

# Technical assessment of the Association Between Air Quality Index and Solar Irradiance in El Progreso, Yoro, Honduras

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**Abstract.** Honduras, located in a tropical zone with high solar exposure, has excellent potential for photovoltaic energy. However, atmospheric pollutants such as PM<sub>2.5</sub> and PM<sub>10</sub> can diminish solar irradiance through scattering and absorption. This study investigates the relationship between the Air Quality Index (AQI) and solar irradiance in El Progreso, Yoro, over 60-day period. Data were collected using a pyranometer and an air quality sensor, and analysed using Python with correlation (Pearson, Spearman, Kendall) and regression models (linear and polynomial). Under clear weather conditions, a weak but significant correlation was observed (Pearson = 0.195,  $R^2 = 0.038$ ), while temperature showed a moderate correlation ( $R = 0.60$ ) and humidity a strong negative one ( $R = -0.68$ ). The results demonstrate how air quality influences solar energy performance and offer insights to improve PV system design and urban energy planning in tropical environments.

## 1 Introduction

Air quality and solar energy potential are increasingly relevant environmental aspects in the context of climate change and the adoption of renewable energies. In tropical areas such as El Progreso, Yoro (Honduras), photovoltaic energy production is directly influenced by solar irradiance, which can decrease due to atmospheric pollution. Pollutants alter solar radiation by scattering, absorbing, or reflecting it, reducing its intensity.

The Air Quality Index (AQI), a widely used indicator to measure particulate matter concentrations such as PM<sub>2.5</sub> and PM<sub>10</sub>, has been used mainly to assess health risks. However, its effect on energy parameters, such as solar irradiance, remains underexplored, particularly in cities in developing countries.

The International Energy Agency [1] projects that solar PV will supply 12% of global electricity by 2025, driven by decarbonization policies and lower technology costs. However, urban air pollution remains a significant barrier to efficiency. Particulate matter such as PM<sub>2.5</sub> and PM<sub>10</sub> can scatter and absorb solar radiation, reducing irradiance levels [2].

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Studies have reported losses of up to 65% in PV output during extreme pollution events, such as forest fires in Australia [3], and annual reductions in Korea linked to PM10 levels [4]. Additional research from China, Kuwait, and Europe confirms that particulate pollution negatively affects solar energy capture [5], [6], [7]. In Honduras, a 6.2% efficiency loss due to marine PM10 [8]. Despite these findings, little research has explored this phenomenon in Central American cities.

Given this need, this study uses statistical analysis and Python programming to examine the relationship between AQI and solar irradiance. For this purpose, real-time data were collected using a pyranometer to measure irradiance and an environmental sensor to record AQI and its components. Linear and polynomial regression methods were applied with correlation coefficients (Pearson, Spearman, and Kendall) to compare favorable and adverse weather conditions.

The research aims to provide quantitative data on how pollution affects solar efficiency, which will be valuable in optimizing the design, operation, and maintenance of photovoltaic systems in tropical urban environments.

## 1.1 Context

Solar energy is a fundamental resource for producing electricity through photovoltaic systems, a sustainable, accessible, and globally expanding technology [9].

However, the solar radiation reaching the Earth's surface varies due to various environmental factors, including air pollution. In particular, fine particles such as PM2.5 and PM10 reduce solar irradiance through absorption, scattering, and reflection processes [10], [3], [11].

Previous studies have identified this relationship under different atmospheric and geographic conditions ; for instance, they reported significant reductions in photovoltaic output during high-smoke events in Australia [11]. In contrast, this study provides novel insights into how urban pollution, under typical tropical conditions, affects solar irradiance levels in El Progreso, Honduras.

### 1.1.1 Solar irradiance

Refers to the amount of energy or solar radiation incident on a unit area of a receiving surface, measured at a specific moment. Its unit in the International System is the watt per square meter ( $W/m^2$ ) [12].

### 1.1.2 Air Quality Index

The Air Quality Index (AQI) is a standardized indicator designed to measure and communicate the degree of air pollution in a specific area. Its primary function is to convert the concentration data of multiple pollutants into a unified numerical scale, allowing a quick and understandable assessment of the potential impact on public health and ecosystems [13]. The calculation of the Air Quality Index (AQI) is based on the concentrations of critical air pollutants, among which the following stand out:

- PM2.5: Ultrafine particles ( $<2.5 \mu m$ ) that can reach the lungs and bloodstream.
- PM10: Respirable particles ( $<10 \mu m$ ) that affect the upper respiratory system.
- Ozone ( $O_3$ ): Secondary pollutant formed by chemical reactions induced by sunlight.
- Nitrogen dioxide ( $NO_2$ ) and sulfur dioxide ( $SO_2$ ): Gases emitted by vehicles and industrial processes.

- Carbon monoxide (CO): Product of deficient combustion, highly harmful to health.

The six levels of health concern and what they mean are shown in Table 1.

**Table 1:** Air Quality Index (AQI) classification by level of health concern

AQI values	Level of health concern (air quality status)
0-50	Good
51-100	Moderate
101-150	Unhealthy for members of sensitive groups
151-200	Unhealthy
201-300	Very unhealthy
301-500	Hazardous

Source: Own Elaboration

### 1.1.3 Statistical correlation

Correlation is a statistical measure that indicates the degree to which two variables are related. When two variables change together consistently, they are said to correlate. This can be positive (both increase or decrease together), negative (one increases while the other decreases), or null (no apparent relationship). Correlation does not imply causation but allows inferences about the strength and direction of a possible relationship [14].

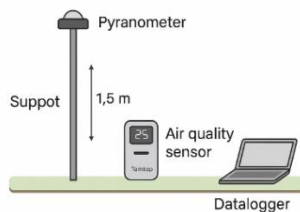
For instance, this study used correlation analysis to determine the relationship between AQI and irradiance levels under different weather conditions.

## 2 Methodology

This study was conducted over 60 days in El Progreso, Yoro (Honduras). The objective was to assess the statistical relationship between air quality and solar irradiance using real-time measurements and data analysis techniques.

A Hukseflux SR20-T2 pyranometer was used to record global horizontal irradiance ( $\text{W}/\text{m}^2$ ), while a Temtop LKC-1000S+ air quality monitor measured PM<sub>2.5</sub> and PM<sub>10</sub> concentrations ( $\mu\text{g}/\text{m}^3$ ) and calculated the corresponding Air Quality Index (AQI). Meteorological variables such as temperature and relative humidity were also recorded as control variables.

All instruments were connected to an LI-19 datalogger, recording data at one-minute intervals. The raw data were first organized, filtered, and pre-processed using Microsoft Excel to calculate basic statistics such as daily averages and identify inconsistencies. All measurements were recorded using a data acquisition system, as illustrated in Figure 1.



**Fig. 1** Experimental setup for solar irradiance and air quality monitoring

Source: own elaboration

To evaluate the statistical relationship between air quality and solar irradiance, various correlation and regression methods were applied using Python. These included Pearson, Spearman, and Kendall correlation coefficients and linear and second-degree polynomial regression models. The coefficient of determination  $R^2$  was used to evaluate the model's goodness of fit. The applied formulas are detailed below:

- **Pearson Correlation Coefficient:**

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \quad (1)$$

Where:

- $x_i$  = Values of the independent variable (AQI)
- $y_i$  = Values of the dependent variable (Irradiance)
- $\bar{x}, \bar{y}$  = Means of the variables

- **Spearman Rank Correlation Coefficient:**

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)} \quad (2)$$

[14]

Where:

- $d_i$  = Difference between the ranks of each pair of observations
- $n$  = Total number of observations

- **Kendall's Tau Coefficient:**

$$\tau = \frac{C - D}{\frac{1}{2}n(n-1)} \quad (3)$$

[14]

Where:

- $C$  = Number of concordant pairs
- $D$  = Number of discordant pairs
- $n$  = Number of observations

- **Linear Regression Equation:**

$$I = \beta_0 + \beta_1 \times ICA + \varepsilon \quad (4)$$

[14]

Where:

- $I$  = Solar irradiance [ $\text{W}/\text{m}^2$ ]
- $\beta_0$  = Is the intercept
- $\beta_1$  = Is the slope of the model
- $\varepsilon$  = Is the error term

To analyze the data collected, we used **Python** as the main programming environment, along with the following libraries:

- **Pandas:** for data cleaning, time series processing, and dataset merging.
- **NumPy:** for numerical operations and data transformation.
- **Matplotlib** and **Seaborn:** for data visualization (histograms, scatter plots, heatmaps).
- **Scikit-learn:** for applying linear and polynomial regression models.

- **SciPy:** for calculating Pearson, Spearman, and Kendall correlation coefficients, as well as p-values for statistical significance as shown in Figure 2.

```
def calcular_correlaciones():
    pearson = df_analisis['AQI'].corr(df_analisis['Irradiancia (W/m²)'], method='pearson')
    spearman, p_spear = spearmanr(df_analisis['AQI'], df_analisis['Irradiancia (W/m²)'])
    kendall, p_kendall = kendalltau(df_analisis['AQI'], df_analisis['Irradiancia (W/m²)'])

    mensaje = f"""Coeficientes de correlación:

- Pearson: {pearson:.3f}
Interpretación: {'Fuerte' if abs(pearson) > 0.7 else 'Moderada' if abs(pearson) > 0.4 else 'Débil'}

- Spearman (ρ): {spearman:.3f} | p-valor: {p_spear:.3f}
Evaluación de relación monotónica (rango ordenado)

- Kendall (τ): {kendall:.3f} | p-valor: {p_kendall:.3f}
Evaluación de concordancia/discordancia en pares
"""

    messagebox.showInfo("Correlaciones entre Irradiancia y AQI", mensaje)
```

**Fig 2.** Sample Python script used for correlation and regression analysis

Source: own elaboration

The dataset was split into two groups:

- **Group A:** Days with clear sky conditions results are shown in Table 2 (sunny, no precipitation).

**Table 2.** Quantitative classification of favorable climatic conditions (Group A)

Subjective rating	Estimated description	Quantitative value (cloud cover)
Clear	Cloudless sky	0%
Mostly clear	Some isolated clouds	10-25%
Sunny	Presence of sun with little cloud cover	20-30%
Mostly sunny	Predominantly sunny with cloudy intervals	30-50%
Partly sunny	Balance of sun and clouds	50-70%

Source: Own Elaboration

- **Group B:** Days with cloud cover or rainfall results are shown in Table 3.

**Table 3.** Quantitative classification of unfavorable climatic conditions (Group B)

Subjective rating	Estimated Description	Quantitative value (cloud cover/ precipitation)
Partly cloudy	Nearly equal proportion of clouds and clear	50-70% cloud cover
Mostly cloudy	Predominant clouds with occasional clearings	70-90% cloud cover
Cloudy	The sky was completely covered with clouds	90-100% cloud cover
Drizzle	Light precipitation, intermittent, with high cloud cover	>90% cloud cover + light precipitation (<1 mm/h)
Light or heavy rain	Continuous precipitation with overcast sky	100% cloud cover + rain (>1 mm/h, light or heavy)

Source: own elaboration

We applied both linear regression and second-degree polynomial regression to model the dependence of irradiance on AQI. In parallel, correlation analysis was conducted to quantify the strength and direction of relationships between variables. A significance level of  $p < 0.05$  was used to validate statistical relevance.

This methodology allowed for a robust and reproducible assessment of how particulate air pollution impacts solar energy availability in a tropical urban context. Figure 3 summarizes the complete methodological workflow.



**Fig. 3** Methodology workflow for data collection and statistical analysis

Source: own elaboration

## 3 Results

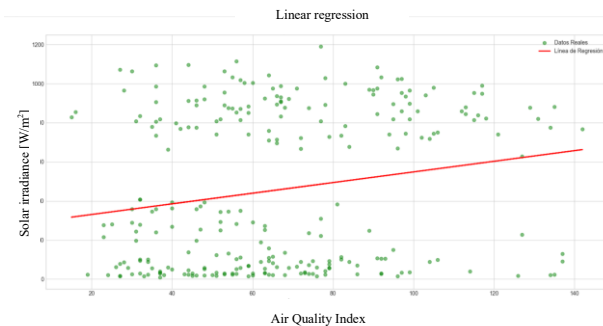
### 3.1 Results of group A (sunny days)

- Pearson: 0.195
- Spearman ( $\rho$ ): 0.175 ( $p = 0.005$ )
- Kendall ( $\tau$ ): 0.117 ( $p = 0.005$ )
- Linear regression:

$$\text{Irradiance} = 2.721 \cdot \text{AQI} + 276.218 \quad (5)$$

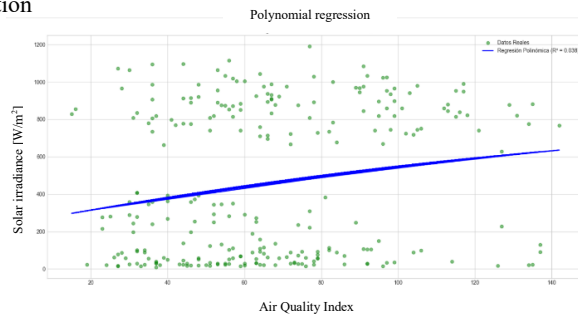
Coefficient of determination:  $R^2 = 0.038$

Although the correlation is not strong, a slight positive trend is observed. This indicates that, under clear sky conditions, there could be a moderate relationship between higher AQI levels and solar irradiance, probably due to fine particles that scatter radiation. Figure 4 and 5 show examples of the scatterplots made for group A.



**Fig. 4** Scatterplot and linear regression between AQI and solar irradiance on clear days (Group A)

Source: Own Elaboration



**Fig. 5** Scatterplot with polynomial regression curve (Group A)

Source: Own Elaboration

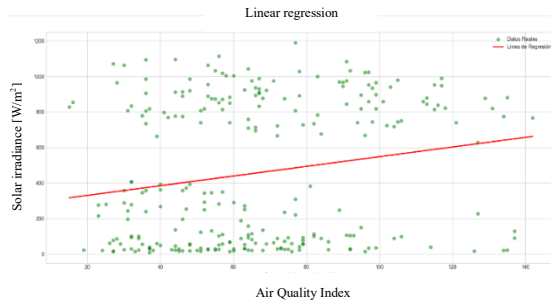
### 3.2 Results of group B (all days)

- Pearson: 0.118
- Spearman ( $\rho$ ): 0.148 ( $p = 0.005$ )
- Kendall ( $\tau$ ): 0.097 ( $p = 0.007$ )
- Linear regression:

$$Irradiance = 1.604 \cdot AQI + 277.866 \quad (5)$$

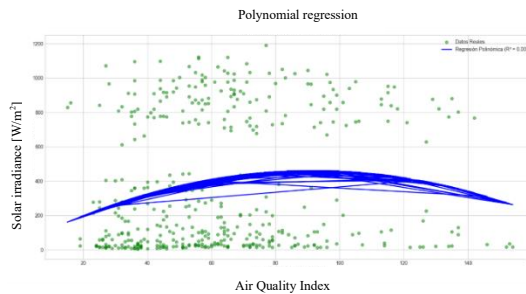
- Coefficient of determination:  $R^2 = 0.038$

The correlation in this case is less significant than in Group A, reflecting that atmospheric variability increases the data dispersion and limits the model's accuracy. Factors such as rainfall and cloud cover act as filters that decrease the intensity of solar irradiance. Figure 6 and 7 show examples of the scatterplots made for group A and B.



**Fig. 6** Scatterplot and linear regression between AQI and solar irradiance considering all climatic conditions (Group B)

Source: own elaboration



**Fig. 7** Scatterplot with polynomial regression curve (Group A)

Source : own elaboration

## 4 Conclusions

The relationship between the Air Quality Index (AQI) and solar irradiance in El Progreso, Yoro, was analysed by collecting and processing environmental data with specialized instruments such as pyranometers and air quality monitors. The analysis revealed the following results:

- Air pollution, especially particulate matter, has a reducing effect on solar radiation, although this correlation was found to be weak. This suggests that other factors, such as meteorological conditions, may significantly influence irradiance variations.
- A statistically significant but weak correlation between AQI and solar irradiance was confirmed by applying linear regression models, with low coefficients in Pearson's, Spearman's, and Kendall's tests. The small value of the coefficient of determination

( $R^2 \approx 0.033$ ) reinforces the idea that AQI alone is not a strong predictor of solar radiation, highlighting the need to consider additional variables in future research.

Despite the modest correlation, this study contributes valuable local evidence for solar energy planning in tropical urban settings. It can inform the design of more robust forecasting models and encourage future research that integrates meteorological and environmental parameters for more accurate prediction of photovoltaic system performance.

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