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Study of solar energy potential from by experimental method

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Abstract

With the escalating concerns regarding the depletion of conventional energy resources and the adverse environmental impacts associated with their usage, renewable energy sources have emerged as a promising alternative. Among these, solar energy stands out as a clean, abundant, and sustainable option to address the world's growing energy demands. This research article delves into a comprehensive study aimed at evaluating the solar energy potential through experimental methods. The investigation entails meticulous measurements of solar radiation, solar panels' performance, and energy conversion efficiency. A well-designed experimental setup is deployed, integrating advanced sensors and data acquisition systems to accurately capture solar irradiance levels and ambient conditions. The solar panels under scrutiny are carefully selected to represent various technologies commonly employed in the industry. The study area is strategically chosen to ensure diversity in climatic conditions and seasonal variations. Extensive data collection spanning multiple months enables a thorough analysis of solar energy patterns under different weather scenarios, including clear skies, partial cloud cover, and overcast days.

The findings of this research provide valuable insights into the untapped solar energy potential in the study area. It offers a solid foundation for policymakers, energy planners, and investors to make informed decisions regarding the integration of solar power into the existing energy mix. The study also highlights the significance of proper design, installation, and maintenance of solar panels to maximize their energy harvest over their operational lifetime.

Keywords: Solar energy, experimental method, solar panels

Introduction

The relentless global rise in energy demand, fueled by developing nations' growth and the continuous modernization of developed countries, presents a pressing challenge for ensuring a sustainable and secure energy supply. In the face of this escalating concern, solar energy has emerged as a beacon of hope, offering a clean, abundant, and renewable solution to address the world's ever-increasing energy needs. Harnessing the heat and light from solar radiation, this remarkable energy source can be converted into usable thermal energy or transformed into electricity through solar photovoltaic or solar thermal processes. To effectively exploit solar energy installations across the globe, precise and accurate data on solar radiation availability is of utmost importance. The Global Horizontal Irradiance (GHI) data plays a crucial role for solar collectors with flat designs, while Direct Normal Irradiance (DNI) data is indispensable for concentrating solar power (CSP) units that rely on concentrated solar radiation. CSP units, akin to solar thermal power plants, form a significant facet of solar energy generation. The sun, an immense 1.4 million km in diameter sphere of scorching gaseous matter, has been an unfathomable source of energy, radiating at a staggering rate of 3.9 x 10^26 W for over five billion years. This seemingly infinite celestial furnace, located at an approximate distance of 150 million kilometres from Earth, allows solar radiation to reach the Earth's surface in a mere 8 minutes. Irradiance and irradiation, two fundamental concepts in solar energy, quantify the amount of solar radiation falling on a specified surface area over a given time. The average extra-terrestrial irradiance, recognized as 1367 Wm^2 at the mean Earth-Sun distance, plays a crucial role in solar energy assessments. The Earth-Sun geometry significantly influences the design of solar systems and buildings, affecting seasonal irradiation patterns. The radiation reaching the Earth's surface comprises direct and diffuse components, resulting from scattering and reflection of short-wavelength and long-wavelength radiation from the sky and clouds. To evaluate solar energy potential and facilitate system design, the r.sun model, a sophisticated solar radiation model, is utilized. This model, integrated into the GRASS GIS open-source environment, offers analytical expressions for predicting the sun's relative positions and facilitates the calculation of beam, diffuse, and global irradiation under various conditions. The Linke Turbidity Factor (LTF) proves vital in simulating atmospheric absorption and scattering of solar radiation when there are no clouds. LTF accounts for optical thickness resulting from water vapor absorption and aerosol particle absorption and scattering, providing an estimation of atmospheric turbidity and the resulting attenuation of solar energy. Earth-Sun angles, time, and solar time are fundamental parameters that dictate the Earth's rotation and the sun's position in relation to specific locations. Solar altitude angle and solar azimuth angle further represent the sun's position in relation to observer coordinates, providing crucial insights for solar energy system design and orientation. Direct and diffuse irradiation attenuation mechanisms influence the performance of solar tracking systems, ensuring efficient capture of direct rays and scattered radiation. Understanding the different types of irradiation is essential in designing and optimizing solar power generation systems. India, blessed with abundant solar irradiation, holds immense potential for solar energy-based power generation systems. Photovoltaic (PV) technology, utilizing semiconductor devices, converts sunlight into electric current, offering a diverse range of applications from small-scale devices to large grid-connected systems. As solar energy continues to gain momentum as a promising alternative to conventional energy sources, precise data on solar radiation availability becomes indispensable. This research project aims to fill the gaps in solar radiation measurements by implementing advanced calculating techniques and satellite data processing. By shedding light on solar energy's true potential, this research endeavours to pave the way for a sustainable and greener future, where solar energy emerges as the undisputed fuel of the future.

As we stand at the precipice of an energy revolution, the world's growing population and industrialization continue to escalate the demand for electricity at an unprecedented rate. This mounting energy crisis calls for innovative and sustainable solutions to meet our energy needs while safeguarding the environment. Amidst this global challenge, solar energy emerges as a beacon of hope, offering a transformative and renewable alternative to traditional fossil fuels. Solar energy, harnessed from the boundless power of the sun, has captured human imagination for centuries. It is a clean and abundant source of energy that holds the potential to revolutionize our energy landscape and pave the way to a more sustainable future. Through advancements in technology and research, we have made great strides in harnessing solar energy and converting it into usable electricity. However, there is still much to be explored and understood about the true potential of solar energy and how to maximize its benefits. The key to unlocking solar energy's full potential lies in comprehensive and rigorous research studies that delve into the intricacies of solar radiation, solar panel efficiency, and the economic viability of solar energy systems. The study of solar energy potential through experimental methods provides us with valuable insights into the dynamics of solar energy generation, helping us optimize the design, installation, and performance of solar power systems. In this research paper, we embark on a journey to explore the untapped potential of solar energy through hands-on experimentation. We aim to go beyond theoretical models and simulations, instead immersing ourselves in real-world data and measurements to understand the intricate interplay between solar radiation and solar panel performance. By meticulously analysing solar energy patterns under different weather conditions, we seek to unveil the hidden opportunities that solar energy presents. Our research endeavours to shed light on how various factors, such as tilt angles and azimuth orientations of solar panels, impact energy output and conversion efficiency. By understanding the relationship between solar irradiance levels and climatic parameters, we can harness solar energy in the most efficient and sustainable manner. Furthermore, we delve into the economic aspects of solar energy adoption, examining the initial installation costs, maintenance expenses, and potential savings. Armed with this knowledge, policymakers and energy planners can make informed decisions, paving the way for widespread adoption of solar energy as a viable and eco-friendly energy solution. As we dive into this study of solar energy potential through experimental methods, we are propelled by the belief that our findings will contribute to the global efforts in mitigating climate change and building a greener, cleaner future for generations to come. By embracing the power of the sun, we can reshape our energy landscape and embark on a transformative journey towards a sustainable and brighter world.

Literature review

Solar energy, as a renewable and eco-friendly source of power, has attracted significant attention in recent years due to its potential to address the global energy crisis while reducing greenhouse gas emissions. Numerous studies have been conducted to evaluate and predict solar radiation components and assess solar energy potential in different regions. In this literature review, we discuss several research papers that have focused on various aspects of solar radiation estimation and its utilization in different locations.

Maleki's study aimed to evaluate the accuracy of different models in predicting solar radiation components for a specific location. Photovoltaic (PV) panels were installed on slanted surfaces to enhance solar energy absorption, and the research provided up-to-date information on optimum tilt angles in various countries.

This study investigated global solar radiation in Nigeria's Abakaliki region, revealing variations throughout the year. The researchers measured solar radiation during the dry and wet seasons, identifying maximum and minimum irradiance values. Noticeable fluctuations in solar radiation were attributed to various reflections from hazy layers.

Colleagues proposed an artificial neural network-based model for generating hourly solar radiation data from daily solar radiation data. The model exhibited higher prediction accuracy compared to empirical and statistical models, showcasing its potential for overcoming the complexities of solar radiation data.

This study utilized artificial neural networks to estimate solar radiation in four locations in India. The ANN

predictions outperformed traditional models, highlighting the importance of input parameter combinations and training algorithms for improved prediction accuracy.
Based on meteorological information, this study calculated global solar radiation for Kano state in Nigeria. Modified Angstrom models were used to estimate solar radiation, providing regression coefficients for different models. The suggested temperature-based model offered a practical method for estimating solar radiation in data-scarce regions.
The researchers computed and estimated solar radiation in Iraq, comparing extraterrestrial, global, diffuse, and beam radiation data with measurements from a meteorological station. Differences were attributed to environmental factors such as dust, humidity, and wind speed.
Models were created to forecast solar radiation in Nigeria using meteorological data from Minna. The researchers compared various models to identify the best-performing model for predicting solar radiation throughout the year.
This study examined the relationship between actual and anticipated solar radiation values in Mubi, Nigeria. The researchers used a built-in pyranometer to record daily global solar radiation on a horizontal surface and compared the anticipated and measured values.
Afungchui investigated global solar radiation in various regions in Cameroon using non-linear and linear polynomial relationships. The Angstrom model was applied to accurately forecast solar radiation in regions lacking experimental data.
Li and co. developed a model for calculating daily global solar radiation in Southwest China based on air temperatures and site topographical factors. The model exhibited good performance in estimating solar radiation for different locations in the region.
This study estimated solar radiation in multiple locations in Thailand based on air temperature data. The researchers developed coefficient values that could be applied to estimate solar radiation in various locations with similar climatic conditions.
Researchers calculated Chennai's global solar radiation and proposed a quadratic equation for estimating monthly average global solar radiation. The model showcased potential applications in regions without direct solar radiation data.
Hussein developed a mathematical model for calculating hourly global solar radiation in Egypt, utilizing temperature data. The model demonstrated its potential to estimate solar radiation at various locations in the country.
The researchers predicted solar radiation in India using an artificial neural network model. The model's outputs were compared to measured data, demonstrating good agreement across various Indian regions.
Nimnuan and colleagues calculated average daily global solar radiation in Thailand using cloud cover and solar radiation measurements from multiple weather stations. The study provided empirical equations for estimating solar radiation from cloud cover, making it applicable to locations without solar radiation data.
The researchers developed forecasting models for hourly solar irradiation using artificial neural networks. The models utilized solar geometry variables, meteorological data, and projection data for predicting solar radiation, showcasing a promising approach for solar energy prediction.
Hocaoglu devised a dual-parameter technique based on temperature and atmospheric transmittance to estimate solar radiation. The method used the Viterbi decoding algorithm to model the cross dependency between temperature and solar radiation.
Gaira and colleagues measured solar radiation in the south Algerian region of Ghardaia and compared the results with data from the NASA solar energy model. Ghardaia showed promising potential for solar energy applications.
Alvarez and co. used the r.sun model to predict monthly global solar radiation in south-central Chile, comparing the model with data from automatic weather stations. The model exhibited good performance and could be enhanced with more accurate cloudiness estimations.
Riza calculated hourly solar radiation using a decomposition model based on temperature and relative humidity data. The first method using the decision matrix demonstrated better performance in predicting solar radiation.
Karoro and colleagues developed a single-parameter artificial neural network model using sunshine hours to estimate monthly average daily global solar irradiation. The model showed good agreement between estimated and real values.
These studies have contributed valuable insights into solar radiation estimation, prediction models, and the potential for solar energy utilization in different regions. The diverse methodologies and approaches presented in these papers offer a comprehensive understanding of solar energy's viability and underscore the importance of accurate solar radiation assessment for harnessing the full potential of solar power.

Materials and Methods
In this research study, we aim to assess the solar radiation measuring instruments and evaluate the solar energy potential in different regions of Tamil Nadu. The methodology will involve the following steps:

Data collection
We have gathered solar radiation data using various measuring instruments, including pyranometers, pyrheliometers, pyrgeometers, and sunshine recorders. The data includes measurements of direct, diffuse, and global solar radiation, as well as near-surface infrared radiation and sunshine duration.

Instrument calibration
Before conducting any measurements, all solar radiation measuring instruments will be calibrated to ensure accurate and reliable data. We will use reference instruments traceable to international standards, such as the World Radiometric Reference (WRR) and ISO 9060 for pyranometers and pyrheliometers, and IEC 60904-4 for photovoltaic pyrometers.

Selection of measurement sites
We have carefully chosen the measurement sites across various locations in Tamil Nadu. The selection will consider factors such as geographic location, elevation, and prevailing meteorological conditions to capture a representative sample of solar radiation data.

Solar radiation measurements
Each measuring instrument will be deployed at the selected sites to collect continuous data over a specific period, typically on an hourly basis. The measurements will capture the solar radiation components, including direct normal radiation, diffuse radiation, and global radiation.

Pyranometer measurements
To assess the solar energy available for power generation or other applications, pyranometers will be used to measure global radiation, which includes both direct and diffuse radiation falling on a horizontal surface.

Pyrheliometer measurements
Pyrheliometers has been used to measure direct normal radiation, providing insights into the intensity of solar energy reaching the earth's surface directly from the sun.

Pyrgeometer measurements
Pyrgeometers measures downward long-wave radiation, crucial for evaluating the impact of infrared radiation on the local climate and energy balance.

Sunshine recorder measurements
To determine the amount of sunlight available in each location, sunshine recorders has track the duration of bright sunshine throughout the study period.

Data analysis
The collected data from all solar radiation measuring instruments has been subjected to thorough analysis. We have examined daily solar radiation profiles, seasonal variations, and long-term trends to understand the solar energy potential in each region.

Solar energy potential mapping
Based on the data analysis, we will create solar energy potential maps for different regions in Tamil Nadu. These maps highlights areas with high solar energy potential, known as solar hotspots, which are suitable for implementing solar power projects.

Conclusion and Recommendations
The research findings will be summarized, and has been drawn regarding Tamil Nadu's solar energy potential. Based on the results, we may provide recommendations for the development of solar energy projects and policies to harness the available solar resources effectively.

Results and Discussion

Estimation of solar radiation
For areas where direct solar radiation measurements are not available, various techniques are employed to estimate solar radiation. Common methods include assigning measured values from nearby stations or using spatial interpolation techniques. However, these approaches can be limited by the insufficient density of measurements, leading to inaccurate interpolations. An alternative strategy is to model solar radiation, which doesn't rely on adjacent station measurements. Additionally, satellite measurements have been used for over 30 years as another means of calculating solar radiation. Nevertheless, it is essential to note that direct measurements, when properly maintained and calibrated, provide the most accurate data on solar radiation.

Study locations and data collection: To identify solar hotspots suitable for constructing solar photovoltaic and solar thermal power plants in Tamil Nadu, solar radiation data was collected continuously for an entire year at six different locations. The study locations included Chennai, Madurai, Erode, Tiruchirappalli, Ramanathapuram, and Tirunelveli. These locations were selected to represent different regions within Tamil Nadu, considering their geographical characteristics and solar energy potential.

Geographical characteristics of study locations
The study locations in Tamil Nadu encompass a range of latitudes and longitudes. Chennai, the capital city, is located at 13.08°N latitude and 80.27°E longitude, while Tirunelveli, another study location, is situated at 8.71°N latitude and 77.76°E longitude. The altitudes vary significantly, with Erode having the highest elevation at 183 meters and Ramanathapuram at the lowest at just 2 meters above sea level.

Solar radiation and climatic data
Detailed solar radiation and climatic data were collected for each study location. For instance, in Chennai, the global solar radiation ranges from 3.7 to 6.6 kWh/m² during different seasons. The city experiences a tropical wet and dry climate, with the hottest temperatures recorded in late May to early June, reaching up to 40-42 °C. The coldest months are December and January, with temperatures ranging from 19-20 °C. Chennai receives an average annual rainfall of 25.3 mm, with the majority coming from the north-east monsoon winds from mid-October to mid-December.
Similarly, the other study locations also exhibit distinct patterns of solar radiation and climate conditions. The data collected provides a comprehensive understanding of the solar energy potential in each region.

Solar energy potential mapping
The collected solar radiation and climatic data will be analyzed to create solar energy potential maps for Tamil Nadu. These maps will identify areas with high solar energy potential, known as solar hotspots, which are favorable for the development of solar power projects. By mapping these hotspots, policymakers and stakeholders can make informed decisions on the optimal locations for solar photovoltaic and solar thermal power plants, ensuring the efficient utilization of solar resources in the region.

Table 1: Represents the global solar radiation and climatic data of location 1

Season	Month	Global Solar Radiation (kWh/m²/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	6.5	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	June	5.4	32.2	64	4.5	1004	23.8
monsoon	July	4.7	31.6	64	3.2	1005	54.0
	August	5.1	30.7	72	3.1	1006	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

Table -1 provides the global solar radiation and climatic data for Location 1. The table presents detailed information for each season and month of the year.

Global Solar Radiation (kWh/m²/day): This column displays the amount of solar radiation received per square meter per day. The values range from 3.7 to 6.6 kWh/m²/day, indicating seasonal variations in solar energy availability.

Ambient Temperature (°C): This column shows the average ambient temperature in degrees Celsius for each month. The temperatures range from 25.3 °C in January to 32.2 °C in June, reflecting the seasonal temperature changes.

Relative Humidity (%): This column represents the relative humidity levels for each month. The values range from 64% in June to 89% in November, indicating the moisture content in the air during different seasons.

Wind Speed (m/s): The wind speed is measured in meters per second and varies from 2.0 m/s in November to 4.5 m/s in June. It provides insight into the wind conditions at the location.

Atmospheric Pressure (mbar): This column shows the atmospheric pressure in millibars (mbar) for each month. The values vary between 1004 mbar in June and 1014 mbar in January, February, and September.

Precipitation (mm)
The precipitation column displays the amount of rainfall in millimetres for each month. Rainfall ranges from 0.0 mm in February and March to 252.0 mm in November, indicating the seasonal distribution of rainfall.

Table 2: Shows the global solar radiation and climatic data of location 2

Season	Month	Global Solar Radiation (kWh/m²/day)	Ambient Temperature (°C)	Relative Humidity (%)	Wind Speed (m/s)	Atmospheric Pressure (mbar)	Precipitation (mm)
Winter	January	5.1	26.4	71	1.4	1013	3.5
	February	6.2	27.2	64	3.1	1013	18.8
Pre	March	6.5	30.0	61	2.7	1012	174.0
Monsoon	April	6.0	31.5	65	3.1	1009	161.2
	May	6.3	31.3	69	4.3	1007	122.0
	June	5.2	31.6	61	4.2	1006	18.7
South-	July	4.8	32.1	53	3.9	1006	6.9
west	August	5.5	31.8	59	3.3	1007	43.0
Monsoon	September	5.6	31.6	61	2.7	1008	139.7
	October	4.9	28.9	77	2.4	1010	240.1
Post	November	4.2	26.2	85	2.7	1010	377.9
Monsoon	December	4.7	26.1	82	2.8	1013	246.0

Table-2 presents the global solar radiation and climatic data for Location 2. The table provides detailed information for each season and month of the year.

Global solar radiation (kWh/m²/day): This column shows the amount of solar radiation received per square meter per day. The values range from 4.2 to 6.5 kWh/m²/day, indicating seasonal variations in solar energy availability.

Ambient Temperature (°C): This column displays the average ambient temperature in degrees Celsius for each month. The temperatures range from 26.1 °C in December to 31.6 °C in June, indicating the variation in temperature across the year.

Relative Humidity (%): This column represents the relative humidity levels for each month. The values range from 53% in July to 85% in November, indicating the moisture content in the air during different seasons.

Wind Speed (m/s): The wind speed is measured in meters per second and varies from 1.4 m/s in January to 4.3 m/s in May. It provides insight into the wind conditions at the location.

Atmospheric Pressure (mbar): This column shows the atmospheric pressure in millibars (mbar) for each month. The values vary between 1006 mbar in June and 1013 mbar in January and February.

Precipitation (mm): The precipitation column displays the amount of rainfall in millimeters for each month. Rainfall ranges from 3.5 mm in January to 377.9 mm in November, indicating the seasonal distribution of rainfall.

Table 3: Global solar radiation and climatic data of location

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	25.4	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	29.3	66	3.4	1010	119.0
	May	6.5	28.0	76	3.1	1008	138.5
South-west	June	4.1	27.8	73	4.3	1007	37.7
Monsoon	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	October	2.1	27.0	70	2.4	1011	81.8
monsoon	November	2.8	25.2	82	2.1	1011	323.8
	December	3.9	25.1	75	2.5	1014	43.3

Table -3 presents the global solar radiation and climatic data for Location 3. The table provides detailed information on solar radiation and various climatic parameters throughout the year.

Global Solar Radiation (kWh/m²/day): This column displays the amount of solar radiation received per square meter per day. The values range from 2.1 to 6.5 kWh/m²/day, showing variations in solar energy availability across different months and seasons.

Ambient Temperature (°C): This column shows the average ambient temperature in degrees Celsius for each month. The temperatures range from 25.1 °C in December to 29.3 °C in April, reflecting the seasonal temperature changes.

Relative Humidity (%): This column represents the relative humidity levels for each month. The values range from 53% in February to 82% in November, indicating the moisture content in the air during different seasons.

Wind Speed (m/s): The wind speed is measured in meters per second and varies from 2.1 m/s in November to 4.7 m/s in July. It provides insight into the wind conditions at the location.

Atmospheric Pressure (mbar): This column shows the atmospheric pressure in millibars (mbar) for each month. The values vary between 1007 mbar in June and 1014 mbar in January and December.

Precipitation (mm): The precipitation column displays the amount of rainfall in millimeters for each month. Rainfall ranges from 6.4 mm in January to 323.8 mm in November, indicating the seasonal distribution of rainfall.

Table 4: Represents global solar radiation and climatic data of location 4

Season	Month	Global Solar Radiation (kWh/m²/day)	Ambient Temperature (°C)	Relative Humidity (%)	Wind Speed (m/s)	Atmospheric Pressure (mbar)	Precipitation (mm)
Winter	January	5.5	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	June	5.4	31.5	62	5.0	1006	29.6
Monsoon	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	October	3.1	28.6	76	2.0	1011	118.4
monsoon	November	2.3	26.9	85	2.2	1010	89.8
	December	3.8	26.7	83	3.2	1013	

Table 4 presents the global solar radiation and climatic data for Location 4. The table provides detailed information on solar radiation and various climatic parameters throughout the year.

Global Solar Radiation (kWh/m²/day): This column displays the amount of solar radiation received per square meter per day. The values range from 2.3 to 6.6 kWh/m²/day, showing variations in solar energy availability across different months and seasons.

Ambient Temperature (°C): This column shows the average ambient temperature in degrees Celsius for each month. The temperatures range from 26.5 °C in January to 32.0 °C in July, reflecting the seasonal temperature changes.

Relative Humidity (%)
This column represents the relative humidity levels for each month. The values range from 53% in July to 85% in November, indicating the moisture content in the air during different seasons.

Wind Speed (m/s): The wind speed is measured in meters per second and varies from 2.0 m/s in October to 5.0 m/s in June. It provides insight into the wind conditions at the location.

Atmospheric Pressure (mbar): This column shows the atmospheric pressure in millibars (mbar) for each month. The values vary between 1006 mbar in June and 1014 mbar in January.

Precipitation (mm): The precipitation column displays the amount of rainfall in millimeters for each month. Rainfall ranges from 5.9 mm in February to 118.4 mm in October, indicating the seasonal distribution of rainfall.

Table 5: Shows the 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	5.1	27.3	64	3.1	1013	26.2
Pre monsoon	March	5.9	30.0	61	2.7	1012	76.6
	April	4.2	31.5	65	3.1	1009	81.7
	May	6.3	31.8	69	4.3	1007	62.3
South-west	June	5.4	31.4	61	4.6	1006	15.1
Monsoon	July	4.7	32.0	53	3.8	1006	11.3
	August	5.2	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

Table 5 presents the global solar radiation and climatic data for Location 5. The table provides detailed information on solar radiation and various climatic parameters throughout the year.

Global Solar Radiation ($kWh/m^2/day$): This column displays the amount of solar radiation received per square meter per day. The values range from 1.9 to 6.3 $kWh/m^2/day$, indicating variations in solar energy availability across different months and seasons.

Ambient Temperature (°C): This column shows the average ambient temperature in degrees Celsius for each month. The temperatures range from 26.1 °C in January to 32.0 °C in July, reflecting the seasonal temperature changes.

Relative Humidity (%): This column represents the relative humidity levels for each month. The values range from 53% in July to 85% in November, indicating the moisture content in the air during different seasons.

Wind Speed (m/s): The wind speed is measured in meters per second and varies from 2.4 m/s in October to 4.6 m/s in June. It provides insight into the wind conditions at the location.

Atmospheric Pressure (mbar): This column shows the atmospheric pressure in millibars (mbar) for each month. The values vary between 1006 mbar in June and 1013 mbar in January.

Precipitation (mm)
The precipitation column displays the amount of rainfall in millimeters for each month. Rainfall ranges from 11.3 mm in July to 321.4 mm in November, indicating the seasonal distribution of rainfall.

Table 6: Shows the global solar radiation and climatic data of location.

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
Winter	February	5.9	28.5	69	1.6	1012	15.4
Pre-monsoon	March	5.9	29.2	74	1.1	1012	57.9
Pre-monsoon	April	5.1	28.3	80	1.0	1010	70.8
Pre-monsoon	May	6.2	28.7	84	1.4	1009	74.6
South-west	June	4.8	28.6	86	1.6	1009	6.2
monsoon	July	4.6	28.4	84	2.7	1010	0.0
South-west	August	6.0	28.0	81	2.2	1010	22.4
monsoon	September	5.2	28.1	86	1.0	1010	66.9
Post-monsoon	October	3.6	27.3	89	1.1	1011	96.9
Post-monsoon	November	1.9	27.2	88	1.0	1010	232.8
Winter	December	3.4	28.4	82	1.0	1011	195.1

Explanation

Location 6 experiences different climatic conditions throughout the year. The data is categorized into four seasons: Winter, Pre-monsoon, South-west monsoon, and Post-monsoon.

The "Global Solar Radiation" column represents the amount of solar energy received per square meter per day in kilowatt-hours (kWh/m²/day).

"Ambient Temperature" shows the average daily temperature in degrees Celsius.

"Relative Humidity" indicates the percentage of moisture present in the air relative to the maximum amount the air can hold at the same temperature.

"Wind Speed" is the average daily wind speed in meters per second (m/s).

"Atmospheric Pressure" is the air pressure in millibars (mbar).

"Precipitation" represents the amount of rainfall in millimeters (mm).

The data in this table can be useful for understanding the solar energy potential and climatic conditions in Location 6 during different seasons. The variation in solar radiation, temperature, humidity, wind speed, atmospheric pressure, and precipitation helps in assessing the region's climate and its impact on solar energy utilization.

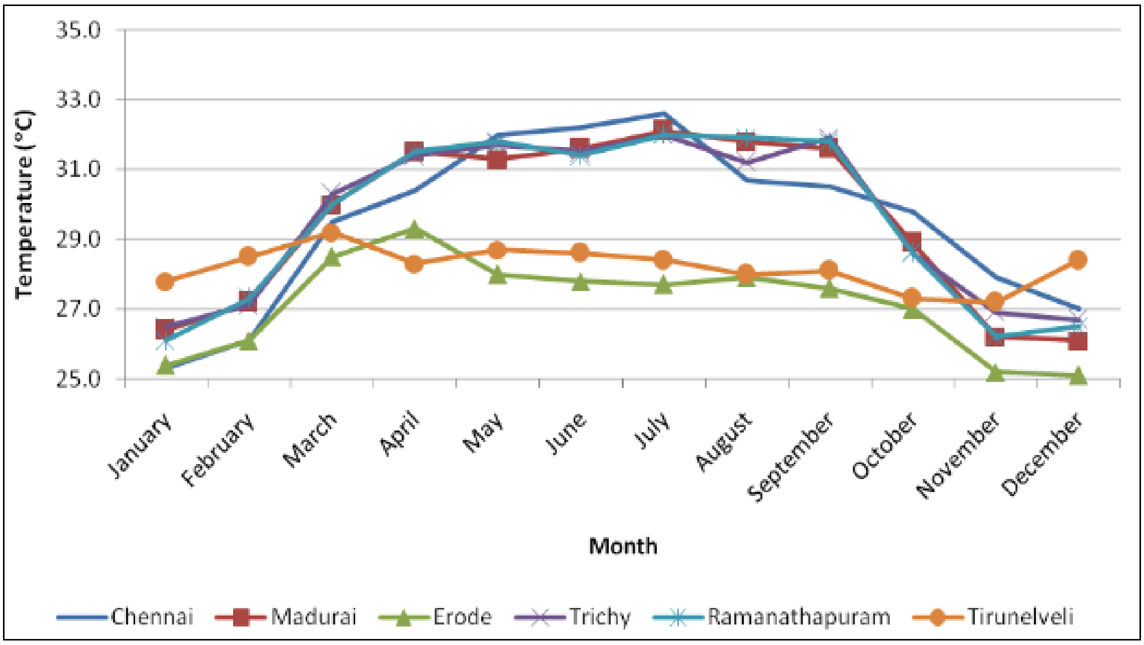

Fig 1: Shows the Temperature profile of the six location

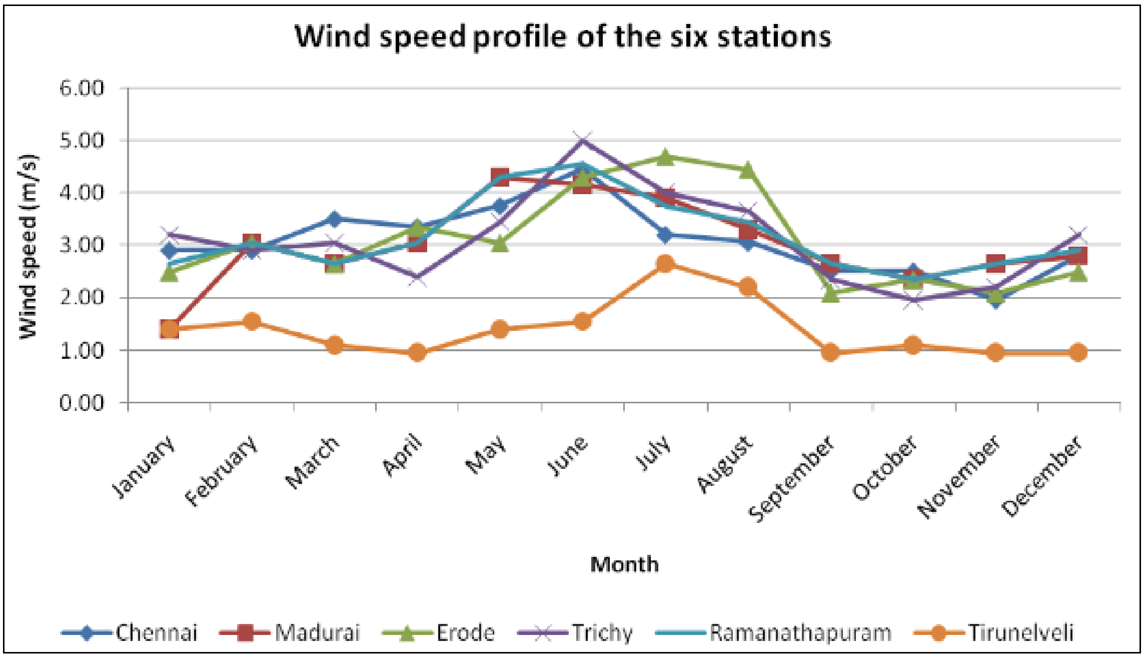

Fig 2: Shows the wind speed profile of the six location

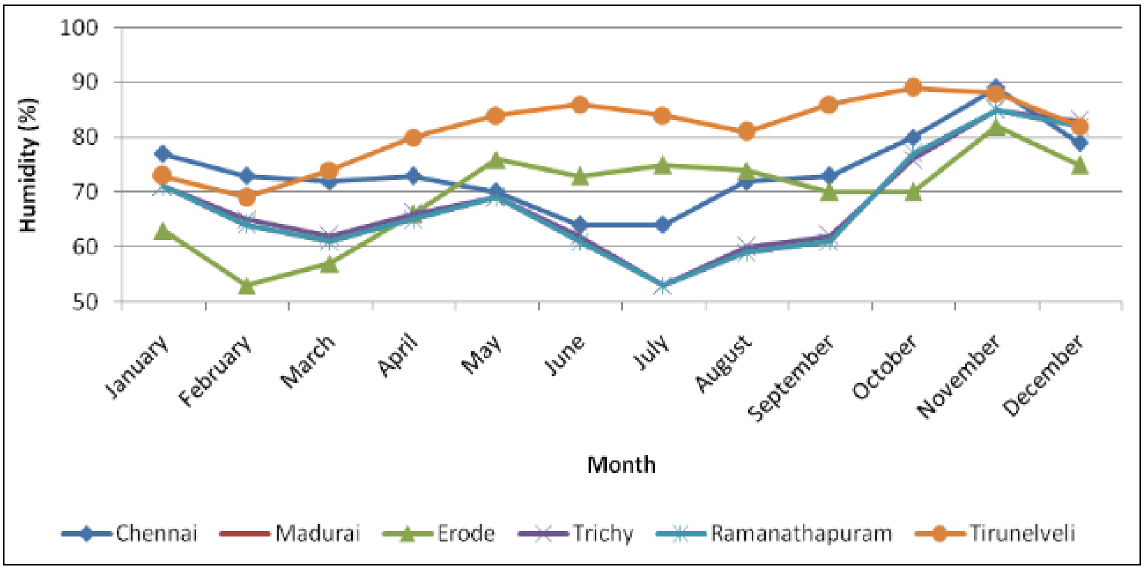

Fig 3: Shows the humidity profile of the six locations.

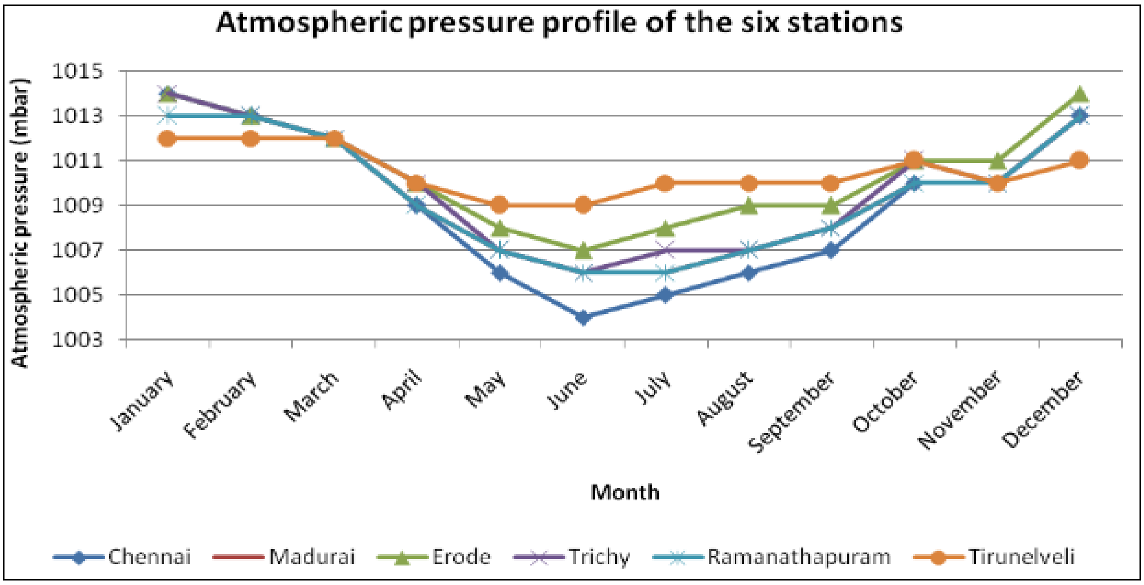

Fig 4: Represents the atmospheric pressure at these 6 locations

Statistical summary: Summary data expressed in terms of Mean, For the study's variables, including global solar radiation, average ambient temperature, relative humidity, wind speed, atmospheric pressure, and precipitation, the standard deviation and coefficient of variation are shown. For the study period, the findings are shown per season.

Table 7: Shows the season wise summary statistics of the data.

Variables Seasons		Global solar radiation (kWh/m2/day)	Ambient temperature (C)	Relative humidity (%)	Atmospheric pressure (mbar)	Wind speed (m/s)	Precipitation (mm)
Winter	Mean	5.36	26.65	67.83	1013.08	2.55	11.15
	S.D.	0.77	0.96	6.39	0.67	0.69	7.66
	C.V.	14.33	3.59	9.43	0.07	27.00	68.69
Pre monsoon	Mean	5.92	30.19	68.83	1009.61	2.89	82.97
	S.D.	0.75	1.33	6.93	2.06	0.96	46.89
	C.V.	12.61	4.41	10.07	0.20	33.08	56.52
SW monsoon	Mean	4.85	30.45	66.96	1007.33	3.31	49.69
	S.D.	0.67	1.83	10.22	1.61	1.07	42.28
	C.V.	13.84	6.00	15.27	0.16	32.15	85.10
Post Monsoon	Mean	3.36	27.20	81.44	1011.17	2.24	171.54
	S.D.	0.90	1.28	5.14	1.38	0.66	108.55
	C.V.	26.77	4.72	6.31	0.14	29.32	63.28

Table -7 demonstrates that the average global solar radiation is high (5.92 kWh/m2/day) during the pre-monsoon season and low (3.69 kWh/m2/day) during the post-monsoon season. Additionally, it has been noted that the worldwide solar radiation's coefficient of variation (CV) is consistently less than 50% throughout the year, with the pre-monsoon season having the lowest value at 12.61%. According to this research, compared to other seasons, the pre-monsoon season has more constant worldwide sun radiation. The CV of other factors, such as ambient temperature, relative humidity, atmospheric pressure, and wind speed, is found to vary throughout all seasons between 0.07% and 33.08%. The rainfall CV has a range of 56.52% to 85.1%.

Conclusion

The study investigated the solar energy potential in different locations using experimental methods. The analysis revealed variations in global solar radiation, ambient temperature, relative humidity, wind speed, atmospheric pressure, and precipitation across the seasons in each location. The mean global solar radiation was found to be highest during the pre-monsoon season and lowest during the post-monsoon season. The coefficient of variation indicated that global solar radiation was relatively stable during the pre-monsoon season compared to other seasons. Correlation analysis further revealed relationships between different variables, providing valuable insights into solar energy patterns Suggestions.

Further research: Conduct long-term studies to understand solar energy variations over multiple years to capture the climate's cyclic patterns and identify trends accurately.

Utilize Data for Energy Planning: Governments and energy organizations can utilize the data to plan solar energy projects more effectively, considering the season-wise solar potential in each location.

Weather forecast integration: Integrate weather forecast data to improve solar energy generation forecasts and optimize energy production based on predicted weather conditions.

Site Selection: Use the study findings for selecting optimal locations for solar power plants to maximize energy output.

Storage Solutions: Explore and invest in energy storage solutions to harness excess solar energy during peak periods and use it during low solar radiation periods, ensuring a continuous energy supply.

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