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A CRITICAL STUDY OF ESTIMATION OF GLOBAL SOLAR RADIATION AND SOLAR ENERGY POTENTIAL

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ABSTRACT

For solar energy applications including solar photovoltaic technology, solar thermal systems, and passive solar designs, solar radiation data is a vital input. For the design, development, and performance assessment of solar technologies for any specific geographic area, solar radiation data should be current, trustworthy, and easily accessible. Applications for solar energy demand thorough understanding and a thorough assessment of the possibilities of the site. As a result, ground-level measurement is a crucial component of solar energy conversion systems. This data can be acquired from a variety of data sources, such as satellite data or measurements made on the ground using pyranometers or reference cells. The best technique to determine the amount of solar radiation is to place pyranometers at numerous points throughout the region in question, and to take care of their daily upkeep and data collection. To create a trustworthy database, a thorough quality control is required when measurements are recorded.

KEY WORDS: Global, Solar, Solar Thermal Systems Radiation and Solar Energy.

INTRODUCTION

The main and essential prerequisite for solar energy installations in any place within the state is solar radiation data. As a result, it's also essential to examine the climatic factors that affect solar radiation on a worldwide scale. Based on variations in geographic angles like latitude and longitude as well as other climatic factors like wind, dust, air temperature, and air pressure, the solar radiation intensity at any site varies throughout the year.

The amount of solar energy that reaches the earth's surface depends on its location, orientation, time of day, season, and atmospheric makeup [1]. As a result, there are large temporal and spatial variations in solar radiation. The earth's rotation around its own axis, which alters the angle at which solar radiation strikes the surface, is what causes the diurnal cycle. Seasonal variations in day duration and sun elevation angle are brought on by the earth's orbit around the sun and its axial tilt with respect to the orbital plane [2]. The latitude of a site also affects the length of the day and the sun's elevation angle there. The solar radiation that reaches the top of the atmosphere can be calculated for any location and time by taking into account these regular (diurnal and seasonal) variations in the earth-sun geometry and the solar constant. Extraterrestrial radiation is another name for the radiation that is present at the top of the atmosphere.

The only elements affecting solar radiation in the absence of an atmosphere would be the slope and aspect of the land. However, the solar energy that the earth's surface receives is strongly influenced by the atmosphere, leading to fluctuation. Since clouds have the ability to reflect a sizable portion of incoming radiation, they are mostly to blame for the great variability in the atmospheric transmissivity.

Agriculture, ecology, biodiversity, hydrology, meteorology, and climatology are just a few of the scientific and practical sectors that benefit from location-specific time series of reliable solar radiation data. The design, performance prediction, and monitoring of solar energy systems all depend on solar radiation [3, 4]. The primary goal of this work is to acquire precise estimates of solar radiation that may be used to boost solar thermal and photovoltaic device performance.

For areas where solar radiation cannot be measured directly, a number of techniques have been devised to estimate it. Assigning measured values from a nearby station or using spatial interpolation techniques is the easiest solution. However, the density of measurements of solar radiation is frequently insufficient for accurate interpolation. Modeling solar radiation is an alternative strategy that is not relied on measurements of solar radiation at adjacent stations [5]. For more than 30 years, satellite measurements have also offered a different way to calculate solar radiation. However, if the equipment is properly maintained and periodically calibrated, direct measurements of solar radiation are the most accurate source of data on solar radiation [6]. In order to identify solar hotspots for the construction of solar photovoltaic and solar thermal power plants, solar radiation was studied at six different places in Tamil Nadu.

RESEARCH METHODOLOGY

STUDY AREA

For the measurements of the worldwide sun radiation, six cities in Tamilnadu were taken into account. For a whole year, data on solar radiation were continuously gathered in these six cities.

CHENNAI (LOCATION 1)

The capital of Tamil Nadu is Chennai, previously Madras. It is one of the largest cultural, commercial, and educational hubs in South India and is situated on the Coromandel Coast, off the Bay of Bengal.

MADURAI (LOCATION 2)

Tamil Nadu's capital city is Madurai. It serves as the district's administrative center. The 25th most populous city in India is Madurai, which is also the second most populous city in Tamil Nadu.

ERODE (LOCATION 3)

Erode, the administrative center of the Erode District, is the seventh-largest urban agglomeration in Tamil Nadu. The coordinates of Erode are 11.21°N 77.44°E.

TIRUCHIRAPPALLI (LOCATION 4)

The administrative center of the Tiruchirappalli District is located in Tiruchirappalli. It is also the state's fourth-largest urban agglomeration and fourth-largest municipal corporation.

RAMANATHAPURAM (LOCATION 5)

In Tamil Nadu's Ramanathapuram district, there are two municipalities: Ramanathapuram and Ramnad. It is the second-largest town in Ramanathapuram district (by population) and the administrative center of the district.

TIRUNELVELI (LOCATION 6)

Tirunelveli, sometimes referred to as Nellai, is where the Tirunelveli District's administrative center is located. It ranks as the state's sixth-largest municipal corporation.

GEOGRAPHICAL FEATURES OF THE LOCATIONS IN TAMIL NADU

Tamil Nadu, one of India's two most southern states, is located between latitudes 8 N and 13 N and longitudes 76 E and 81 E. Table -1 provides the latitude and longitude of the various study locations. As can be observed, the several places' latitudes range from 8.72 N to 13.09 N and their longitudes from 77.73 E to 80.28 E. From 3 meters in Ramanathapuram to 184 meters in Erode, the altitude varies.

Table-1Geographical features of the locations under study

Location	Latitude (N)°	Longitude (E)°	Altitude (m)
Location 1	13.09	80.28	6.8
Location 2	9.93	78.13	102
Location 3	11.35	77.73	184
Location 4	10.80	78.71	86
Location 5	9.42	78.71	3
Location 6	8.72	77.77	48

RESULTS AND DISCUSSION

GLOBAL SOLAR RADIATION AND CLIMATIC DATA AT LOCATION 1

During the winter, Location 1 receives global solar radiation in the range of 3.7 to 5.7 kWh/m2, during the pre-monsoon, 6.3 to 6.6 kWh/m2, during the south-west monsoon, and during the post-monsoon, 4.7 to 5.4 kWh/m2. The climate here is tropical wet and dry. Extreme seasonal temperature variance is avoided because the city is located along the coast and on the thermal equator. Late May to early June is the hottest time of the year, with highs of 40 to 42 degrees Celsius. The coldest months of the year are December and January, when lows range from 19 to 20 degrees Celsius. About 25.3 mm of rain falls on average per year. The north-east monsoon winds, which blow from mid-October to mid-December, are responsible for the majority of the region's seasonal rainfall. In November, 252.0 mm is the highest value ever recorded. The observed average relative humidity varies from 64% in the south-west monsoon to 89% in the north-east monsoon. In this area, the predominant winds are southwesterly from April to October and northeasterly the rest of the year. In November, the average wind speed is 2.0 m/s, whereas in June, it is 4.5 m/s. Between 1004 mbar during the south west monsoon and 1014 mbar during the winter, the air pressure changes.

Table 2 Global solar radiation and climatic data of Location 1

Season	Month	Global Solar Radiation ($kWh/m^2/day$)	Ambient Temperature (°C)	Relative humidity (%)	Wind speed (m/s)	Atmospheric pressure (mbar)	Precipitation (mm)
Winter	January	4.5	25.3	77	2.9	1014	3.0
	February	5.7	26.1	73	2.9	1013	0.0
Pre monsoon	March	6.6	29.5	72	3.5	1012	0.0
	April	6.6	30.4	73	3.4	1009	104.0
	May	6.3	32.0	70	3.8	1006	12.0
South-west monsoon	June	5.4	32.2	64	4.5	1004	23.8
	July	4.8	31.6	64	3.2	1005	54.0
	August	5.1	30.7	72	3.1	1007	61.2
	September	4.8	30.5	73	2.5	1007	23.0
Post monsoon	October	4.1	29.8	80	2.5	1010	25.0
	November	3.8	27.9	89	2.0	1010	252.0
	December	3.7	27.0	79	2.8	1013	34.5

Global solar radiation and climatic data in Location 2

Location 2 receives 4.8 to 6.2 kWh/m2 of global solar radiation in the winter, 6.0 to 6.6 kWh/m2 in the pre-monsoon, 4.8 to 5.5 kWh/m2 in the south-west monsoon, and 4.2 to 5.6 kWh/m2 in the post-monsoon. Nearly eight months of the year are hot and dry in this area. During the months of January and February, there are chilly winds. The summer's warmest months are March through July. The area receives a slightly cooler environment from November to February and a moderate climate from August to October, which is mitigated by heavy rain and thundershowers. Although temperatures as high as 42 °C are not unusual, summertime temperatures typically range from 25 °C to 40 °C. Wintertime lows range from 18 to 31 degrees Celsius. Dew and fog are uncommon; they only happen in the winter. Due to its proximity to both the sea and mountains, it experiences both the Northeast and Southwest monsoons, with the former bringing greater rain from October to December. The largest amount of rainfall, 377.9 mm, was recorded in the month of November. The average yearly rainfall for this site is approximately 64.6 mm. During the north-east monsoon, the relative humidity increases from 53% in the winter to 85%. During the south west monsoon, the air pressure is 1007 mbar, but in the winter, it is 1013 mbar.

Table- 3 Global solar radiation and climatic data of Location 2

Season	Month	Global Solar Radiation (kWh/m^2/day)	Ambient Temperature (C) °	Relative humidity (%)	Wind speed (m/s)	Atmospheric pressure (mbar)	Precipitation (mm)
Winter	January	5.1	26.4	71	1.4	1013	3.5
	February	6.2	27.2	64	3.1	1013	18.8
Pre monsoon	March	6.6	30.0	61	2.7	1012	174.0
	April	6.1	31.5	65	3.1	1009	161.2
	May	6.3	31.3	69	4.3	1007	122.0
South-west monsoon	June	5.2	31.6	61	4.2	1006	18.7
	July	4.8	32.1	53	3.9	1006	6.9
	August	5.5	31.8	59	3.3	1008	43.0
	September	5.6	31.6	61	2.7	1008	139.7
Post monsoon	October	4.9	28.9	77	2.4	1010	240.1
	November	4.3	26.2	85	2.7	1010	377.9
	December	4.7	26.1	82	2.8	1013	246.0

GLOBAL SOLAR RADIATION AND CLIMATIC DATA IN LOCATION 3

Location 3 receives 3.9 to 6.1 kWh/m2 of global solar radiation in the winter, 4.8 to 6.6 kWh/m2 in the pre-monsoon, 3.0 to 4.1 kWh/m2 in the south-west monsoon, and 2.1 to 4.3 kWh/m2 in the post-monsoon. The climate in this area is hot and dry all year round. Although the Palghat Gap in the Western Ghats has a moderating influence on the climate of Coimbatore district, it does nothing to alleviate the region's arid climate. The cool, moist breeze that blows from the west coast through Palghat Gap loses its coolness and turns dry before it reaches Erode after passing through Coimbatore District.

The first two months of the year are typically comfortable, but in March the temperature starts to increase and stays that way through May. Pre-monsoon temperatures can reach as high as 37 °C or as low as 22 °C.

The hottest months are March through June, while the coldest months are December through January, just like the rest of the state. May is often when the highest temperatures are reported. The few showers that occur at this time don't offer much relief from the stifling heat. On the other hand, the weather gets better from June through August. The trend of the temperature changes during the pre-monsoon season. Even if it rains nonstop, the sky becomes very cloudy by September. There is little rain during the South West monsoon, which begins in June and lasts until August. The North East monsoon, which occurs in the months of October, November, and December, brings the majority of the rain. Rainfall at this area is 48.8 mm on average every year, with November seeing the greatest total of 323.8 mm. Only between October and November does the post-monsoon season begin to intensify, and by December the rains had stopped, leaving the weather clear and chilly. Wintertime temperatures are typically between 17 C and 32 C at their lowest. The city's relative humidity varies from 53% in the winter to 82% in the post-monsoon. During the south west monsoon, the air pressure is 1008 mbar, but in the winter, it is 1014 mbar.

Table -4Global solar radiation and climatic data of Location 3

Season	Month	Global Solar Radiation (kWh/m²/day)	Ambient Temperature (°C)	Relative humidity (%)	Wind speed (m/s)	Atmospheric pressure (mbar)	Precipitation (mm)
Winter	January	5.6	25.5	63	2.5	1014	6.4
	February	6.0	26.1	53	3.1	1013	16.0
Pre monsoon	March	6.2	28.5	57	2.7	1012	83.2
	April	4.8	29.4	66	3.4	1010	119.0
	May	6.5	28.0	76	3.1	1008	138.5
South -west Monsoon	June	4.1	27.8	73	4.3	1007	37.7
	July	3.0	27.7	75	4.7	1008	49.9
	August	3.6	27.9	74	4.5	1009	112.2
	September	4.3	27.6	70	2.1	1009	159.7
Post monsoon	October	2.1	27.0	70	2.4	1012	81.8
	November	2.8	25.2	82	2.1	1011	323.8
	December	3.9	25.1	75	2.5	1015	43.3

GLOBAL SOLAR RADIATION AND CLIMATIC DATA IN LOCATION 4

Location 4 receives 3.8 to 6.4 kWh/m2 of global solar radiation in the winter, 4.5 to 6.6 kWh/m2 in the pre-monsoon, 5.1 to 5.4 kWh/m2 in the south-west monsoon, and 2.3 to 4.7 kWh/m2 in the post-monsoon. This area has a tropical savanna climate that is classified as "Aw" by Koppen, with little difference in temperature between pre-monsoon and winter. Low humidity and high temperatures are the defining characteristics of the climate. The area is among the hottest in the state, with an average monthly temperature of 26.5°C and an annual mean temperature of 29.7°C. Due to the two nearby rivers, Kaveri and Kollidam, and the lack of any nearby vegetation, the high temperatures have been attributed to these factors. Being on the Deccan Plateau, this region experiences extremely hot and dry days, with cooler evenings brought on by brisk south-easterly winds.

This area gets a mild climate from June to September, with occasional thunderstorms and heavy rain. Due to the north-east monsoon winds, the rainiest months are from October through December. The highest precipitation of 118.4 mm was recorded in October, and the average amount of precipitation each year is 29.7 mm. The winter months of December through February are chilly and humid. The winter season's highest and lowest recorded temperatures are 34 C and 18 C, respectively. Dew and fog are uncommon and only happen in the winter. The city's relative humidity varies from 53% in the south-west monsoon to 83% in the winter. During the south west monsoon, the air pressure is 1007 mbar, but in the winter, it is 1015 mbar.

Table -5Global solar radiation and climatic data of Location 4

Season	Month	Global Solar Radiation ($kWh/m^2/day$)	Ambient Temperature (°C)	Relative humidity (%)	Wind speed (m/s)	Atmospheric pressure (mbar)	Precipitation (mm)
Winter	January	5.5	26.5	71	3.2	1014	13.4
	February	6.4	27.1	65	2.9	1013	5.9
Pre monsoon	March	6.1	30.3	62	3.1	1012	34.3
	April	4.5	31.4	66	2.4	1010	56.1
	May	6.6	31.7	69	3.5	1007	65.3
South west monsoon	June	5.5	31.5	62	5.0	1008	29.6
	July	5.2	32.0	53	4.0	1007	51.5
	August	5.1	31.2	60	3.7	1007	77.2
	September	4.7	31.9	62	2.4	1008	103.7
Post monsoon	October	3.1	28.6	76	2.0	1011	118.4
	November	2.3	26.9	85	2.2	1010	89.8
	December	3.8	26.7	83	3.2	1014	65.5

GLOBAL SOLAR RADIATION AND CLIMATIC DATA IN LOCATION 5

Location 5 receives 3.3 to 5.1 kWh/m2 of global solar radiation in the winter, 4.2 to 6.4 kWh/m2 in the pre-monsoon, 4.7 to 5.5 kWh/m2 in the south-west monsoon, and 1.9 to 4.1 kWh/m2 in the post-monsoon. Tropical weather prevails in this area. Rainfall in winter is significantly lower than in summer. The Koppen-Geiger classification of the climate is Aw. 29.6°C is the average annual temperature. Most precipitation is obtained in November, when the greatest total of 321.4 mm is recorded, with an annual average of 43 mm. The average maximum temperature is roughly 41°C in April. Wintertime high and low temperatures are 32 C and 18 C, respectively. In the city, the relative humidity varies from 53% in the south-west monsoon to 85% in the north-east monsoon. During the south west monsoon, the air pressure is 1008 mbar, but in the winter, it is 1014 mbar.

Table 6 Global solar radiation and climatic data of Location 5

Season	Month	Global Solar Radiation (kWh/m^2/day)	Ambient Temperature (°C)	Relative humidity (%)	Wind speed (m/s)	Atmospheric pressure (mbar)	Precipitation (mm)
Winter	January	4.2	26.1	71	2.7	1013	14.9
	February	5.2	27.3	64	3.1	1013	26.2
Pre monsoon	March	5.8	30.0	61	2.7	1013	76.6
	April	4.2	31.5	65	3.1	1008	81.7
	May	6.3	31.8	69	4.3	1007	62.3
South west monsoon	June	5.4	31.4	61	4.6	1006	15.1
	July	4.7	32.0	53	3.8	1006	11.3
	August	5.4	31.9	59	3.5	1007	31.4
	September	4.1	31.8	61	2.7	1008	47.4
Post monsoon	October	3.0	28.6	77	2.4	1010	174.2
	November	1.9	26.2	85	2.7	1010	321.4
	December	3.3	26.5	82	2.9	1013	169.3

GLOBAL SOLAR RADIATION AND CLIMATIC DATA IN LOCATION 6

Location 6 receives 3.4 to 5.8 kWh/m2 of global solar radiation in the winter, 5.2 to 6.2 kWh/m2 in the pre-monsoon, 4.6 to 6.0 kWh/m2 in the south-west monsoon, and 1.9 to 5.4 kWh/m2 in the post-monsoon. This area often has a hot and muggy climate. Averaging 24 to 35 degrees Celsius in the summer (March to June) and 21 to 33 degrees Celsius the rest of the year. 35.4 mm of rain falls annually on average. Precipitation is at its maximum during the northeast monsoon (October to December), reaching a peak of 232.8 mm in November. The city's relative humidity varies from 69% in the winter to 89% in the post-monsoon. In the late summer and early south west monsoon season, the air pressure ranges between 1008 and 1013 millibars, while in the late winter and early premonsoon, it is 1013 millibars.

Table-7 : Global solar radiation and climatic data of Location 6

Season	Month	Global Solar Radiation ($kWh/m^2/day$)	Ambient Temperature (C) °	Relative humidity (%)	Wind speed (m/s)	Atmospheric pressure (mbar)	Precipitation (mm)
Winter	January	4.1	27.8	73	1.4	1010	10.4
	February	5.9	28.5	69	1.6	1012	15.4
Pre monsoon	March	5.9	29.2	74	1.1	1012	57.9
	April	5.1	28.3	80	1.0	1010	70.8
	May	6.2	28.7	84	1.4	1009	74.6
South west monsoon	June	4.8	28.6	86	1.6	1009	6.2
	July	4.6	28.4	84	2.7	1010	0.0
	August	6.0	28.0	81	2.2	1010	22.4
	September	5.2	28.1	86	1.0	1010	66.9
Post monsoon	October	3.6	27.3	89	1.1	1011	96.9
	November	1.9	27.2	88	1.0	1010	232.8
	December	3.4	28.4	82	1.0	1011	195.1

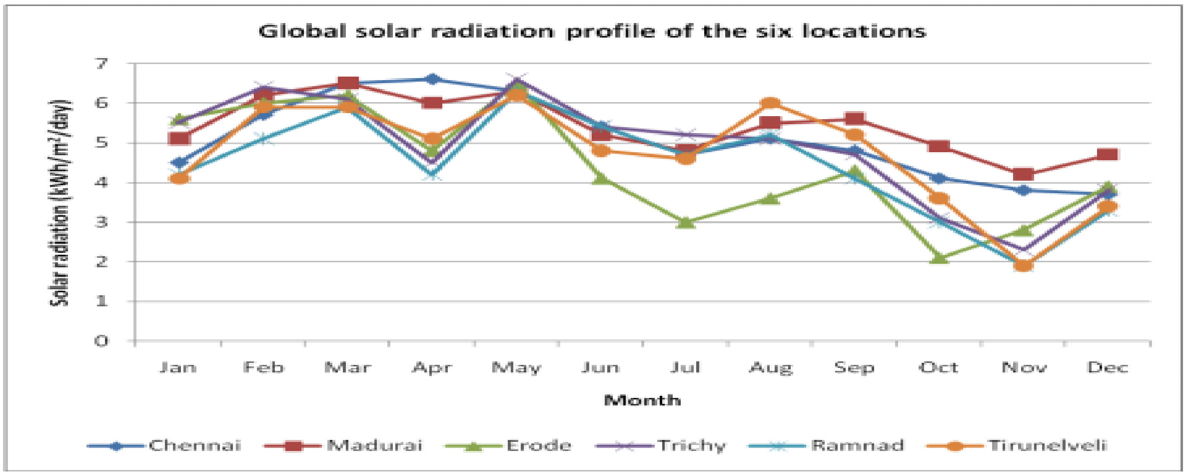

Figure -1 Global solar radiation profile of the six locations

ANALYSIS OF GLOBAL SOLAR RADIATION

Global solar radiation was analyzed using the mean, standard deviation, coefficient of variation, and coefficient of correlation. The coefficient of determination is used to determine the amount of explanation that each independent variable contributes by using global solar radiation as the dependent variable and all other factors as the independent variables. It is clear that during the winter, the relationship between ambient temperature and sun radiation is significantly positive. There is no discernible relationship between any other factors and the total amount of solar radiation. At this site, there is a clear positive association between the amount of precipitation and the wind speed. All climatic variables do not significantly correlate with global sun radiation during the pre-monsoon season. At this location, there is no discernible relationship between global solar radiation and the south-west monsoon season. The relationship between wind speed and air pressure is clearly negative. While all other factors do not significantly correlate during the post-monsoon season, atmospheric pressure and global sun radiation do.

CONCLUSION

Solar power is an environmentally friendly, renewable form of electricity. A precise, in-depth understanding of the solar radiation potential over the long term, taking into account seasonal changes, is necessary for the development of systems to harness this energy. The term "solar belt" refers to the area of the planet between the latitudes of 40°N and 40°S, which gets a significant amount of solar energy. The six study sites are strategically located within the solar belt, making it easier to capture and use solar energy. According to the study, Tamil Nadu's six areas with abundant year-round global sun radiation are perfect for capturing solar energy.

According to the correlation analysis, precipitation at Location 1 during the winter has a substantial relationship with atmospheric pressure. Relative humidity and wind speed are significantly correlated with global sun radiation during the pre-monsoon season. The relationship between wind speed and relative humidity is also very strong. There is a strong inverse relationship between relative humidity and ambient temperature during the south-west monsoon season. Relative humidity and ambient temperature are significantly negatively correlated for Location 2 during the south-west monsoon season. At Location 3, it can be seen that the relationship between global solar radiation and relative humidity is noticeably negative throughout the winter. There is a strong relationship between atmospheric pressure and relative humidity during the pre-monsoon season. There is a considerable relationship between wind speed and relative humidity during the south-west monsoon season. Relative humidity can be seen to significantly negatively correlate with ambient temperature at Location 4 throughout the winter. Precipitation and air temperature are shown to be significantly correlated. The relationship between precipitation and relative humidity is also very strong. At this region, there is a strong inverse relationship between global solar radiation and air pressure, wind speed, and precipitation during the south-west monsoon season. The relationship between wind speed and air pressure is clearly negative.

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