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Analysis of Urban Heat Islands in São Paulo: Development of a Statistical Model for Mitigation and Sustainable Planning

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Abstract: This study proposes a Multiple Linear Regression (MLR) model to analyze the Urban Heat Island (UHI) phenomenon in São Paulo, Brazil, using data from three strategic regions. By integrating meteorological and environmental data, the model predicts temperature variations based on variables such as humidity, particulate matter (PM2.5), and precipitation. The results validate the model's effectiveness and offer valuable tools for decision-making in public policies and urban planning in response to climate change. The methodology proves useful for urban climate analysis and sustainable territorial management.

Keywords: technological innovation management; sustainability; urban heat islands; linear regression model.

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1. Introduction

Rapid urbanization has transformed natural landscapes and intensified environmental and climate challenges. In the city of São Paulo (State of São Paulo, Brazil), this process has exacerbated spatial inequality and urban thermal discomfort, especially in peripheral zones. The Urban Heat Island (UHI) effect, marked by increased temperatures in urban areas compared to rural surroundings, is a critical manifestation of this issue [1-4].

This study applies a Multiple Linear Regression (MLR) model to investigate how environmental variables influence UHI behavior across three strategic zones in São Paulo. By incorporating temperature, humidity, pollutant concentration (PM2.5), and precipitation data from 2019 to 2023, the study aims to contribute to urban climate analysis and evidence-based planning.

2. Area of study

The selected areas for analysis are:

- A1: Santana (North zone),
- A2: Congonhas (Central-South zone),
- A3: Grajaú/Parelheiros (South zone).

Each region was chosen based on proximity to automatic weather and air quality stations maintained by CETESB, INMET, and IAG-USP [5-7] as shown in Figure 1.

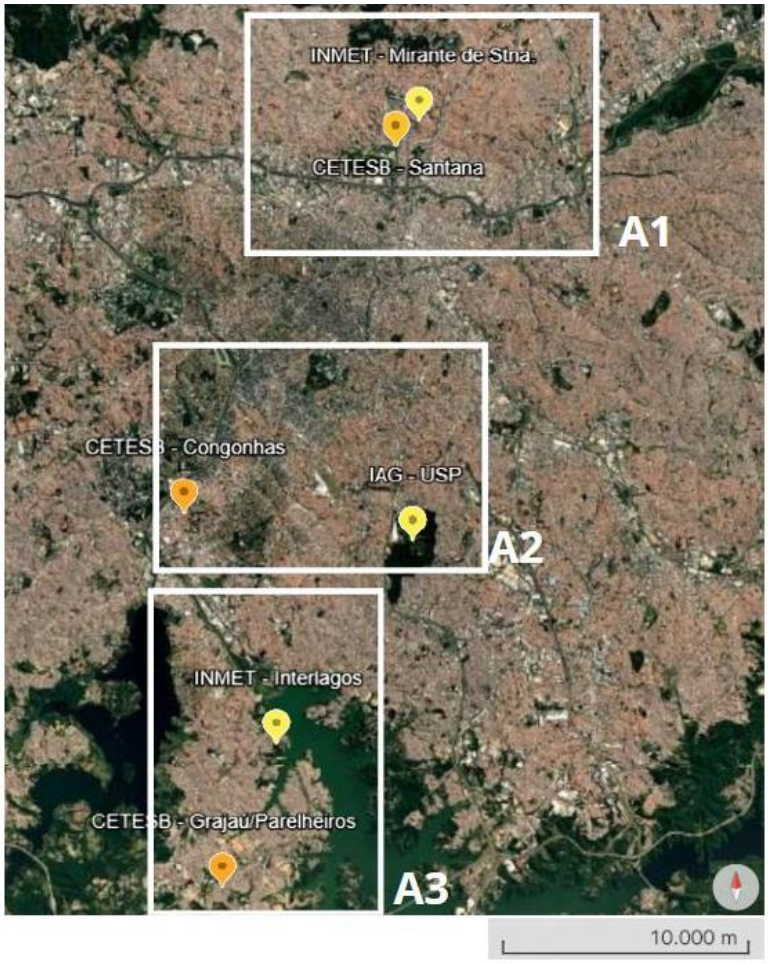

Figure 1. Location of the study areas.

3. Methodology

Meteorological and environmental data were collected from the three areas for the period 2019 to 2023. The variables considered were:

- Dependent: Monthly average air temperature (°C).
- Independent: Monthly average relative humidity (%), PM2.5 concentration (μg/m³), and monthly precipitation (mm).

After data cleaning and standardization in Excel®, the statistical modeling was carried out using EViews® software. The MLR model was adjusted using the Ordinary Least Squares method. Model performance was evaluated through the F-test, adjusted R^2, multicollinearity checks, homoscedasticity (White Test), and normality of residuals (Jarque-Bera test) [8, 9].

4. Results

The regression model obtained the following estimated equation:

$$T = 20.643 + 1.335 * U + 3.513 * EP - 1.746 * PT \quad (1).$$

All coefficients were statistically significant ($p < 0.05$). The adjusted R^2 value of 0.3226 indicates that approximately 32% of the temperature variability is explained by the

independent variables. Specifically, humidity (U) and pollutants (PM2.5 or EP) have a positive relationship with temperature, meaning they contribute to its increase, while precipitation (PT) shows a negative relationship, helping to reduce temperature levels.

Residual analysis confirmed the absence of multicollinearity, heteroscedasticity, and autocorrelation [10] as shown in Figure 2.

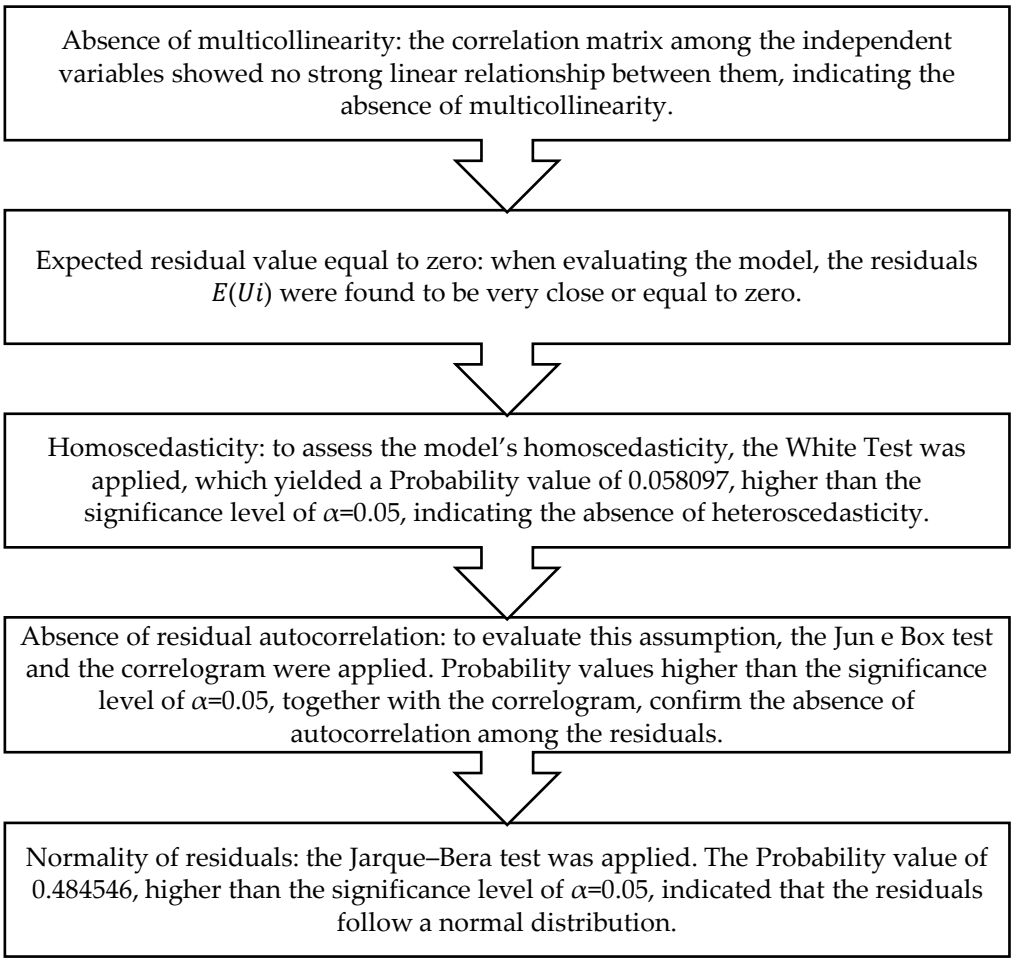

Figure 2. Results of the statistical model validation tests.

5. Conclusion

The MLR model effectively identified the impact of key environmental factors on the UHI phenomenon in São Paulo. The findings reinforce the potential of data-based modeling for urban planning and climate adaptation strategies. Future research can expand this model by incorporating land surface parameters and socio-economic indicators.

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Conflicts of Interest: The authors declare no conflict of interest.

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