Fluctuations in Insolation during 1962 - 2019 for Municipalities in Pernambuco, Brazil

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Authors’ contributions

Authors RMM, MCF and MVF conducted the study, collected the analyzes in the field and did the statistical analysis of the data, wrote the protocol and wrote the first draft of the manuscript. Authors RMH, VCP and JSR were the masters of the first author, they designed the study and monitored and supervised all of this study. Authors TOFP, ALXC, GRM and RNAF assisted in literature searches, writing in the manuscript and discussing the data. Author MLLC helped in the search of the literature and in the translation of the same into English language. All authors read and approved the final manuscript.

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ABSTRACT

This study evaluates the insolation calculations and their analysis soon after plotting their respective local historical average graph from 1962 to 2019 for some municipalities in Pernambucana. Monthly and annual insolation data for the study period was obtained from the National Institute of Meteorology. After homogenization, data consistency and failure filling of each series, the spatial and temporal insolation densities were performed for municipalities like Arcoverde, Cabrobó, Garanhuns, Ouricuri, Petrolina, Recife, Surubim and Triunfo. The average and its historical average were calculated and appropriate analysis was performed. The spatial distribution of the monthly insolation data showed great variability for the months studied, ranging from approximately 3 to 4 hours. The median values most likely occurred during the months for the eight municipalities under study. The municipality of Garanhuns presented higher insolation values than Petrolina. Comparing the values obtained in this study with the values of the Solarimetric Atlas of Brazil, indicated a good similarity of the recorded data.

Keywords: Agriculture; climatology; climate variability; spatial and temporal distribution.

1. INTRODUCTION

The importance of climatic procedures, air temperature, and all climatic variables are targets for studies, mainly related to agriculture [1]. The temporal space oscillations of the angle of incidence of the sun's rays on the surface influence its quantitative results. However, it is registered daily, as the anthropogenic activities result in changes in the environment through the replacement of the natural ecosystem by artificial structures. Being a continuous process insolation can cause environmental impacts at various levels, especially in relation to the quality of air and climate, thereby reducing the quality of human life. According to the IPCC / TAR [2] the warming happening during the last 100 years is not only a consequence of the natural variations in the climate as revealed by the assessments of the climate models. Therefore this process is mainly responsible for the increase of the air temperature in urban areas.

Bayer [3] and Bley [4] stated that the North, Northeast and Midwest regions of Brazil have a high incidence of solar radiation, insolation, and air temperature because of their proximity to the equatorial region and the tropical area where the incidence of heat stress is critical.

Medeiros [5] monitored insolation as a relevant factor for agriculture, renewable energy and heat source by analyzing its average historical buoyancy in the municipality of Caruaru, Brazil. According to the author, there is a lack of more in-depth and specific studies for the semi-arid region, including the methodologies to study the influence of radiation and energy balances on the biomes. The variabilities in insolation are associated with the thermodynamic conditions of the South Atlantic Subtropical Anticyclone, which inhibits the formation of clouds, and favors an increase in the short-wave radioaction. An increase in the flow of the radiation balance enhances the incidence of diseases in the population through warming of the atmosphere.

Frota [6] stated that the maximum influence of solar radiation is on the distribution of global temperature. The amount of radiation varies depending on the time of year and latitude. This phenomenon can be better examined by observing the movement of the sun in relation to the earth.

Silva et al. [7] showed that direct sunlight can be intercepted very effectively through the shade provided by trees and the wind, which is cooled when it comes in contact with leaf surfaces and makes changes by convection.

Silva [8,9] indicated that the direct effects of the differentiated incidence of solar radiation on the soil surface can be confirmed through determination of soil temperature and humidity.

The Northeast region of Brazil (NEB) has an annual average solar radiation values similar to the desert regions with the maximum incidence of solar radiation.

Pereria et al. [10] stated that the solar energy and water availability are the two edaphoclimatic factors which influence the development and productivity of plants.
Bigarella et al. [11] reported that the high radiation and temperature dries the soil resulting in its disintegration and hardening which favor the runoff of water.

According to Moreno and Martin [12] and Rata [13], solar radiation heats the atmosphere differently. As the cold air is denser than the hot air, pressure differences arise which, associated with the rotation of the earth, produce the circulation of the winds in the world.

The incidence of solar radiation differs with the time of year, the slope of the terrain, and exposure of the land as stated by Silva et al. [14]. The solar radiation on the soil surface is a decisive factor and conditions the processes that take place in the environment, by interfering with the cycle of its nutrients. Thus, if we vary the amount of incident solar radiation, different environmental conditions can be obtained and, therefore, promote changes in other processes [14]. The aim of the study was to evaluate the insolation data and to analyze these after plotting graphically with their respective local historical average for the period from 1962 to 2019 of some municipalities in Pernambucana, Brazil.

2. MATERIALS AND METHODS

The State of Pernambuco is located in the central-eastern region of the NEB with a northern limit with Paraíba, northwest with the state of Ceara, southeast with the states of State and Bahia_South like Piauí_to the east fur Atlantic Ocean. It occupies an area of 98,937.8 km². The archipelagos are part of the territory of Fernando de Noronha, São Pedro, and São Paulo.

Pernambuco is one of the smallest states in Brazil as per the territorial extension, and possess great diversity of landscapes like plateaus, mountains, swamps, semiaridity and beautiful beaches. The relief is almost regular, being formed by a coastal plain around 76% of it. As we move inland, there are mountain peaks exceeding 1000 meters in altitude.

The vegetation cover is diversified, with forests, mangroves and savannahs, in addition to the strong presence of the caatinga. Coastal vegetation predominates in areas close to the ocean, with coconut trees, mangroves and, in some cases, shrubs. The tropical forest is where the Atlantic Forest originally existed. Few remnants of this important Brazilian forest remain. Finally, in the wild and in the Pernambuco countryside, the vegetation of the caatinga predominates. As for hydrography, there are many rivers, mainly in the Metropolitan Region of Recife, which has 14 municipalities. The main rivers in the state are Capibaribe and Beberibe, Ipojuca, Una, Pajeú, Jaboatão and the São Francisco River, the latter is extremely important in the development of the sertão, since it enables the distribution of water to regions affected by drought [15].

The meteorological factors that cause or inhibit rainfall for the state of Pernambuco contribute to moderate to weak rainfall levels are the vestiges of frontal systems in the southern sector of the state less frequently, to the contributions of the South Atlantic Convergence Zones (ZCAS), in addition to the formation of convective clusters and the contribution of Alta da Bolivia. The Intertropical Convergence Zone (ZCIT), a disturbance associated with the expansion to the southern hemisphere of the thermal equator (zone of ascension of the trade winds by thermal convection) causes moderate to heavy rains in almost the entire northern area of the State, followed by the contributions of the formations from the High Level Cyclonic Vortices (VCAN) the Eastern Wave Disorders and the Sea and Land Breezes, the latter originating in the Atlantic Ocean.

We used monthly sunshine data from 1962 to 2019, obtained from the National Institute of Meteorology [16]. In order to homogenize the spatial and temporal density of the municipalities: Arcoverde, Cabrobó, Garanhuns, Ouricuri, Petrolina, Recife, Surubim and Triunfo, we analyzed their consistency, homogenization and filling in gaps in each series.

The monthly and annual sunshine data were entered into an electronic spreadsheet where the monthly and annual averages, standard deviation, Coefficient of variance, median, maximum and minimum absolute values were calculated. These were plotted in the referred municipal charts and were compared with the regional average.

3. RESULTS AND DISCUSSION

The municipalities and their geographic locations where the National Meteorological Institute (INMET) operates the conventional meteorological stations since 1962 are presented in Table 1.
Figs. 1 to 10 show the monthly spatial distribution of sunshine, in hours and tenths, of the municipalities Arcoverde, Cabrobó, Garanhuns, Ouricuri, Petrolina, Recife, Surubim and Triunfo. The graphs compose approximations due to the order of magnitude of the average value and the averages of the referred municipalities in studies. Kozhminsky [17] interpolated insolation variations in the State of Pernambuco using the kriging method and observed higher incidence of insolation than the normal patterns recorded in the regions of the sertão. The high insolation in sertão was due to low cloud cover, the abnormal temperature fluctuations and occurrences of fires. The interpolation method of kriging indicated optimal levels of significance when extended to the other regions studied. The author found climatic conditions identical to the values used for the seasons worked.

The monthly variability and the average historical insolation in the municipality of Arcoverde for the period 1962-2019 are shown in Fig. 1. It is observed that the insolation recorded was higher than the historical insolation except for the months of June, July and December. The months of August and October stand out as the high incidences of solar radiation. The solar radiation registered ranged between 180 and 279 hours.

Fig. 2 shows the changes observed sunshine that exceeded the historical values for the municipality of Cabrobó - PE from the period 1962-2019, except in the month of January when their values were almost similar. Higher insolation values were recorded between August and December. These fluctuations may have been caused by the absence of cloud cover and the inhibition of the factors causing local and regional rainfall. The months of February and July stand out with low incidence of solar radiation and the month of October with high incidence.

Table 1. Municipalities and their geographical coordinates where the National Meteorological Institute conventional weather stations are located

<table>
<thead>
<tr>
<th>Counties</th>
<th>Longitude (°) W</th>
<th>Latitude (°S)</th>
<th>Altitude (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green arch</td>
<td>-37.05</td>
<td>-8.43</td>
<td>680.7</td>
</tr>
<tr>
<td>Cabrobó</td>
<td>-39.33</td>
<td>-8.51</td>
<td>341.5</td>
</tr>
<tr>
<td>Garanhuns</td>
<td>-36.51</td>
<td>-8.88</td>
<td>822.8</td>
</tr>
<tr>
<td>Ouricuri</td>
<td>-40.05</td>
<td>-7.90</td>
<td>459.3</td>
</tr>
<tr>
<td>Petrolina</td>
<td>-40.48</td>
<td>-9.38</td>
<td>370.5</td>
</tr>
<tr>
<td>Recife</td>
<td>-34.95</td>
<td>-8.05</td>
<td>10.0</td>
</tr>
<tr>
<td>Surubim</td>
<td>-35.71</td>
<td>-7.83</td>
<td>418.3</td>
</tr>
<tr>
<td>Triumph</td>
<td>-38.11</td>
<td>-7.81</td>
<td>1105.0</td>
</tr>
</tbody>
</table>

Fig. 1. Average historical solar radiation and heat stroke from the 1962-2019 periods for the municipality of Arcoverde - PE
Source: Medeiros, (2020)
Fig. 2. Average historical solar radiation and solar radiation for 1962-2019 for the municipality of Cabrobó - PE

Source: Medeiros, (2020)

Fig. 3 shows the changes in solar radiation for the municipality of Garanhuns from 1962 to 2019. The sunshine period was below the average climatological sunshine hours and the months of August to December had the greatest incidences of historical sunshine hours ranging from 238.2 to 264.1 hours. In the months of June and July, the lowest incidences of historical sunshine hours were recorded. The sunshine hours of 1962 to 2019 were below the historical sunshine hours.

Silva et al. [18] showed that the fluctuations between the amounts of monthly sunshine happened due to variations in the meteorological conditions prevailed in those periods like the amount of cloud cover and not by the conditions of the astronomical photoperiod.

Fig. 4 shows the variability of the historical average sunshine and insolation of the 1962-2019 periods for the municipality of Ouricuri - PE. The sunshine hours of the period was below the historic values for the months of January to April and December, it was similar in the months of May and November and was greater than the historical sunshine hours for the months of June to October. These variations were due to the meteorological systems operating in the study area.
Medeiros et al. [19] proved that the high incidence of insolation in the state of Piauí is due to its close proximity to the equator. They also stated that the low cloud cover, the thermal oscillation over normalities and fire outbreaks may have affected the incidence values in the Piauí regions during the months of July to October. These variabilities are associated with the thermodynamic conditions of the South Atlantic Subtropical Anticyclone, which inhibits the formation of clouds, favoring an increase in the short-wave radioactive flow and in the radiation balance flow, thus potentiating diseases to the population that, through heating of the Atmospheric Boundary Layer, will imply in the pre-disposition of this area the proliferation of vectors.

In Fig. 5 the insolation of 1962-2019 for the municipality of Petrolina - PE overcame the historical insolation in the months of February to September and December, it was similar during the months of October and November in the month of January oscillated close to climatology, these fluctuations were due to the atmospheric systems that acted on the municipal area aided by large, meso and micro scale systems. The variability of historical insolation versus insolation observed in Recife as shown in Fig. 6, were balanced in the months from January to March, for the other months the historical insolation exceeded that observed, such variability can be justified by the predominant cloud cover and / or occurrence of isolated rains.
Medeiros [20] carried out the monitoring of heat stroke as a relevant activity for agriculture, renewable energy and heat source, analyzing the decadal behavior and its comparison with the historical average of heat stroke in the face of the temporal variation that occurred in the period of 1962-2011 in the city from Recife. The incidences of heat stroke above normal patterns in the region, conditioned by the low incidence of cloud cover, temperature fluctuations higher than normal and the occurrence of fires. It is observed that the positive deviations outweighed the negative deviations, in the majority the negative deviations predominated between the years 1972 to 1992, showing reductions of up to 15% in their monthly and annual values. Part of the interannual variability of heat stroke is associated with the occurrence of local and regional effects and the contributions of large and meso-scale phenomena recorded during the study period. The study corroborates the results discussed here.

Fig. 7 characterizes the average heat stroke of the period 1962-2019 and the historical heat stroke for the municipality of Surubim. The historical insolation were above the average of the period in the months of June, July, August, September and October, showing reduction in sunlight by twenty minutes to two hours, in the months of January, February, March, April,

Fig. 8 shows the statement of average heat stroke and heat stroke of the 1962-2019 period for the municipality of Triunfo - PE. Historical sunshine flows between 180 to 280 hours of sunlight, with the highest incidence occurring from October to January and the months from May to July having the lowest incidence. In the heat stroke curve, the months of January, March, May, June stand out as their indexes flowed close to or close to historical values. In the months of February, July to December the insolation received exceeded the climatology around 3 am.

A Fig. 9 represents the historical distribution of the monthly sunshine in the study area. It is noteworthy that in the months of April to July there are monthly reductions in the values of sunshine, these reductions are linked to the rainfall indexes and the cloud cover seen to be the rainy season. In the months from August to September, there is a gradual increase in the insolation rates, with an emphasis on the months from October to January, where their values are high and corresponds to the four-month dry study area.

Fig. 10 shows the annual variability of average sunshine and their respective climatology for the eight municipalities under study where INMET operate its conventional stations. Values range from 2,861.1 to 2,289.7 hours with a climatological average of 2,644.7 hours. The insolation difference between the municipalities of Garanhuns and Petrolina is 14 hours.

The municipalities of Arcovender, Cabrobó, Petrolina and Triunfo have more than historic annual sunshine, in Garanhuns, Recife and Surubim the annual sunshine varies below the historic and in the municipality of Ouricuri annual sunshine and practically the value of history.
Fig. 7. Average historical heat stroke and heat stroke from the 1962-2019 period for the municipality of Surubim - PE

Source: Medeiros, (2020)

Fig. 8. Average historical heat stroke and heat stroke from the 1962-2019 period for the municipality of Triunfo - PE

Source: Medeiros, (2020)

Fig. 9. Average monthly historical heat stroke of the study area

Source: Medeiros, (2020)
Studying heat stroke in the municipality of Juazeiro - BA according Silva et al. [21] annual sunshine is 2,880 hours for the period 2000 to 2009.

Table 2 shows the maximum, minimum, average, median, standard deviation and coefficient of variance of monthly and annual sunshine in hours and tenths of the study area.

Maximum monthly values of heat stroke flow between 216.6 at 286.1 hours and tenths with an annual average of 2,861.1 hours and tenths. The minimum values are recorded in the month of July with 145.9 hours and tenths, the minimum minimum value occurs in the month of November with 245.6 hours and tenths and has an annual average of 2,289.7 hours and tenths. Average fluctuations occur between 197 (May) to 259.5 (November) with an annual average of 2,644.7 hours and tenths. In the median column, there is variability from 216.5 in February to 267.4 in October with a historical average of 2,861.1 hours and tenths, the median values are representative and those most likely to occur. The standard deviations as well as the coefficients of variances do not present values of high significance showing that the values of possible occurrence are between the mean and the median.

[22] Showed that the standard deviation is extraordinary to have information on the “degree of dispersion of the values in relation to the average value”. The coefficient of variance was used to make comparisons in relative terms and
expresses "the variability of each data set normalized in relation to the average, in percentage."

In panoramas of future changes caused by increased concentrations of gases in the atmosphere, it is assumed that only the average can change, with the standard deviation unchanged according to [23]. According to the authors [24] and [25] showed that the relative frequency of extreme events depends on changes in standard deviation and not just on the mean.

Information on climatic conditions in a region are necessary for establishing strategies, aimed at the proper management of natural resources, the search for sustainable development and the implementation of viable and safe agricultural practices for the various biomes in accordance with [26].

4. CONCLUSIONS

The spatial distribution of insolation data showed great variability for the months studied, with a variation of approximately 3 to 4 hours in the monthly distribution.

The median values are the most likely to occur during the months for the eight municipalities under study.

The municipality of Garanhuns presented higher insolation values than Petrolina. Comparing the values obtained in this article with the values of Atlas Solarimetric analysis of Brazil, there is a good similarity of the registered data.

Fluctuations in cloud cover and isolated rainfall may have influenced the values of insolations for the municipals studied, their variability is associated with the thermodynamic conditions of the South Atlantic Subtropical Anticyclone, which inhibits the formation of clouds, increases short-wave radiations flow and increases the flow of radiation balance.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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