Research, Society and Development, v. 9, n. 10, e5599108708, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i10.8708

Distribution of heat stroke in the Ipojuca/PE river basin, Brazil

Distribuição da insolação na bacia hidrográfica do rio Ipojuca/PE, Brasil

Distribución del golpe de calor en la cuenca hidrográfica del río Ipojuca/PE, Brasil

Received: 09/23/2020 | Reviewed: 10/01/2020 | Accept: 10/07/2020 | Published: 10/08/2020

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(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i10.8708

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Abstract

Heat stroke is part of solar energy that spreads without the need for a material medium and is represented by the hours of the day that the solar disk remains visible on the earth's surface. The objective is to characterize the climatic conditions of insolation using the interpolation method for the area of the hydrographic basin of the Ipojuca River and its surroundings, elaborating a monthly and annual graph for the period from 1962 to 2019. The average climatological data of the total monthly and annual sunshine were generated by the simple interpolation method, using electronic spreadsheets to extract the averages values of the monthly, annual, median, standard deviation, coefficient of variance, maximum and minimum absolute values. Total sunstroke is greater than the cloud coverage in the period from August to March, totaling 1861.8 hours and tenths, while in the same period, the cloud coverage is 0.45 tenths. Low cloud cover, temperature fluctuations and low or no ground cover conditions these incidences of insolation rates above normal. The importance of heat stroke is verified for purposes of applicability in the agricultural sectors, energy generations, aiming at helping industrial parks, energy distributors, agricultural sector and climatic studies that are scarce or widespread. It is observed that the deviations are positive, showing increases in the monthly and annual values, even though the straight line trends show us insignificant reductions for the period studied. The trend lines of the respective 12 months are negative and without insignificance, agreeing with the calculations of the moving averages, stating that there has been a reduction in the sunstroke in the next 9 years and, after 10 years, the insolation rates return to the level of the historical average.

Keywords: Climate variables; Renewable energy; Heat source; Trend lines; Temperature.

Resumo

A insolação é parte da energia solar que se propaga sem necessidade da presença de um meio material e é representada pelas horas do dia que o disco solar permanece visível à superfície terrestre. Objetiva-se caracterizar as condições climáticas da insolação utilizando-se do método da interpolação para a área da bacia hidrográfica do rio Ipojuca e seu entorno elaborando-se gráfico mensal e anual do período de 1962 a 2019. Os dados climatológicos médios da insolação total mensal e anual foram gerados pelo método da interpolação simples onde se empregaram do software em planilhas eletrônicas, para extrair os valores das médias mensais, anuais, mediana, desvio padrão, coeficiente de variância, máximos e mínimos valores absolutos. A insolação total é maior que a cobertura de nuvem no período de agosto a março totalizando 1861,8 horas e décimos ao passo que no mesmo período a cobertura de nuvem é de 0,45 décimos. Estas incidências de índices de insolação acima da normalidade estão condicionadas a cobertura de nuvem baixa, as flutuações das temperaturas e a baixa ou nenhuma cobertura do solo. A importância da insolação para fins agrícolas, gerações de energia visando auxílio aos parques indústrias, distribuidoras de energia, setor agropecuário e aos estudos climáticos que são escassos ou poucos difundidos. Observa-se que os desvios são positivos demonstrando aumentos nos valores mensais e anuais, mesmo que as tendências das retas nos mostrem reduções insignificantes para o período estudado. As retas de tendências dos respectivos 12 meses são negativas e sem insignificância, o que vem a concordar com os cálculos das médias móveis nos afirmando que ocorrera redução da insolação nos próximos 9 anos e após os 10 anos os índices de insolação voltam ao patamar da média histórica.

Palavras-chave: Variáveis climáticas; Energia renovável; Fonte de calor; Retas de tendências; Temperatura.

Resumen

La insolación es parte de la energía solar que se propaga sin necesidad de un medio material y está representada por las horas del día en que el disco solar permanece visible en la superficie terrestre. El objetivo es caracterizar las condiciones climáticas de insolación mediante el método de interpolación para el área de la cuenca hidrográfica del río Ipojuca y sus alrededores mediante la elaboración de un gráfico mensual y anual para el período de 1962 a 2019. Los datos climatológicos promedio de la insolación mensual total y anuales se generaron por el método de interpolación simple donde se utilizó el software en hojas de cálculo electrónicas, para extraer los valores de los valores mensuales, anuales, mediana, desviación estándar, coeficiente de varianza, máximos y mínimos absolutos. La insolación total es mayor que la nubosidad en el período de agosto a marzo totalizando 1861,8 horas y décimas, mientras que en el mismo período la cobertura de nubes es de 0,45 décimas. Estas incidencias de tasas de insolación por encima de lo normal están condicionadas por una nubosidad baja, fluctuaciones de temperatura y una cobertura del suelo baja o nula. La importancia del golpe de calor para fines agrícolas, generaciones de energía destinadas a ayudar a parques industriales, distribuidores de energía, sector agrícola y estudios climáticos que son escasos o generalizados. Se observa que las desviaciones son positivas, mostrando incrementos en los valores mensuales y anuales, aunque las tendencias en línea recta nos muestran reducciones insignificantes para el período estudiado. Las líneas de tendencia de los respectivos 12 meses son negativas y sin insignificancia, lo que concuerda con los cálculos de las medias móviles que señalan que ha habido una reducción de la insolación en los próximos 9 años y luego de 10 años las tasas de insolación vuelven al nivel promedio histórico.

Palabras clave: Variables climáticas; Energías renovables; Fuente de calor; Líneas de tendência; Temperatura.

1. Introduction

Souza et al. (2008) showed that an equally important element in the influence of atmospheric processes and the climatic variability of the planet Earth is the energy originating from the Sun, responsible for the heating of the air and soil, photosynthesis and evaporation. Differences in the radiation balance are of fundamental importance for atmospheric and terrestrial processes, changing the surface temperature, the vertical heating rate profile and atmospheric circulation.

Sansigolo & Kayano (2010) stated that studies involving the time series of climatic elements must be superimposed and analyzed in a non-parametric statistical manner, having a more rigid mathematical basis for the theoretical models of climatic description.

Santos (2014) explains that the main modulator of atmospheric dynamics is solar radiation, which provides energy for the oscillations that stimulate the general circulation of the atmosphere, supplying energy to all living beings on the planet, as an example we have the use of solar energy in photosynthesis and photovoltaic cells.

Holanda et al. (2019) carried out the monitoring of heat stroke as being a relevant activity for agriculture, energy and heat source, and analyzed its average buoyancy in the municipal area of Caruaru. They also showed that the lack of more in-depth and specific studies for the Brazilian semi-arid region, including methodological ones, revealed that it is necessary to carry out the balance of radiation and energy with approaches to the influence on biomes.

Medeiros et al. (2018) showed that in the State of Piauí, because it is located close to the equator, it receives a higher incidence of sunstroke directly on the surface. According to the authors, the low cloud cover, thermal oscillation, the occurrence of fire outbreaks and fires may have influenced the values of the incidence of insolation in the Piauí regions during the months of July to October. This favors an increase in the short-wave radioactive flow and an increase in the flow of the radiation balance, thus, potentiating diseases to the population, by heating the Atmospheric Limit Layer.

Kozmhinsky et al. (2018) characterized the climatic species of insolation in the state of Pernambuco by the kriging interpolation method, produced maps representative of the monthly and annual variations and accounted for the low and high variability of the sunstroke. The records showed an incidence of heat stroke above normal standards in the regions of the sertão and high sertão, conditioned by low cloud cover and temperature fluctuations above normal.

Medeiros (2018) compared the total insolations recorded in the Brazilian capitals and detected them as having low insolative rates in Rio Branco (1700.7 hours and tenths), Manaus (1828.5 hours and tenths), Porto Velho (1988.4 hours and tenths) and Boa Vista (1896.1 hours and tenths). The capitals with the highest insolation rates are: Fortaleza (2843.4 hours and tenths), Teresina (2781.7 hours and tenths), Goiana (2606.7 hours and tenths), João Pessoa (2695.1 hours and tenths), Natal (2968.4 hours and tenths), Aracaju (2721 hours and tenths) and Recife (2550.7 hours and tenths). In other capitals, the insolation rates are lower than the records of the capital of Pernambuco.

Medeiros et al. (2020) carried out the insolation calculations and their analysis, drawing an average graph between the years 1962 to 2019 for some municipalities in Pernambuco. The monthly and annual data sunstroke were obtained from the National Institute of Meteorology (INMET, 2020). The monthly spatial distribution for heat stroke data showed great variability, with oscillations of 3 to 4 hours. The median values probably occurred during the months of September, October, November, December, January and February, for the municipalities studied. The municipality of Garanhuns had higher insolation values than Petrolina. The values obtained in this study, compared to the values of the Solarimetric Atlas of Brazil, indicated a good similarity of the recorded data.

The objective was to study the climatic conditions of the sunstroke, using the interpolation method for the Ipojuca River Basin (BHRI) and its surroundings. For that,

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graphs were presented that represent the monthly and annual variations and the accounting for the low and high variability of heat stroke, between the years 1962 to 2019.

2. Methodology

The Ipojuca River Basin (BHRI) is in its entirety inserted in the State of Pernambuco, between 08º09'50" and 08º40'20" south latitude, and 34º57'52 "and 37º02'48" west longitude. Due to its elongated shape in the west-east direction, this basin has a strategic position in the state space, serving as an extensive water link between the Metropolitan Region of Recife and the Sertão of Pernambuco, according to Pereira et al. (2018). The upper, middle and middle stretches of the basin are located in the regions of the Sertão and Agreste, while the lower stretch is located in the Zona da Mata of Pernambuco, including the coastal strip of the State. BHRI is limited: to the north, with the Capibaribe River basin, the set of small riverside basins, but relevant, and with the State of Paraíba; to the south, with the Sirinhaém River basin; to the east, with the Atlantic Ocean; to the west, with the Ipanema and Moxotó river basins and the State of Paraíba (Figure 1).

Figure 1 – Hydrographic basin of the Ipojuca River, including the municipalities of Caruaru, Riacho das Almas, Bezerros, Gravatá, Pombos, Chã Grande, Vitória de Santo Antão, Poção, Belo Jardim, Arcoverde, Pesqueira, Tacaimbó, São Caetano, Saioré, Camocim de São Félix, Amaraji, Alagoinha, São Bento do Una, Cachoeirinha, Altinho, Agrestina, Escada, Ipojuca, Venturosa, Capoeiras.

Source: Medeiros et al. (2020).

According to the classification of Köppen (1928); Köppen & Geiger (1931), BHRI's climate is characterized by three climatic types: Bsh (warm semi-arid climate with summer and dry winter rains), “Am” (monsoon climate) and “AS” (tropical climate with dry season summer). These classifications agree with the studies by the authors Alvares et al. (2014); Medeiros (2018).

The rainy season begins in February with pre-season rains (rains that occur before the rainy season), ending in the second half of August and may continue until the first half of September. The rainy quarter focuses from May to July and the dry months occur between October and December. The elements that cause rain at BHRI are the contribution of the Intertropical Convergence Zone, the formation of cyclonic vortices, the contribution of northeast trade winds in the transport of steam and moisture, which condense and form clouds causing moderate to heavy rainfall, line formations instabilities, orography, heat exchange and their local and regional contributions, according to Medeiros (2018).

The average climatological data for monthly and annual sunshine were determined by the simple interpolation method, using the R Development Core Team (2010) software to extract the monthly, annual values and the statistics: median, standard deviation, coefficient of variance, values absolute maximum and minimum for the period 1962 to 2019, plotting the respective graphs and trends. This is confirmed in Table 1, in which the municipalities and their geographic coordinates were identified, followed by the period of study of their series. The interpolated values were compared with data from the National Institute of Meteorology, represented in the Atlas of Solar Irradiation of Brazil (INMET, 1988), whose values are consistent with their climatic variations (1962-2010) (INMET, 2020).

Table 1 – Location of the municipalities of: Arcoverde, Agrestina, Alagoinha, Altinho, Amaraji, Belo Jardim, Bezerros, Cachoeirinha, Caruaru, Chã Grande, Escada, Gravatá, Ipojuca, Fishing, Potion, Pigeons, Spring, Riacho das Almas, Sairé, Sanharó, São Caetano, Tacaimbó, Venturosa and Vitória de Santo Antão, with the geographical coordinates (latitude, longitude and altitude) and the interpolation period of the insolation data for the hydrographic basin of the Ipojuca River between 1962-2019.

Parameters/municipalities	Latitude	Longitude	Altitude	Observed period
Arcoverde	-37.0556	-8.4336	794	1962-2019
Agrestina	-35.9536	-8.4578	458	1962-2019
Alagoinha	-36.7739	-8.4661	717	1962-2019
Altinho	-36.0597	-8.4906	530	1962-2019
Amaraji	-35.4472	-8.3778	386	1962-2019
Belo Jardim	-36.4208	-8.3333	727	1962-2019
Bezerros	-35.7528	-8.2433	553	1962-2019
Cachoeirinha	-36.2375	-8.4839	572	1962-2019
Caruaru	-35.9158	-8.2383	539	1962-2019
Chã Grande	-39.2361	-7.7211	466	1962-2019
Escada	-35.2333	-8.3667	145	1962-2019
Gravatá	-35.5431	-8.2006	460	1962-2019
Ipojuca	-35.0058	-8.5144	62	1962-2019
Pesqueira	-36.6972	-8.3531	791	1962-2019
Poção	-36.7053	-8.1836	904	1962-2019
Pombos	-35.3961	-8.1386	341	1962-2019
Primavera	-35.3475	-8.3483	367	1962-2019
Riacho das Almas	-35.8592	-8.1381	443	1962-2019
Sairé	-35.7089	-8.3267	628	1962-2019
Sanharó	-36.5664	-8.3639	726	1962-2019
São Caitano	-36.1375	-8.3283	639	1962-2019
Tacaimbó	-38.1533	-9.1089	621	1962-2019
Venturosa	-38.9694	-7.9286	638	1962-2019
Vitória de Santo Antão	-35.6347	-8.8383	253	1962-2019

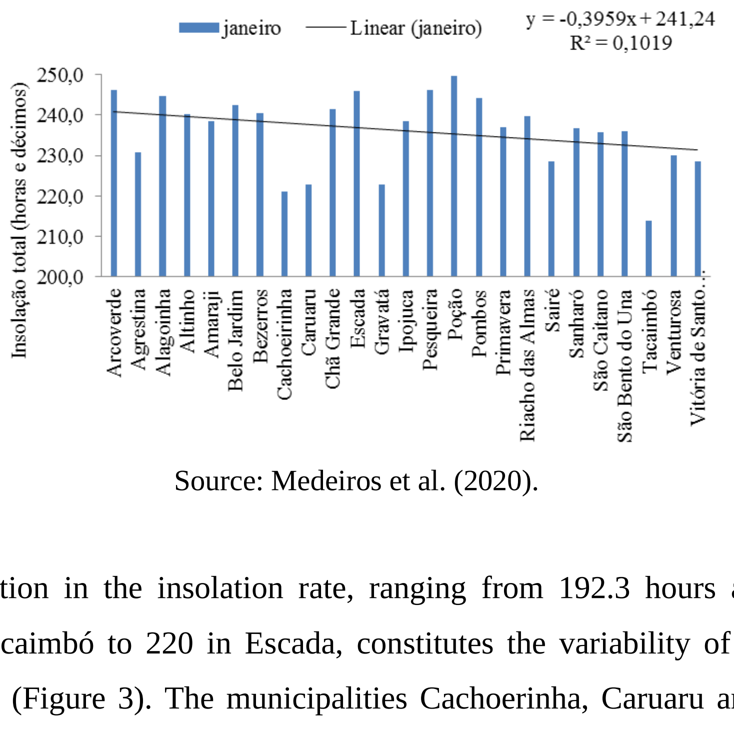
Source: Medeiros et al. (2020).

3. Results and Discussion

Figures 2 to 13 show the monthly fluctuations in heat stroke and the trend line for BHRI. In Figure 14, the annual heat stroke, Figure 15, the distribution of the heat stroke anomaly, Figure 16, the absolute maximum and minimum heat stroke and their respective historical average, Figure 17, the histogram of the average heat stroke and the polynomial trend for 1962 to 2019.

The month of January (Figure 2) presented a negative trend line with a low level of significance in relation to the others, due to the low incidence of rain. The oscillations of the insolations flowed between 215 hours and tenths to 250, between the municipalities of Tacaimbó and Poção. Noteworthy are the municipalities of Arcoverde, Alagoinha, Escada, Pesqueira, Porção, Pombos with high insolation values, considering the content of solar incidence. The municipalities of Cachoeira, Caruaru, Gravatá and Tacaimbó registered low levels of insolation.

Figure 2 – Total heat stroke for the month of January and its trend line for the Ipojuca River Basin between 1962-2019.



Source: Medeiros et al. (2020).

The fluctuation in the insolation rate, ranging from 192.3 hours and tenths in the municipality of Tacaimbó to 220 in Escada, constitutes the variability of insolation in the month of February (Figure 3). The municipalities Cachoerinha, Caruaru and Tacaimbó had the lowest insolation rates, in the municipalities of Escada, Ipojuca and Pombos, high insolations were recorded, noting that the solar incidence was lower due to the great temporal and spatial variability in the region.

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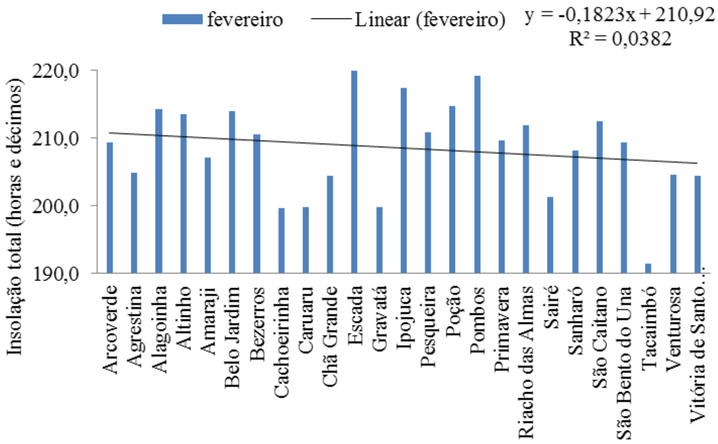
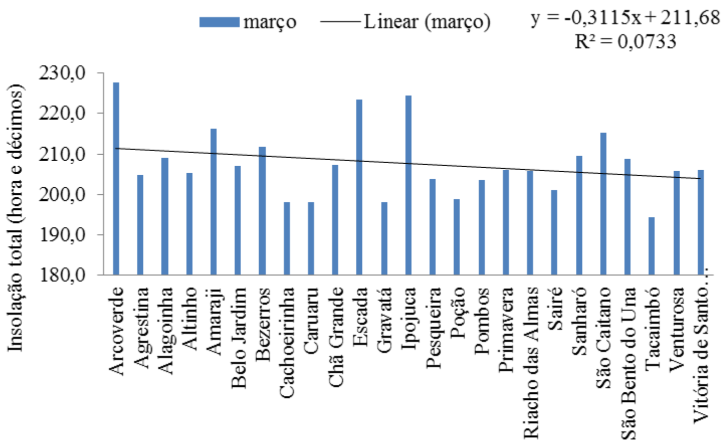
Figure 3 – Total heat stroke for February and its trend line for the Ipojuca River Basin between 1962-2019.



Source: Medeiros et al. (2020).

The month of March (Figure 4) has a straight line with negative slope and R2 of low significance, oscillating between 195.5 hours and tenths in Tacaimbó to 229.2 hours and tenths in Arcoverde. The municipalities Cachoeirinha, Caruaru, Gravatá and Tacaimbó registered low insolations and the municipalities of Arcoverde, Escada and Ipojuca, high insolations.

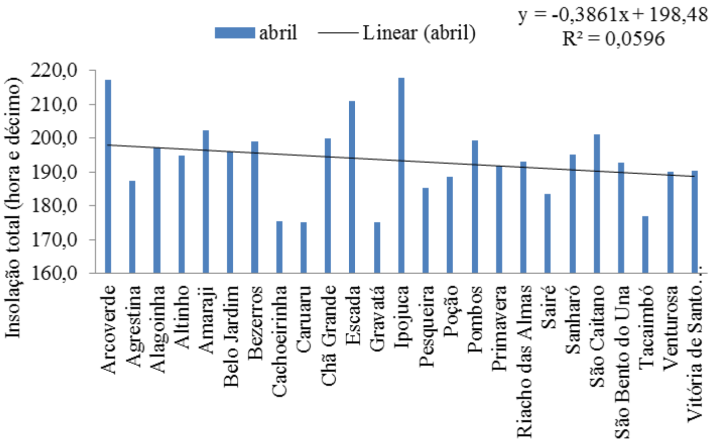
Figure 4 – Total heat stroke for the month of March and its trend line for the Hydrographic Basin of the Ipojuca River between 1962-2019.



Source: Medeiros et al. (2020).

In April, heatstroke fluctuations were recorded between 173.2 and 219.8 hours and tenths in the municipalities of Cachoeirinha, Caruaru and Gravatá. In the municipalities of Arcoverde and Ipojuca the total sunshine was 219.2 hours and tenths. Figure 5 shows a line with a negative slope and a low level of significance. These fluctuations are due to local effects, such as high cloud cover, aided by transient factors of meso and microscale.

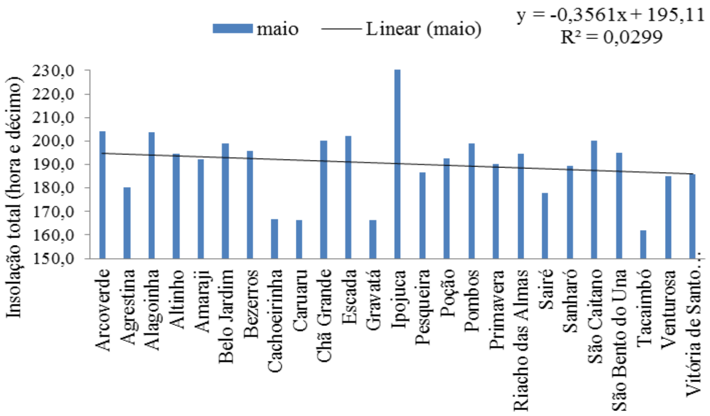
Figure 5 – Total heat stroke for the month of April and its trend line for the Ipojuca River Basin between 1962-2019.



Source: Medeiros et al. (2020).

In Figure 6, we observe the variability of total sunshine in May and its trend line for the hydrographic basin of the Ipojuca River. The trend line has a negative slope and a low level of significance R2. However, the hydrographic basin of the Ipojuca River has a very susceptible ratio over 12 months, which was referred to properly (1962 to 2019). In the municipalities of Cachoeirinha, Caruaru, Gravatá and Tacaimbó, there are low levels of insolation, in the municipalities of Arcoverde, Agrestina, Escada, Ipojuca and São Caetano, there are high incidences of insolation. The fluctuations in total sunshine in May fluctuated from 169.8 hours and tenths to 230 hours and tenths.

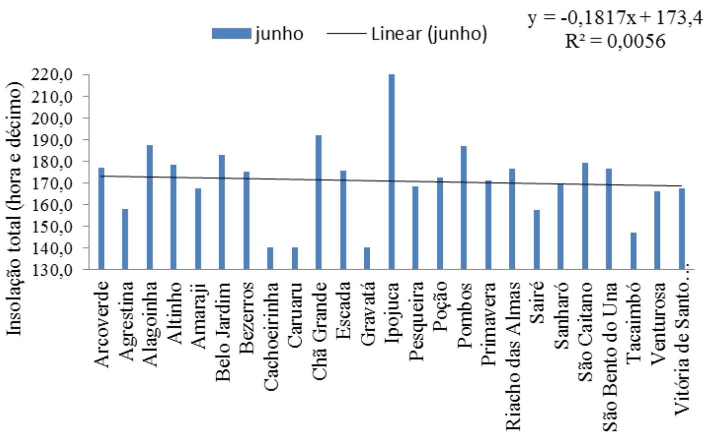
Figure 6 – Total heat stroke for the month of May and its trend line for the area of the Ipojuca River Basin between 1962-2019.



Source: Medeiros et al. (2020).

The fluctuations in total insolation rates occurred between 140 hours and tenths in the municipalities of Cachoeirinha, Caruaru, Gravatá and Tacaimbó at 220 hours and tenths in the municipality of Ipojuca, according to the monthly distribution shown in Figure 7. The month of June had a negative slope and R2 of low significance. It is important to note that previous studies have already proven this correlation coefficient to be directly proportional, that is, the higher the total insolation rate, the greater the fluctuation rate. Fluctuations in disordered heat stroke are caused by the transient factors of the atmospheric meso and microscale systems and by local and regional contributions according to the results of the study by Medeiros et al. (2018).

Figure 7 – Total heat stroke for the month of June and its trend line for the Ipojuca River Basin between 1962-2019.



Source: Medeiros et al. (2020).

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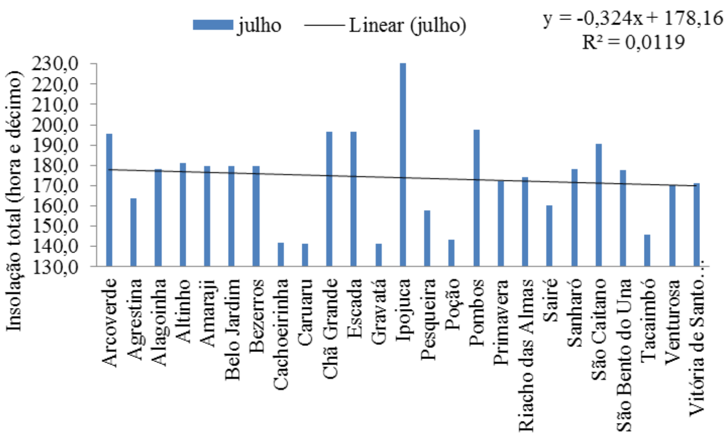
A trend line with negative slope and with no significant R2 characterizes the month of July (Figure 8). Total sunshine varied between 140 hours and tenths in the municipalities of Cachoeirinha, Caruaru, Gravatá, Poção and Tacaimbó to 230 hours and tenths in Ipojuca. Insolations varying from 191.1 to 198.3 in the municipalities of Arcoverde, Chã Grande, Escada and Pombos, show that the variables are directly proportional, when one increases the other increases.

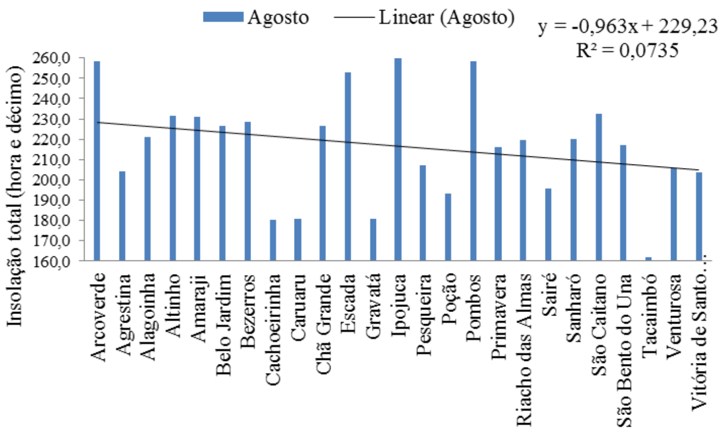
Figure 8 – Total heat stroke for the month of July and its trend line for the area of the Hydrographic Basin of the Ipojuca River between 1962-2019.



Source: Medeiros et al. (2020).

In Figure 9, the variability of the total insolation of the month of August and its oscillations that vary between 161.3 hours and tenths in the municipality of Tacaimbó to 260 hours and tenths in the municipalities of Arcoverde, Ipojuca and Pombos were obtained. The month of August is marked with a negative trend line and an insignificant R2, thus, there was a proportionality of the calculated values.

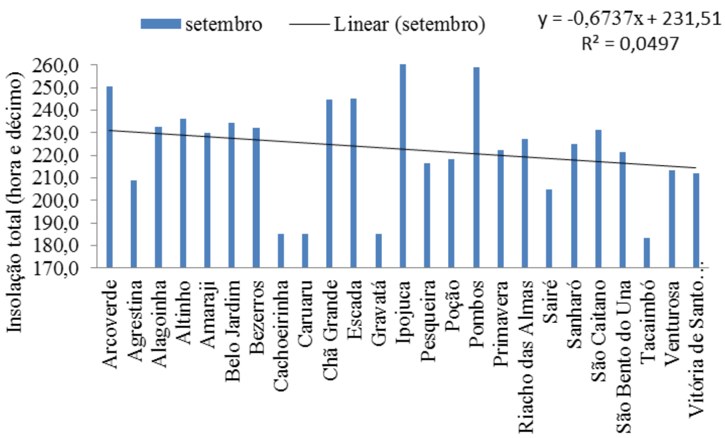
Figure 9 – Total heastroke for the month of August and its trend line for the area of the Hydrographic Basin of the Ipojuca River between 1962-2019.



Source: Medeiros et al. (2020).

The municipalities Cachoeirinha, Caruaru, Gravatá and Tacaimbó had the lowest insolation rates. In the municipalities of Arcoverde, Ipojuca and Pombos, the insolation values are high. The month of September (Figure 10) has an insignificant R2 and the trend line is negative, showing that in Brazil there is no proportionality, that is, a predictability regarding the studied variables. In need of investments in science and technology.

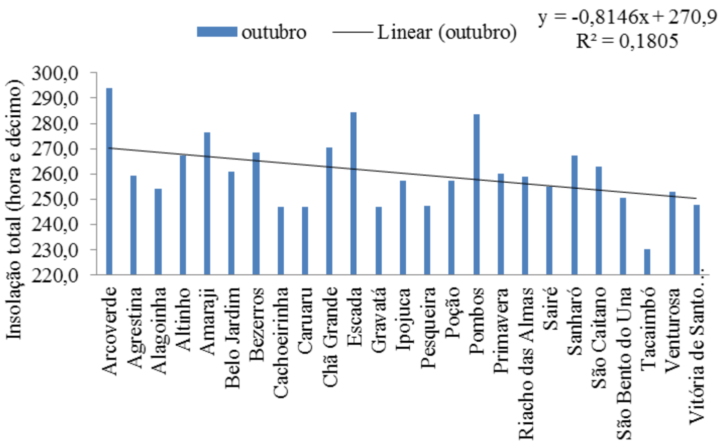
Figure 10 – Total heat stroke for the month of September and its trend line for the Ipojuca River Basin between 1962-2019.



Source: Medeiros et al. (2020).

The month of October (Figure 11) had insolation fluctuations that flow from 230 hours and tenths in Tacaimbó to 294.6 hours and tenths in the municipality of Arcoverde. The municipalities with high insolation are Arcoverde, Escada, Pombos and with low insolation Tacaimbó stands out. The negative trend line and a low R2 characterized the month of September. The months of October, with low cloud cover, allowing high rates of direct sunlight to pass through the soil surface, differentiate the months of October, November and December. The negative trend line and a low R2 characterized the month of September. The months of October, November and December were distinguished by low cloud coverings, allowing high rates of direct sunlight to pass through the soil surface, which could compromise the quality of life for people

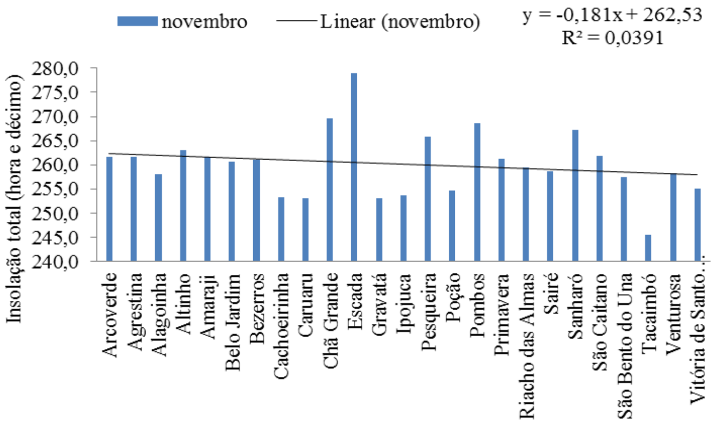
Figure 11 – Total heat stroke for the month of October and its trend line for the Ipojuca River Basin between 1962-2019.



Source: Medeiros et al. (2020).

In Figure 12, there were oscillations of total sunshine in November and its trend line with a negative and insignificant slope (R2). Insolation fluctuations flow between 243.2 hours and tenths in the municipality of Tacaimbó to 280 hours and tenths in the municipality of Escada. These variabilities are due to the transient meso and micro scale systems of the studied area.

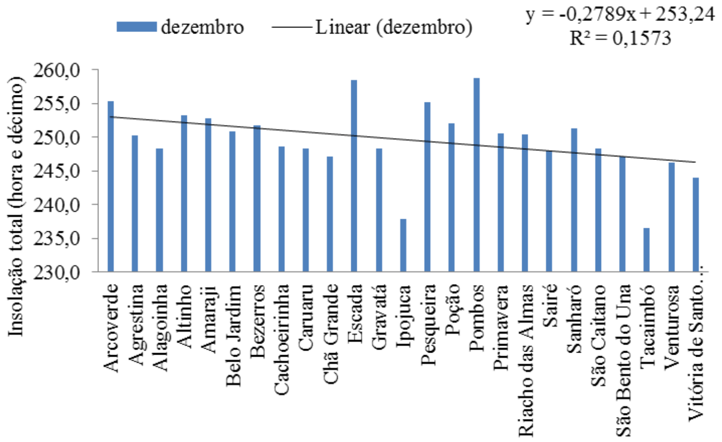
Figure 12 – Total heat stroke for the month of November and its trend line for the Hydrographic Basin of the Ipojuca River between 1962-2019.



Source: Medeiros et al. (2020).

The month of December (Figure 13) presents a negative trend line and R2 of moderate significance. Insolation fluctuations range from 236.1 hours and tenths in the municipality of Tacaimbó to 259.4 hours and tenths in the municipalities of Escada and Pombos. The moderate correlation coefficient confirmed that the regions are very close and, therefore, easy to move and with little travel time.

Figure 13 – Total heat stroke for December and its straight line to the Hydrographic Basin of the Ipojuca River between 1962-2019.

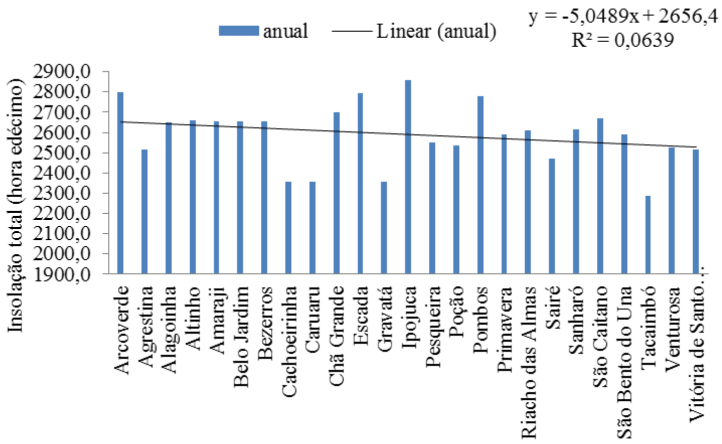


Source: Medeiros et al. (2020).

These fluctuations in the monthly insolation abundance are due to the meteorological conditions of those months, that is, due to the amount of cloudiness and not by the conditions of the astronomical photoperiod. In these periods, they are associated with the thermodynamic conditions of the South Atlantic Subtropical Anticyclone, of the Convergence Zones of the South Atlantic in the NEB region (Silva & Severo, 2012).

The total annual heat stroke and its trend line for BHRI are shown in Figure 14, with a negative trend line and an R^2 of 6.4 of significance, showing reductions in the studied variable. The municipalities of Arcoverde, Alagoinha, Altinho, Amaraji, Belo Jardim, Chã Grande, Escada, Ipojuca, Pombos and São Caetano had annual insolation rates above 2,693 hours and tenths, thus, a higher incidence of sunlight and consequent vulnerability to not reach the hydrical stress. The municipalities of Agrestina, Cachoeira, Caruaru, Gravata and Tacaimbó had heat stroke ranging from 2,395 to 2,398.8 hours and tenths.

Figure 14 – Total annual heat stroke and its trend line for the Ipojuca River Basin between 1962-2019.

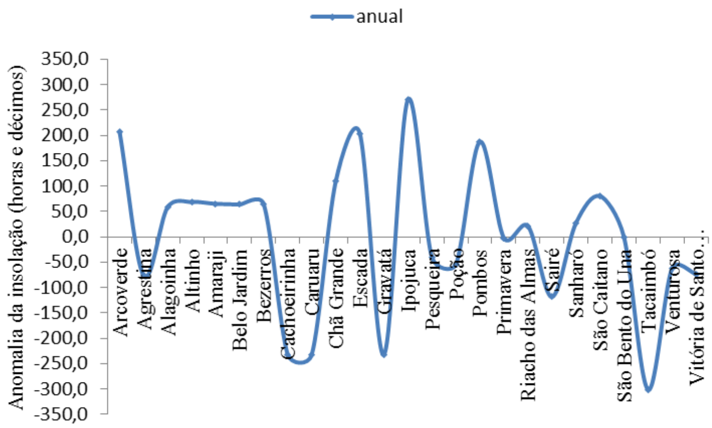


Source: Medeiros et al. (2020).

Silva et al. (2013) and Medeiros (2018) stated that the variability of cloud cover in the state of Piauí (PI) is conditioned by the elements that provide rain in the different areas of their rainfall regimes. In the months from April to September, cloud coverage in the southern region of the state of PI ranges from 26 to 45% in the central and northern regions of the study area, heat stroke flows from June to December, cloud coverage flows from 25 to 50%, consistent with the results obtained by Tubelis & Nascimento (1988). These results corroborate with the study under development.

The anomaly of the total annual heat stroke for the BHRI area is shown in Figure 15. The municipalities with positive anomalies oscillating between 48.2 hours and tenths (Riachão das Almas) and 2937 hours and tenth in the municipality of Ipojuca stood out. The municipalities: Alagoinha, Altinho, Amaraji, Belo Jardim and Bezerros had heat stroke anomaly of 62 hours and tenths. The indices of negative insolation anomalies ranged from 50.9 to 299.7 hours and tenths, the municipalities of Cachoeirinha, Gravatá and Tacaimbó stood out with the lowest negative indices, Pesqueira, Porção and Agrestina with high negative values due to geographical distance.

Figure 15 – Total annual heat stroke anomaly for the Ipojuca River Basin between 1962-2019.

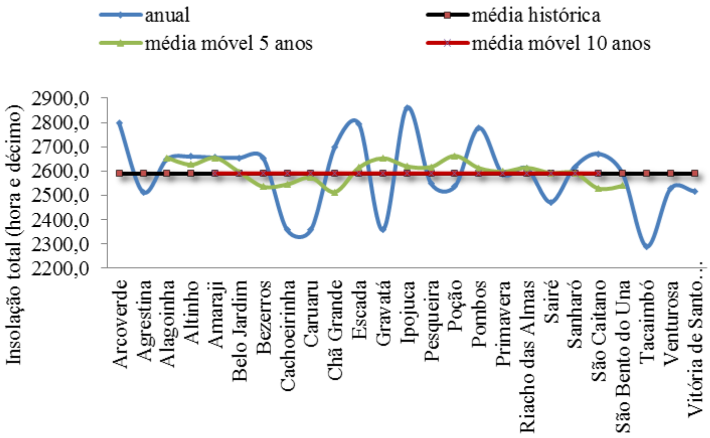


Source: Medeiros et al. (2020).

Figure 16 represents the heat stroke observed and estimated by the moving averages for 5 and 10 years, for the area under study. The observed insolation behavior follows the insolation estimates by the moving average in the studied period; the rhythm of the observed insolations is of reduction of amplitude and flatness between years. Estimates of 10 years moving averages show values of greater significance than for 5 years. Since, over the next 10 years, the insolation values will be equal to the annual average for the period 1962-2019.

Research, Society and Development, v. 9, n. 10, e5599108708, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i10.8708

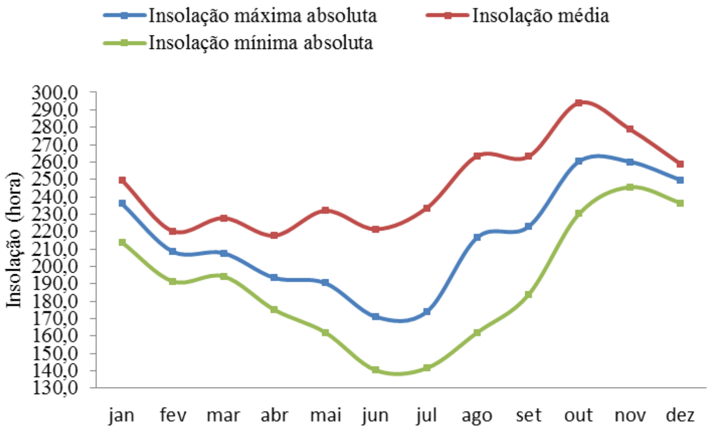
Figure 16 – Total annual heat stroke, historical average and its 5 and 10 years moving averages for the Ipojuca River Basin between 1962-2019.



Source: Medeiros et al. (2020).

Figure 17 covers the variations of maximum total, mean and absolute minimum heat stroke for the BHRI area. Maximum insolation flows between 217.7 hours and tenths in the month of April to 294 hours and tenths in the month of October. The maximum annual insolation recorded was 2860.6 hours and tenths. The record of annual minimum heat stroke is 2289.7 hours and tenths and with monthly heat stroke flowing between 140.3 hours and tenths in the month of June to 245.6 with monthly heat stroke flowing between 140.3 hours and tenths. The average annual sunstroke is 2590.8 hours and tenths, its monthly fluctuations vary between 171 hours and tenths in the month of June to 260.3 hours and tenths in the month of October. The oscillations of the sunstroke follow the behavior of the cloud cover, the variability of the rainy season and its aid of the transient factors of meso and micro scale.

Figure 17 – Total absolute maximum, mean and absolute minimum heat stroke for the Ipojuca River Basin between 1962-2019.



Source: Medeiros et al. (2020).

Table 2 shows that the best coefficients for determining the regression are R^2 = 0.1019 (January), R^2 = 0.1805 (October) and R^2 = 0.1573 (December). The worst coefficients for determining the regression were recorded in June (R^2 = 0.0056) and July (R^2 = 0.0119). Meaning that, when the value is higher, it indicates the degree of approximation of the model to the averages; already, when the value is lower, it indicates the degree of distance of the model to the averages. It is concluded that in the other months the model distances from the averages.

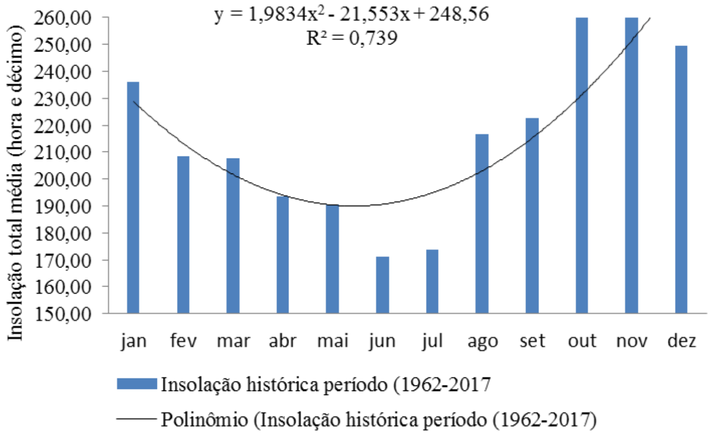
Table 2 – Linear equation, regression determination coefficient (R^2), monthly historical average and annual total heat stroke from 1962 to 2019.

Months	Linear equation	R2	Mean
January	y= -0,3959x+241,24	0.1019	236.1
February	y= -0,1823x+210,92	0.0382	208.5
March	y= -0,3115x+211,68	0.0733	207.6
April	y= -0,3861x+198,48	0.0596	193.4
May	y= -0,3561x+195,11	0.0299	190.4
June	y= -0,1817x+173,40	0.0056	171.0
July	y= -0,3240x+178,16	0.0119	173.9
August	y= -0,9630x+229,23	0.0735	216.7
September	y= -0,6737x+231,51	0.0497	222.7
October	y= -0,8146x+270,90	0.1805	260.3
November	y= -0,1810x+262,53	0.0391	260.1
December	y= -0,2789x+235,24	0.1573	249.6
Yearly	y= -5,0489x+2656,4	0.0639	2590.7

Source: Medeiros et al. (2020).

With positive angular coefficient and R^2 of high significance, the polynomial curve is increasing between the months of August and January and registered decreases between the months of February and July. It can be seen in Figure 18 that from October to December the highest average monthly insolation rates are concentrated, with an average value of the period of 770.1 hours and tenths corresponding to 30% of the annual insolation. Between February and August, there is 52% of the amount of annual heat stroke. The months with the lowest insolation rates fluctuated between September and January, which corresponded to 48% of the annual total, showing, over time, a spatial variability characteristic of the northeast region of Brazil, which evidences the data that should compose the historical series of the hydrographic basin of the Ipojuca River.

Figure 18 – Histogram with a correlation coefficient of R = 0.739, indicating that the variables are directly proportional and with moderate strength between them, in the phenomenology of the historical average heat stroke and polynomial tendency between 1962 to 2019 in the area of the Ipojuca river basin.



Source: Medeiros et al. (2020).

Table 3 showded the statistical parameters of total sunstroke for the area of the Ipojuca River basin. The annual average is 2590.8 hours and tenths and its monthly fluctuations vary between 171 tenths hours in the month of June to 260.3 hours and tenths in the month of October. The annual median is 2860.6 hours and tenths, with monthly fluctuations between 217.7 in April and 263.5 in August with hours and tenths. The probability of occurrence of the median values is of low insignificance, in view of its dispersion. The average values with the increase or reduction of the standard deviations can be registered or happen as stated by the authors Katz (1991) and Katz & Bronw (1992), who showed that the relative frequency of extreme events depends on the changes in the standard deviation and not only on the average. In which the mean is a stationary statistical measure and the measure of dispersion or variability allows bettering inferring about the phenomenon.

Table 3 – Statistical parameters of total heat stroke (hour and tenth) in the area of the Ipojuca River Basin.

Months	Mean	Median	Deviation Standard	Coefficient of Variance (%)	Absolute Maximum	Absolute Minimum
January	236.1	238.5	9.1	0.039	249.6	213.8
February	208.5	217.4	6.9	0.033	220.3	191.4
March	207.6	224.4	8.5	0.041	227.8	194.3
April	193.5	217.7	11.6	0.060	217.7	175.1
May	190.5	232.0	15.1	0.080	232.0	162.1
June	171.0	221.4	17.9	0.105	221.4	140.3
July	173.9	233.5	21.9	0.126	233.5	141.5
August	216.7	263.5	26.1	0.121	263.5	162.1
September	222,7	263,1	22.2	0.100	263.1	183.6
October	260.3	257.5	14.1	0.054	294.0	230.2
November	260.2	253.7	6.7	0.026	278.9	245.6
December	249.6	237.9	5.2	0.021	258.8	236.5
Yearly	2590.8	2860.6	147.0	0.057	2860.6	2289.7

Source: Medeiros et al. (2020).

The maximum and minimum absolute values have a return time between 3 and 5.5 years, to be repeated. These variabilities are linked to the meso and micro scale transient systems in the studied area.

According to Galvani (2011), the standard deviation is important to obtain information on the “degree of dispersion of the values in relation to the average value”. The coefficient of variance is used to make comparisons in relative terms and expresses “the variability of each data set normalized in relation to the average, in percentage”.

Extreme events of high magnitude and short time are expected to occur. As stated by Marengo et al. (2015), these results are in accordance with the study under development.

In panoramas of future changes caused by increased concentrations of gases in the atmosphere, it is assumed that only the mean can change, with the standard deviation unchanged according to Bem-Gai et al. (1998).

4. Final Consideration

Total sunstroke is greater than the cloud coverage in the period from August to March, totaling 1861.8 hours and tenths, while in the same period, the cloud coverage is 0.45 tenths. Low cloud cover, temperature fluctuations and low or no ground cover conditions these incidences of insolation rates above normal.

The importance of heat stroke is verified for purposes of applicability in the agricultural sectors, energy generations, aiming at helping industrial parks, energy distributors, agricultural sector and climatic studies that are scarce or widespread.

It is observed that the deviations are positive, showing increases in the monthly and annual values, even though the straight line trends show us insignificant reductions for the period studied.

The study provides a tool for planning and actions aimed at the best way to implement solar parks, using the systems that influence the high and low values of the insolation recorded, in terms of strategic planning for Brazil and the planet.

The hydrographic basin of the Ipojuca River has excellent heat stroke values for generating renewable energy and reducing air pollutants.

Comparing the values obtained in this article with the values of the Solarimetric Atlas of Brazil, we can see a good similarity of the recorded data.

The municipalities Cachoeirinha, Caruaru, Tacaimbó, Sairé, Poção, Pesqueira and Gravata had the lowest insolation rates. The municipalities Arcoverde, Alagoinha, Escada, Ipojuca, Pesqueira, Poção, Pigeons, São Caitano and Chã Grande registered the greatest buoyancies in total sunstroke during the period studied.

The trend lines of the respective 12 months are negative and without insignificance, agreeing with the calculations of the moving averages, stating that there has been a reduction in insolation in the next 9 years, and after 10 years the insolation rates return to the level of the historical average.

In addition, the results obtained in this study provide subsidies for decision making, with regard to the use of the territory of the Ipojuca River Basin (agricultural use, use of water resources and generation of renewable energy) and full improvement of people's quality of life.

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