.

While B_1 is 0.00064 and has a positive value, the mean annual solar radiation increase would be 0.00064 kW-hr/m² for every 1.0% increase in mean annual relative humidity. The analysis also showed that the study area's incoming solar radiation increases slightly with relative humidity. This further corroborates the almost direct relationship between the sun's radiation and relative humidity of the area, while the result derived in Table 2 depicts that for every one percent increase in the temperature, the solar radiation reduces by a value of 0.20015; this indicates an inverse relation (Kesavan & Senthilkumar, 2019).

CONCLUSION

This study investigated the relationships among solar radiation, relative humidity, and temperature in Ugwalawo, Kogi State, Nigeria. It utilized historical climate data from the NASA Power archive, covering 1991 to 2020. The research employed graphical and statistical techniques, specifically a simple linear regression model, to extract significant insights regarding the interactions between these variables. The findings reveal that relative humidity has a minor impact on solar radiation, showing a positive correlation. As relative humidity increases, solar radiation rises slightly as well. The regression analysis revealed that for each 1% increase in relative humidity, solar radiation rises by 0.00064 kW-hr/m², indicating a somewhat direct correlation. However, the low coefficient of determination (R^2 = 0.00004) suggests that relative humidity alone does not significantly explain the variations in solar radiation in the region. However, the link between solar radiation and temperature was determined to be inversely proportional. A rise of 1°C in temperature caused a reduction in radiation by 0.20015 kW-hr/m². This finding implies that heightened temperatures negatively influence solar radiation. These results align with findings from other research and highlight the crucial impact of temperature on solar radiation. These outcomes emphasize the importance of considering both temperature and relative humidity when analyzing solar radiation trends, especially for solar energy system development and climate modeling initiatives. The identified inverse relationship suggests that prolonged high temperatures may hinder solar energy production in the area. Additionally, understanding these correlations is essential for alleviating the impacts of climate variability on solar energy systems and agricultural output. The slight positive correlation with relative humidity indicates potential strategies for energy optimization in humid regions, while the significant negative relationship with temperature points to the necessity of integrating alternative energy sources, such as wind or hydroelectric power, during times of increased temperatures.

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