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Statistical analysis of the climatological variables an their potential applications in the city of Cucuta

Análisis estadístico de variables climatológicas y posibles aplicaciones en la ciudad de Cúcuta

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ABSTRACT

The main objective of this work is to present a descriptive statistical analysis of the climatological variables in the city of San Jose de Cúcuta, and with this data, understand the interrelation of the aforementioned variables and how they have kept on over time, therefore making it possible to identify their potential applications in different areas. To develop the analysis, the Pearson correlation coefficient was calculated among the relative variables of humidity, solar radiation, sunshine duration, temperature and wind speed. Climographs and the data from the variables were plotted together with their respective linear regression; alongside their fluctuations through the months and years. It was evidenced that the analyzed climatological variables are directly and inversely correlated, and the highest value of the correlation coefficient was -0.9056, corresponding to temperature and relative humidity.

Keywords:

Climatological variables
Climograph
Coefficient
Pearson correlation

RESUMEN

El objetivo del presente estudio es presentar una estadística descriptiva de las variables climatológicas en la ciudad de San José de Cúcuta; para con esos datos, conocer cuál es su interrelación y cómo ésta se ha mantenido en el tiempo, determinando así posibles aplicaciones de estas variables en diferentes áreas. Para el desarrollo de este análisis se calculó el coeficiente de correlación de Pearson entre las variables de humedad relativa, radiación solar, brillo solar, temperatura ambiente y velocidad del viento. Se graficaron climogramas y las relaciones de las variables junto con su respectiva regresión lineal; además, de la variación de éstas a través de los años y los meses. En tal sentido, se logró evidenciar que las variables climáticas analizadas se encuentran correlacionadas inversa y directamente entre ellas, y el valor más alto del coeficiente de correlación es de -0.9056 presente entre la humedad relativa y la temperatura ambiente.

Palabras Clave:

Climograma
Coeficiente de correlación de Pearson
Variables climatológicas

Introduction

Climatology is the science which studies climate and its variations. By making analytical interpretations and practical deductions from them, it favors a detailed insight of the meteorological variables of a region.

When studying the behavior of these meteorological variables, the characteristics of a particular region can be clearly defined [1]; by knowing the climate of a region it is possible to discover the optimal places are to live, the fruit or vegetable that can be grown in the area, the characteristics of the flora and fauna, and other activities which require intricate knowledge of the climate: such as industrial, environmental, and energy operations, among others [2].

As San Jose de Cúcuta is located approximately at a latitude of 7°54' north of the Equator, it is a city with only two seasons: dry and wet. The dry season is characterized by a relative humidity which can reach maximum levels of 50% and in the rainy season can reach an average level between 70% and 100% [3].

In this regard, studies have been carried out related to the city's wind and solar power potential, which have determined that the amount of solar radiation present in the city is greater compared to the energy power that was extracted by wind energy generation systems [4] [5].

There are also studies measuring climate variability over the years, where an increase in temperature and precipitation is evident, demonstrating the present climate change in the city [6]. Currently, there are not enough statistical studies involving a larger number of meteorological variables in Cúcuta.

This work aims aims to present a statistical description of the variables, using data obtained from two meteorological stations belonging to the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM).

The results of the statistical analysis of this data are shown in graphs and tables created by specialized statistical software, which facilitates a more thorough interpretation of the data.

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Materials and methods

This study was divided into two phases. The first consisted of collecting and organizing hourly and monthly data from two weather station shown in Table I.

The second stage concerned the statistical analysis of the meteorological variables contained in the databases from each one of the stations.

Table I. Weather Stations

Location	Latitude	Longitude	Institution
Camilo Daza International Airport	7°55′49′′N	72°30′33′′ O	IDEAM
Francisco de Paula Santander University (UFPS)	7°53′38′′N	72°30′28′′ O	IDEAM

The weather station at the Francisco de Paula Santander University (UFPS), stores hourly information, while the station at the airport takes monthly records; thus, the analysis from each station differed significantly. Accordingly, the existing databases from both two weather stations in the city were requested to the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM). The data was organized based on the climatic environment variables: environmental temperature, relative humidity, solar radiation, sunshine and wind speed. However, due to failures in the measuring instruments and/or communication stations, there is missing data for some of the time periods, therefore, the data was filtered to make a correct assessment, and by doing so creating complete information for the climate variables under study. It is important to clarify at this point that the data used in the UFPS station is part of a record from 2005 to 2015, while the data from the airport station is from 1944 to 2014. A descriptive and graphic analysis of data from the UFPS station was conducted. It comprised of climographs, correlations, and linear regressions between the tested variables.

To do so, a time range in which all variables would have a significant value was selected, (between 06:00 and 19:00). Otherwise, the data from sunlight and solar radiation would be recorded at zero, and thus affect the proposed interrelationship with the other variables.

The variables and measurement units were as follows:

• ***Environmental temperature*** Related to the perceived thermal sensation on any given object at a specific location. It can be measured by thermometers, sensors and/or thermistors. Temperature can be expressed in three globally known scales: Fahrenheit (°F), Kelvin (K) and Celsius (° C)[7]. Celsius was the temperature scale used in this research.

• ***Solar radiation.*** This concerns the electromagnetic radiation emitted by the Sun; which is distributed from ultraviolet radiation (λ = 250 nm) to infrared radiation (λ = 2500 nm) going through visible light. When studying the amount of solar radiation measured at the earth's surface in Cúcuta, it is shown in units of W / m2[8].

• ***Sunshine.*** The number of hours a day in which sunlight is visible on a given surface [9].

• ***Relative humidity.*** This refers to the percentage of vapor pressure of water in the air [10].

• ***Wind speed.*** This represents the rate at which air on the Earth's crust moves. It represents the energy in the atmospheric air. This is expressed in units of m/s[10].

• ***Precipitation.*** This is the amount of water that falls from the atmosphere onto the earth's crust, expressed in mm, representing the height of the water level formed by precipitation. 1mm equals 1 liter / m2 [10].

Results and analysis

To analyze the climatic variables behavior, the data was filtered considering the information for each of the intact variables. The filter individually analyzed the average behavior of each variable of throughout the day for twelve months; Figures 1, 2, 3, 4 and 5 correspond to the intensities of the variables: environmental temperature, relative humidity, solar radiation, sunshine and wind speed respectively.

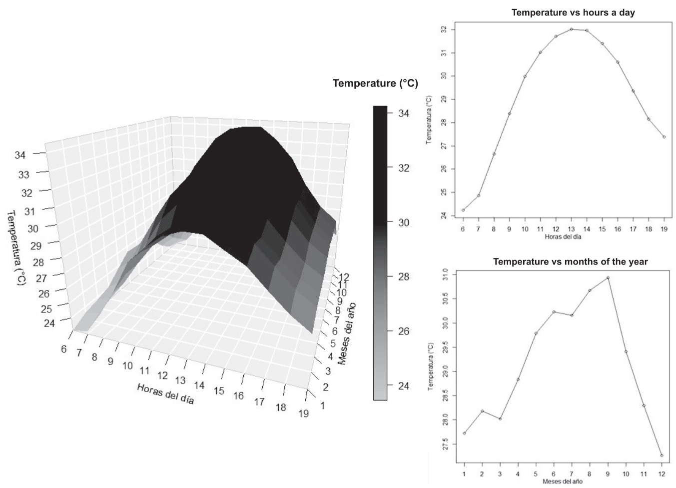

Figure 1. Behavior of Cúcuta room temperature

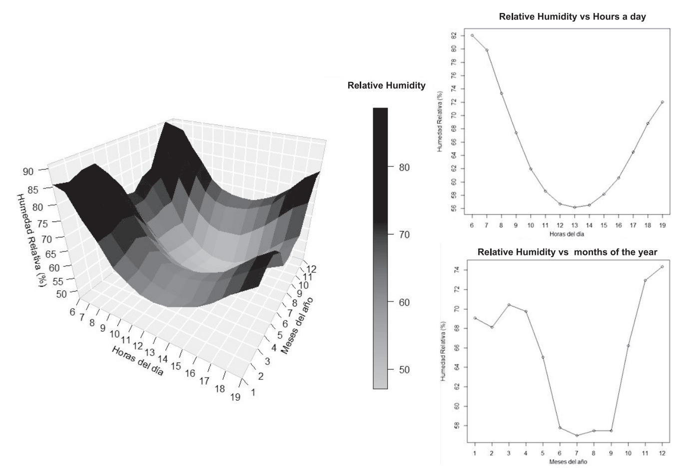

Figure 2. Behavior of the relative humidity in Cúcuta

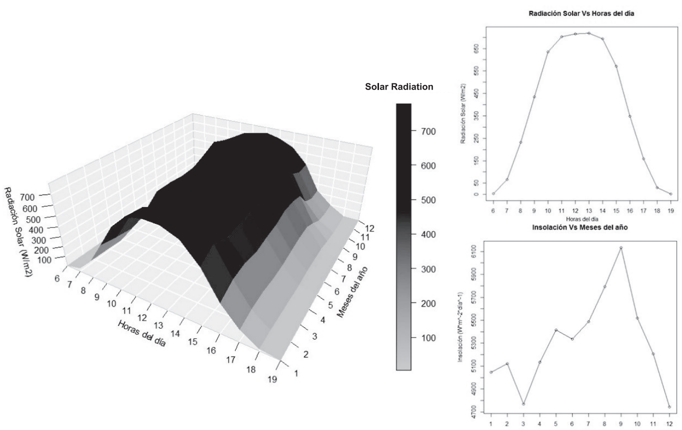

Figure 3. Behavior of Cúcuta sunlight

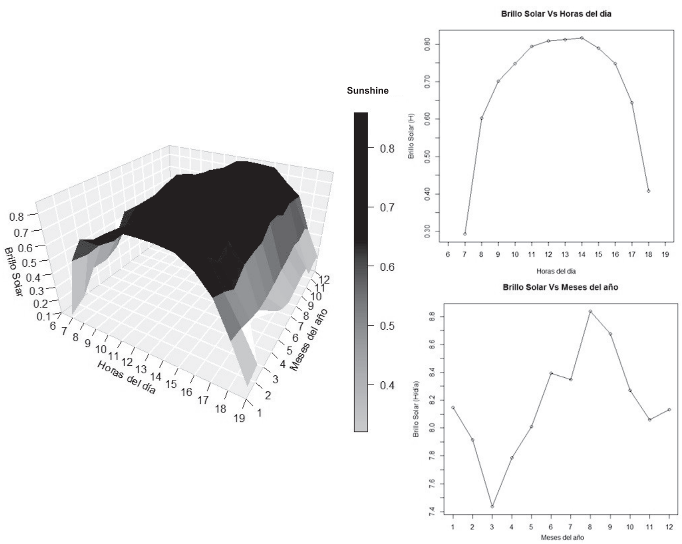

Figure 4. Behavior of sunshine in Cúcuta

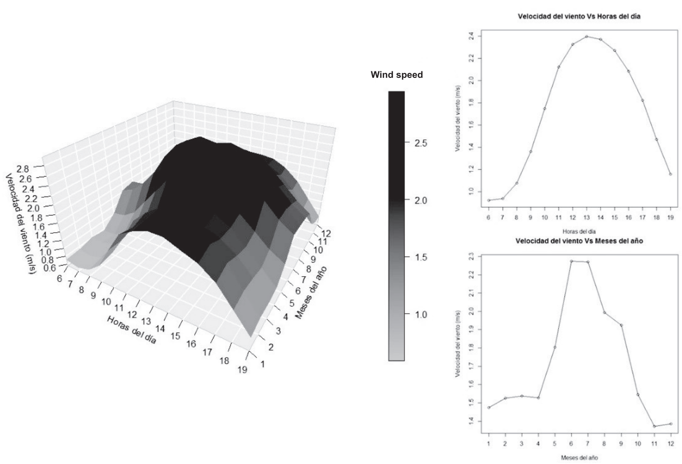

Figure 5. Behavior of Cúcuta wind speed

Figure 3 shows the high solar potential of the city throughout the year – the minimum average insolation is 4743 W*m-2*day-1, which represents 4.7 minimum peak solar hours.

From Figures 1 and 2 it can be deduced that the months of March, April, November and December are the wettest and that temperatures reach the lowest values. Continuing, Figure 7 displays the precipitation behavior in the city dating from 65 years back. Moreover, Figure 5 shows that the months with the most wind potential are June, July and August. As seen in Table II, some climatic variables have an inversely proportional relationship, as is the case for wind speed and relative humidity. That is to say, as wind increases, humidity decreases, indicating that the environmental temperature increases as humidity decreases; this behavior is clearly evident in Figures 1 and 2. On the other hand, temperature is directly linked to solar radiation, which in turn depends on sunlight; subsequently indicating the length of time that the sun hits the earth surface, which in effect can be interpreted as solar radiation.

From this perspective, the climatic conditions set forth in Table II make Cúcuta a suitable city to implement projects to harness renewable energy resources, such as solar energy, due to the consistently high radiation. Wind energy is also a good choice when considering renewable energy; this type of generation would be at its highest point in June, July and August; However, it is recommended that only low-power wind generators are used [6].

In addition, these environmental conditions facilitate the execution of agricultural activities, such as growing rice, cassava, bananas and coffee. It is also suitable climate for breeding farms, such as fish (bream and cachama) and other livestock.

Table II. Climatic Variables

Characteristic	Temp. (° C)	Rh (%)	Insolation (W * m-2 * day-1)	Sunlight (h / day)	Wind speed (m/s)
Minimum value	22.0	23	4743	7.44	0.20
Average	29.2	64	5309	8.2	1.65
Maximum value	39.7	100	6133	8.84	5.63
Month with the lowest average	December	September	March	March	December
Month with the highest average	September	December	September	September	July

In the climograph (Figure 7), the two stations of the equatorial country present various data. An average temperature of 20°C and a maximum average of 37°C can be observed. In October and November heavy rainfall occurs, and in contrast the months June, July and August present the lowest values of precipitation.

When considering the relationships between the climatic variables, the Pearson correlation coefficient was used, as indicated in Table III. It can be deduced that the variables solar radiation, relative humidity, environmental temperature and wind speed are correlated both directly and inversely.

The highest value of the correlation coefficient is -0.9056, a value that links relative humidity and environmental temperature.

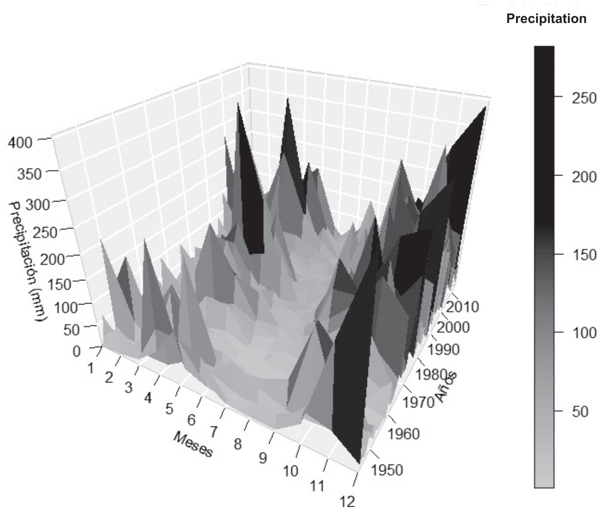

Figure 6. precipitation behavior through the years

Figure 7 shows a summary of the precipitation data and the minimum, maximum and average room temperature. This graph is called a climograph.

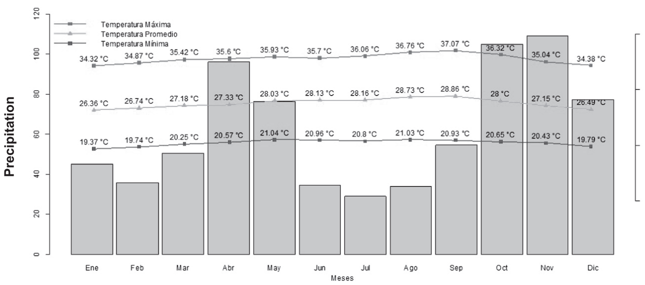

Figure 7. Cúcuta city climograph

Similarly, sunlight has very low correlation values with the other variables; this is because the city of Cúcuta has a tropical climate with sunlight for on average over 90% of daylight hours (06: 00-19: 00 hours), as was evidenced in Table II, therefore, it is not necessary to perform a correlation between sunlight and other variables, as it remains at a high value for most hours of the day.

In Table IV, the coefficient of determination (R2) between the variables is observed.

Table III. Pearson product-moment correlation coefficient between climate variables

Variables	Rh	Environmental temperature	Wind speed	Sunshine	Solar radiation
RH	1	-0.9056	-0.6873	-0.2931	-0.5714
Environmental temperature	-0.9056	1	0.6340	0.3694	0.7001
Wind speed	-0.6873	0.6340	1	0.1950	0.4415
Sunshine	-0.2931	0.3694	0.1950	1	0.3773
Solar radiation	-0.5714	0.7001	0.4415	0.3773	1

Table IV. Coefficient of determination (R) between climatic variables

Variables	RH	Environmental temperature	Wind speed	Sunshine	Solar radiation
RH	1	0.82	0.4724	0.086	0.3265
Environmental temperature	0.82	1	0.402	0.137	0.49
Wind speed	0.4724	0.402	1	0.04	0.195
Sunshine	0.086	0.137	0.04	1	0.14
Solar radiation	0.3265	0.49	0.195	0.14	1

Furthermore, a linear regression was calculated to determine the approximate behavior that a variable has with respect to each other, behavior that can be demonstrated in graphs 8, 9, 10, 11, 12 and 13 together with their respective equations, representing performed linear regression.

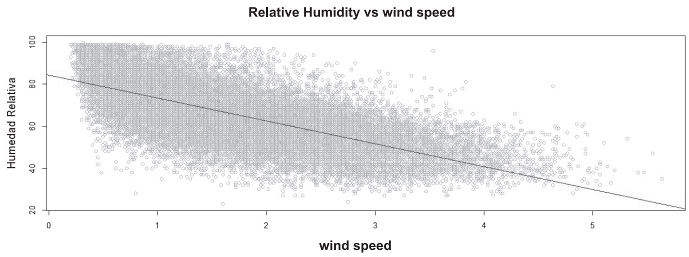

Figure 8. Linear regression between relative humidity and wind velocity
Humidity= -10.93*Wind Speed+ 84.41 (1)

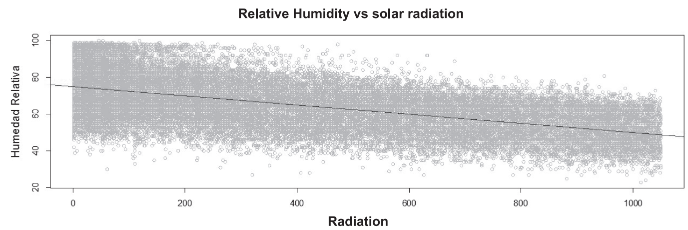

Figure 9. Linear Regression between relative humidity and solar radiation
Humidity= -0.02475*Radiation+ 74.91583 (2)

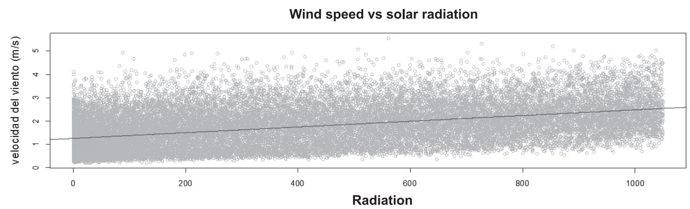

Figure 10. Linear regression analysis between wind speed and solar radiation
Wind speed= 0.001218*Radiation+ 1.258031 (3)

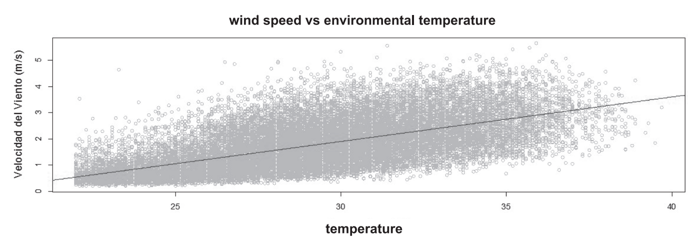

Figure 11. Linear regression between wind speed and temperature
Wind speed= 0.1697*Temperature-3.1949 (4)

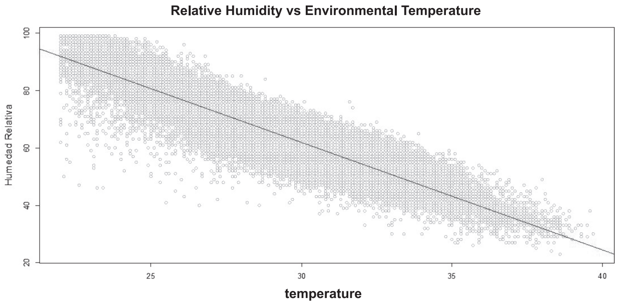

Figure 12. Linear regression relative humidity and room temperature
Humidity= -3.745*Temperature+174.32 (5)

Conclusions

The average annual temperature of Cúcuta is 27 ° C, which is characteristic of a warm climate. This temperature is vital to the advancement of farming processes such as the cultivation of rice [11], yucca[12], banana [13], and many others; as well as the fattening of fish species such as crappie[14] and cachama [15]; pigs and other livestock also feature strongly in the city's agriculture.

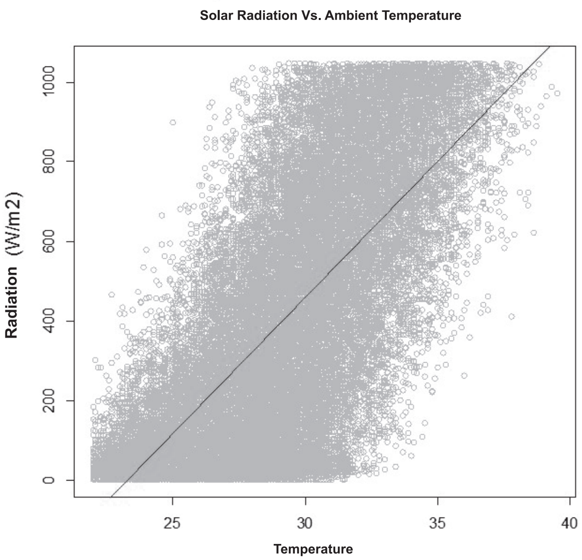

Figure 13. Linear regression between solar radiation and ambient temperature
Radiation= 68.48*Temperature-1595 (6)

The coldest month of the year is January, with an average temperature of 26.3 ° C, while in September an upper temperature of 37 ° C can be reached.

With regards to solar radiation in Cúcuta, the average value is 5309 W/m2, which is equivalent to 5.3 peak sun hours (PSH). This value favors the implementation of future photovoltaic or thermal systems.

The total average precipitation per annum is 747.7438 mm and the months where there is more rainfall are October and November; and June and July are months where less rainfall occurs. However, during the months of scant rainfall, humidity was lower, which led to an increase in wind speed.

In periods of clear skies, solar radiation and environmental temperature also increases. Based on this information, in the months of June, July and August, the wind and solar potential are greater.

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