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INVESTIGATION OF THE EFFECT OF WEATHER CONDITIONS ON SOLAR ENERGY IN RIVERS STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY, PORT HARCOURT, NIGERIA

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ABSTRACT
This study presents the effect of temperature, relative humidity, rainfall and evaporation on solar energy in Port Harcourt City, Nigeria. The data was recorded every 5 minutes daily and monthly, covering 2008 – 2014, in The Rivers State University of Science and Technology, Port Harcourt Meteorological Logging Unit. The MATLAB software used in the analysis of the data reveal a direct relationship between solar radiation and temperature and evaporation, and an inverse relationship with rainfall and relative humidity. The mean atmospheric temperature is 26.02°C, while solar energy varies between 47.07 mJm^{-2} month^{-1} and 113.99 mJm^{-2}month^{-1} with a mean of 87.87 mJm^{-2}month^{-1}. During the rainy season (April – September), the mean monthly solar energy is 86.69mJm^{-2}month^{-1}, while in the dry season (October – March), the mean is 89.05mJm^{-2}month^{-1}. The amount of evaporation per temperature ranges from 2.92 mm/°C to 4.47 mm/°C with a mean annual of 3.57 mm/°C. In the rainy season, this value varies from 2.79 mm/°C to 3.79 mm/°C. In the dry season months, the variation is from 3.12 mm/°C to 4.47 mm/°C. The rainfall-to-evaporation ratio of 5.71 in rainy month demonstrates that about the amount of rainfall is recorded for the amount of water evaporated. This correlates with the fact that humidity is high. The results of this work could be used in the design and construction of solar energy technologies to provide energy. Moreover, the results could also provide input for climate risk information, local and national planning and decision-making for sustainable development in the areas of agriculture, aviation, health, and weather forecasting.

Keywords: Solar energy, Temperature, Relative humidity, Rainfall, Evaporation, Solar panel, Port Harcourt City, Nigeria.

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1. INTRODUCTION

Energy is the motivating force behind the sustained technological development of any nation. Solar energy is now considered to be the most effective and economical of the alternative energy source [1]. The knowledge of the patterns of solar radiation is very vital in our contemporary world since the use of solar energy has become an integral part of energy source. Different researchers have explored the area of the variability of solar radiation with weather parameters such as temperature, humidity, rainfall etc. and also its variation with latitudes. Yazdani, et al. [2] in their investigation of effect of weather conditions on solar radiation in Brunei Darusaalam found that solar radiation is directly proportional to atmospheric temperature while it is inversely proportional to relative humidity. Also, Trabea and Mosalam [3] confirmed that there is correlation of global solar radiation with weather conditions. Low relative humidity leads to increase in solar flux, thus enhancing output current and improving efficiency of solar panel in Port Harcourt city of Niger Delta [4].

The Rivers State University of Science and Technology (RSUST) Metrological Station was donated by The Centre for Climatic Research, Delaware, United States and The Nigerian Environmental Climatic Observing Program (NECOP) is being executed in collaboration with The Centre for Basic Space Science (CBSS), University

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of Nigeria, Nsukka, Nigeria. In our research we investigated the influence of weather conditions of temperature, relative humidity, rainfall and evaporation on the amount of solar energy received in the study area Port Harcourt.

Precise knowledge of the global solar radiation at a location of study is required for the design and estimation of the performance of any solar energy system [5]. Therefore the result of this work can be used in the design and construction of solar energy for the RSUST and Port Harcourt city at large. Moreover, the results possibly can also offer input for climate risk information for local and national planning and decision-making for sustainable development in the areas of agriculture, aviation, health, weather forecasting [6].

1.1. The Area of Study

The study area is Rivers State University of Science and Technology is in Port Harcourt City, Nigeria (Figures 1 and 2). The City is a coastal city located in Niger Delta region of Nigeria within latitudes 6°58' – 8°00' E and longitudes 4°40' – 4°55'. Niger Delta is one of the largest wetlands of the world. Its total land area is approximately over 2900km^2 [7]. The monthly rainfall in Port Harcourt follows a sequence of increase from March to October before decreasing in the dry season months of November to February [8]. Rainfall in Port Harcourt exhibits double maxima regime with peaks in July and September. Port Harcourt does experience mostly two weeks window of little or no rain within July and August otherwise described as "August break" though the time of occurrence varies from year to year. Temperature in Port Harcourt is low at night and high in the day as a result of the external heat supply by the sun.

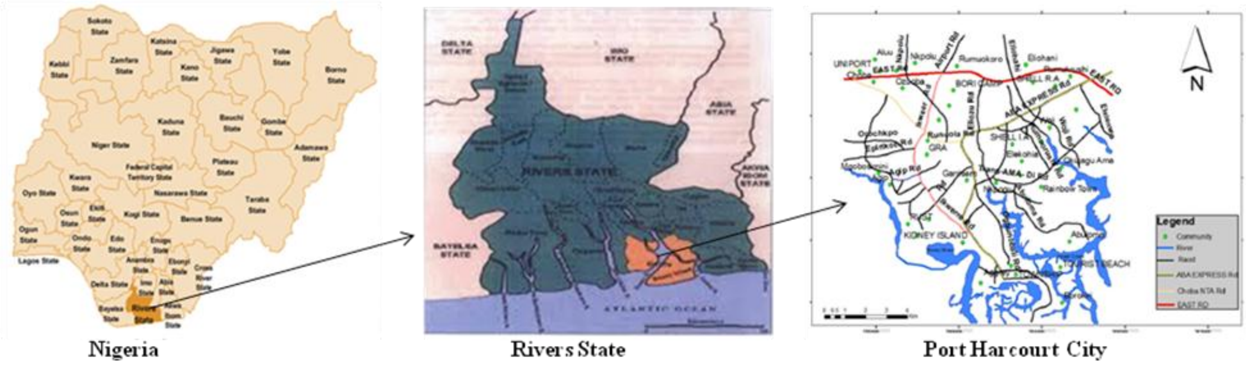

Figure-1. Map of Nigeria showing Rivers State and Port Harcourt City [9]

Figure-2. Aerial view of RSUST showing Meteorological Garden: Photo by E. Uko

2. METHODOLOGY

The Rivers State University of Science and Technology (RSUST), Port Harcourt Meteorological Station (Figure 2) is built up with meteorological weather Decoder equipped with sensors, solar power system for uninterruptible power supply, measurement and control system and the data logging system. The Station is a fully computerized real-time data analysis system. This has aided the precision, accuracy and performance of the associated devices. The entire setup contains rain gauge, barometer, wind vane/speedometer, maximum and minimum thermometer, solar panel, Pyranometer, and hygrometer. The Decoder houses the power backup, the measurement control device, sensor interfacing and data logging units, the pressure sensor and the wireless telemetry device. The suit of the data was recorded continuously every 5 minutes daily throughout the years. The data was downloaded into the laptop computer for analysis. The weather data of interest used in this study are rainfall, humidity, temperature, solar energy, and evaporation. Daily averages are computed into monthly averages from which yearly patterns are derived. The variables were cross-plotted against months of the year; for the seven (7) years period (2008 – 2014) under review.

3. RESULTS AND DISCUSSION

3.1. Temperature and Solar Energy

The monthly and yearly average temperatures are presented in Table 1 and Figure 3. During the dry season (October – March), the average temperature in RSUST ranged between 26.48 – 27.79^oC and in rainy season (April – September), the average monthly temperature ranged 25.01 – 27.15^o. Temperature in Rivers State University of Science and Technology (RSUST) is low at night and high in the day as a result of the external heat supply by the sun.

In rainy season (April – September), monthly Solar energy mean is 83.75mJm^{-2} month^{-1}, while in dry season (October – March) mean monthly is 102.86 mJm^{-2} month^{-1}. Solar energy has its maximum in May (113.35 mJm^{-2}month^{-1}) and minimum in September (47.07 mJm^{-2} month^{-1}), this corresponds with Olatona and Adegoke [10] result that the amount of solar radiation and actual sun shine hours reaching the surface, has its maximum of 16.1mJm^{-2} day^{-1} in May and the minimum of 10.7mJm-^{2}day^{-1} occurred in August. Moreover, the Pearson Product moment correlation coefficient for temperature with Solar Radiation gives r = 0.48; this implies that there is a direct positive relationship between solar radiation.

3.2. Rainfall and Solar Energy

The monthly rainfall in RSUST follows a sequence of increase from March to October before decreasing in the dry season months of November to February, Table 1 and Figure 5. Annual average rainfall amount of 203.03mm was recorded in the region, Figure 4; Rainfall in RSUST exhibits double maxima regime with peaks in July and September. RSUST does experience mostly two weeks window of little or no rain within July and August otherwise described as “August break” though the actual time of happening varies from year to year. It is observed in the area of study over the years (2008 – 2014); an increasing daily amount of rainfall. Solar energy varies between 47.07 mJm^{-2}month^{-1} and 113.99 mJm^{-2}month^{-1}; with the mean of 87.87 mJm^{-2}month^{-1}. In rainy season months of April – September, mean monthly solar energy is 86.69mJm^{-2}month^{-1}, while in the dry season monthly mean is 89.05mJm^{-2}month^{-1}.

Also, the Pearson product moment correlation coefficient(r) for Rainfall gives, r = - 0.460. This indicates an inverse relationship between solar radiation and rainfall. This is expected because during rainy season, since there is little or no sunshine in the location of the study.

3.3. Humidity, Evaporation and Solar Energy

The mean monthly temperature (26.02^oC) of the area is enough to cause substantial monthly evaporation (93.30mm) of water to saturate (monthly maximum humidity = 93.30%) the atmosphere with water vapour that in turn condenses and precipitates as monthly rain (203.03mm). In dry season, evaporation exceeds precipitation [Table 1 and Figure 5]. High humidity is followed by low temperature and lower solar radiation values [Figures 5 and 6]. These results are in agreement with Ettah, et al. [11] that increase in solar flux is observed when relative humidity is low.

In rainy season, humidity varies between 73.66 and 82.48mm with mean of 78.06mm. In dry season, humidity varies between 68.06% and 79.46% with mean of 73.25%. These values correlate with solar energy within the same period. Solar energy varies between 47.07 and 113.99 $mJm^{-2}day^{-1}$ with annual mean of 87.87 $mJm^{-2}day^{-1}$. In rainy season months of April – September, mean monthly solar energy is 86.69$mJm^{-2}day^{-1}$, while in the dry season monthly mean is 89.05$mJm^{-2}day^{-1}$. The higher the humidity, the lower the solar energy reaching the Earth. Finally, the Pearson product Moment coefficient for humidity, r = -0.375. This shows an inverse relationship with the solar energy.

Table-1. Mean monthly values of weather parameters for RSUST, Port Harcourt (2008-2014)

Month	Solar Radiation ($mJm^{-2}month^{-1}$)	Atmospheric Temperature (°C)	Relative Humidity (%)	Rainfall (mm)	Rainfall-Evaporation Ratio	Evaporation (mm)	Evaporation-Temperature Ratio (mm/°C)
January	106.08	27.16	68.06	19.06	0.16	114.80	4.23
February	113.99	27.79	70.35	45.75	0.38	119.85	4.31
March	111.04	26.93	76.12	141.43	1.18	120.32	4.47
April	111.35	25.08	77.33	154.9	1.63	95.15	3.79
May	113.35	27.15	73.66	209.81	2.11	99.56	3.67
June	88.05	23.75	76.51	222.39	2.71	81.93	3.45
July	83.26	25.77	81.78	460.22	5.71	80.53	3.12
August	77.03	25.01	82.48	361.7	4.95	73.10	2.92
September	47.07	23.32	76.56	361.44	5.01	72.21	3.10
October	54.50	26.48	79.455	293.98	3.55	82.76	3.12
November	87.14	27.12	73.825	142.71	1.64	87.12	3.21
December	61.53	26.68	71.66	22.94	0.25	92.29	3.46
Mean	**87.87**	**26.02**	**75.65**	**203.03**	**2.18**	**93.30**	**3.57**

Source: Avearge monthly Data downloaded from the Meteorological Decoder

Table 1 shows the mean monthly values of solar radiation, atmospheric temperature, rainfall, relative humidity and evaporation data collected at the Rivers State university of Science and Technology, Port Harcourt for a period of 7 years (2008-2014).

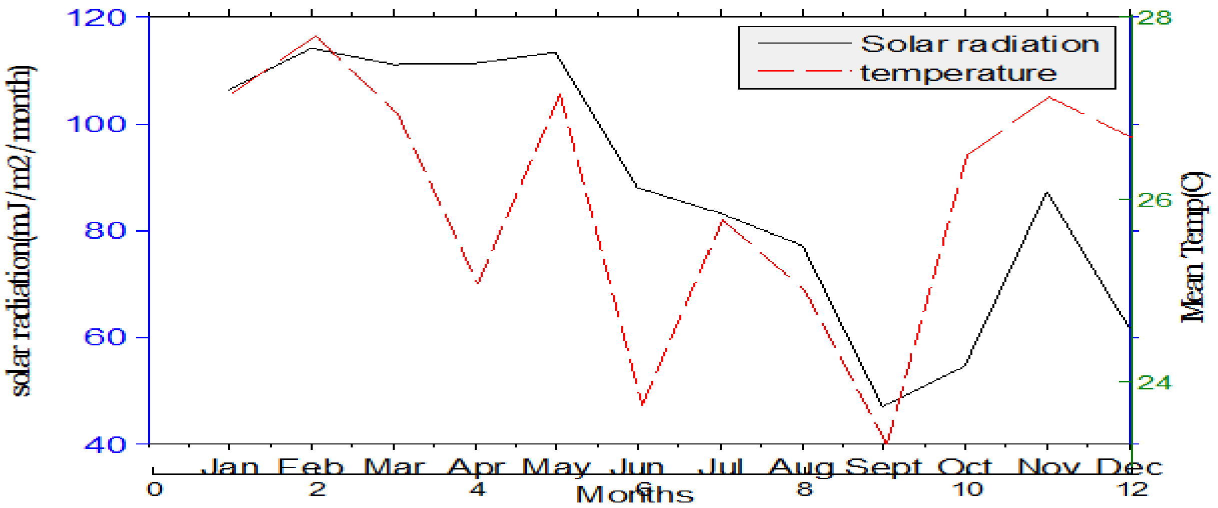

Figure-3. Solar energy-Temperature profile

Source: The cross-plot of the downloaded data

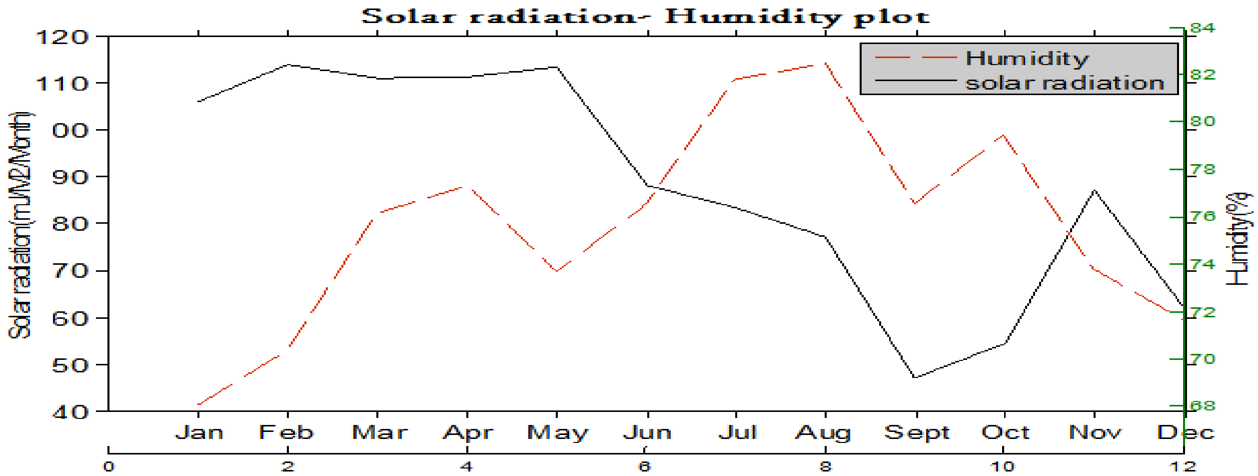

Figure-4. Solar energy-Humidity profile

Source: The cross-plot of the downloaded data

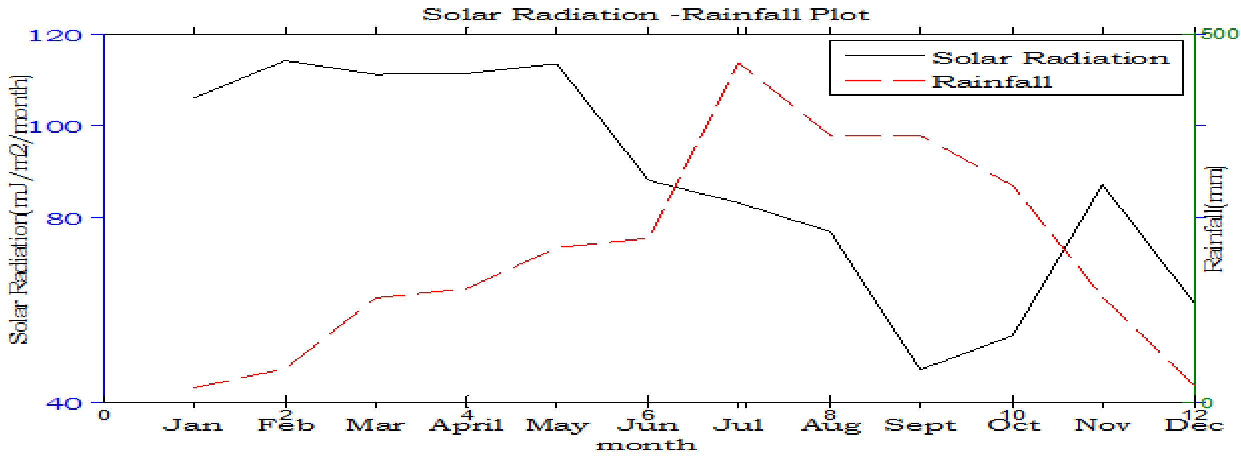

Figure-5. Solar energy-Rainfall profile

Source: The cross-plot of the downloaded data

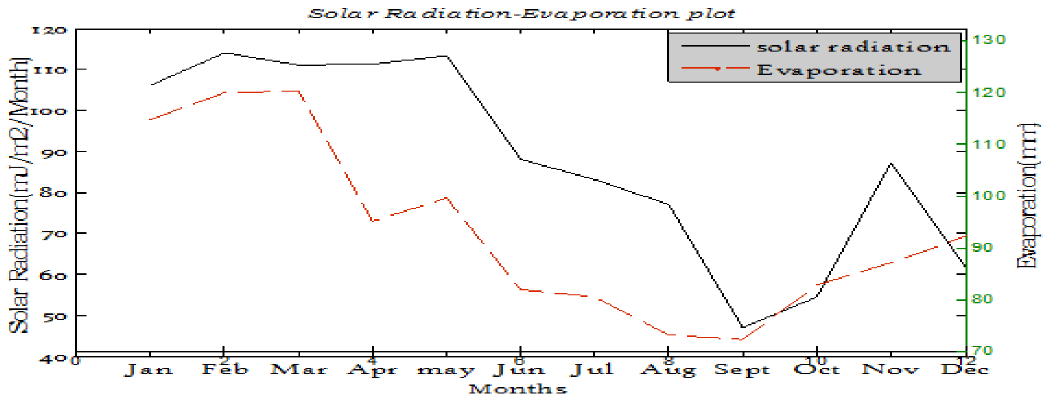

Figure-6. Solar energy-Evaporationprofile

Source: The cross-plot of the downloaded data

Table-2. The Pearson product moment correlation coefficient value of the weather parameters with solar radiation in RSUST, Port Harcourt

Weather parameter	Correlation coefficient (r)	Remark
Temperature	0.480	Positive correlation
Rainfall	-0.460	Negative correlation
Humidity	-0.375	Negative correlation
Evaporation	0.757	Positive correlation

Source: The computed Pearson product moment correlation coefficient (r) on the Weather parameters

3.4. Evaporation/Temperature and Rainfall/Evaporation Ratios

The amount of evaporation per temperature ranges from 2.92 mm/°C to 4.47 mm/°C with a mean annual of 3.57 mm/°C (Figure 7). In the rainy season, this quantity varies from 2.79 mm/°C (August) to 3.79 mm/°C in April. In the dry season months, the variation is from 3.12 mm/°C (October) beginning of dry season to 4.47 mm/°C in March the end of dry season.

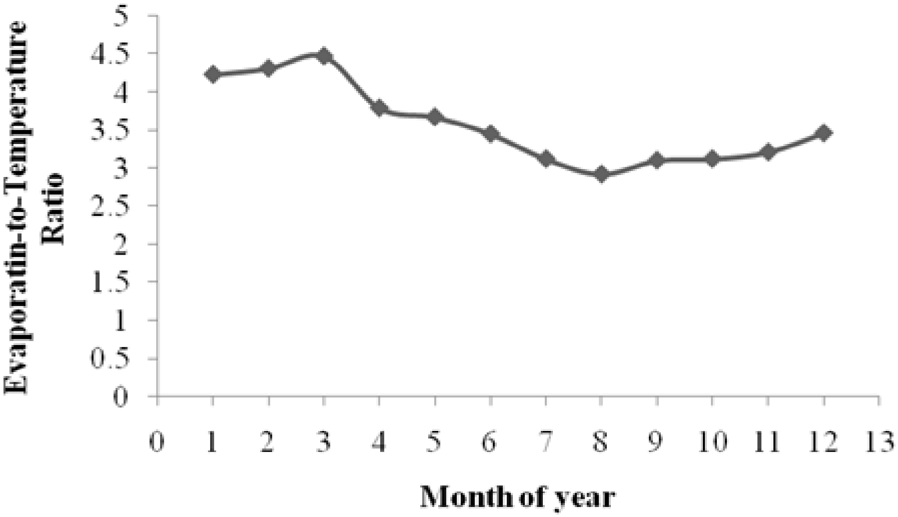

Figure-7. Rainfall-to-Temperature Ratio profile
Source: Computed from Evaporation, Temperature and Monthly data from Table-1.

3.5. Evaporation Ratios

The amount of rainfall with evaporation are also compared (Figure 8). The months of January, February and December which have the least amount of rainfall have the lowest rainfall-to-evaporation ratios of 1.61, 3.89, and 2.49 respectively. The rainfall-to-evaporation ratio ranges from 1.61 in January to 5.71 in July with an annual average of 2.18 which shows that about twice the amount of rainfall is recorded for the amount of water evaporated. This correlates with the fact that humidity is high.

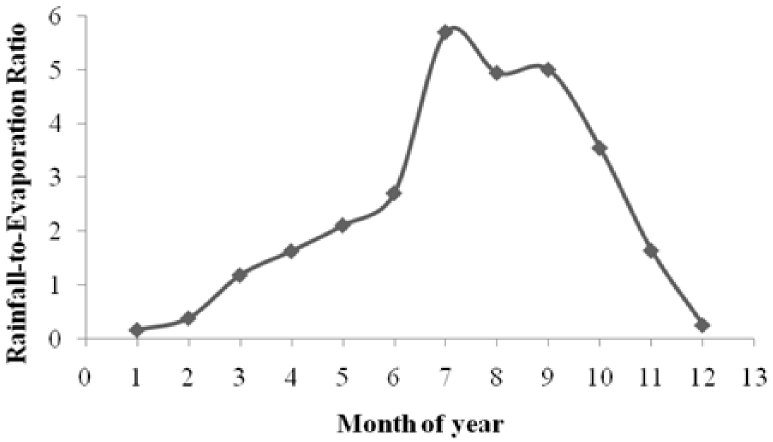

Figure-8. Rainfall-to-Evaporation Ratio profile

4. CONCLUSION

From the results of the research, the following conclusions are drawn for the study area:

Solar energy varies between 47.07 and 113.99 $mJm^{-2}month^{-1}$ with annual mean of 87.87 $mJm^{-2}month^{-1}$. In rainy season months of April – September, the monthly mean value of solar energy is low with value of 86.69$mJm^{-2}day^{-1}$, while in the dry season monthly mean is high with 89.05$mJm^{-2}day^{-1}$. The observed mean annual humidity is 75.65%

correlates well with the rainfall-to-evaporation ratio of 2.17 and the mean evaporation-to-temperature of 3.57mm/°C. The high levels of humidity, rainfall-to-evaporation ration and evaporation per unit atmospheric temperature indicates that the amount of available solar energy depends on the amount of rainfall, humidity and the atmospheric temperature. The amount of evaporation per temperature ranges from 2.92 mm/°C to 4.47 m/°C with a mean annual of 3.57 mm/°C (Figure 8). In the rainy season, this quantity varies from 2.79 mm/°C (August) to 3.79 mm/°C in April. In the dry season months, the variation is from 3.12 mm/°C (October) beginning of dry season to 4.47 mm/°C in March the end of dry season. February and December which have the least amount of rainfall have the lowest rainfall-to-evaporation ratios of 1.61, 3.89, and 2.49 respectively. The rainfall-to-evaporation ratio ranges from 1.61 in January to 5.71 in July with an annual average of 2.18 which shows that about twice the amount of rainfall is recorded for the amount of water evaporated. This correlates with the fact that humidity is high. In general, the results show that weather parameters exert both positive and negative effects on the solar radiation received in RSUST Port Harcourt, Nigeria. The correlation analysis of solar radiation shows a positive relationship with temperature and evaporation; which implies that as temperature and evaporation increases, solar radiation also increases and vice versa. Also, from our results we deduced that solar energy decreases as relative humidity and high rainfall increases; this indicates that relative humidity and rainfall have negative effect on the output of solar energy; which in turn limits the efficiency of solar Panels. Thus, in designing a solar panel for RSUST and Port Harcourt at large; these factors should be put into consideration.

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