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Original Research Article

Analysis and Evaluation of Photovoltaic and Solar Radiation

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Abstract

This research work focused on the variability of global solar radiation over the area of extension site which is situated in Federal Polytechnic Oko, Orumba North Local Government Area, Anambra State, Nigeria. (6°20'N. 7^{U}00'E) which was located in South Eastern part of Nigeria for the month of December 2016. The global solar radiation was measured every thirty minutes from 6:00am to 6:00pm for the period of five days. To measure the intensity of solar radiation in a particular geographical area is one of the necessary tools used for the investigation of the intensity of solar power radiation and necessary for the implementation of photovoltaic systems in that particular geographical area. To determine the solar radiation intensity, data were collected over a given period of days using an instrument called solarimeter. Solarimeter is an instrument used to determine the intensity or thermal radiation and photovoltaic principles of the sun in a particular geographical area. The data collected were analyzed to observe the behavior or the data and what the data portrays. The data were analyzed using radial plot, line plot, scatter plot main effect, correlations and probability plots. From the analysis, it was observed that the Sun radiation is highest from around 12 noon to 2 pm of the day time and lowest around 6AM to 7AM in the morning hours and around 6 PM in the evenings of 6th to 10th February, 2017. The high intensity is as a result of high atmospheric temperature in the area. The correlations of the intensity and the temperature reveals that they are correlated to each other. The probability plots show that the exponential probability plots are more significance than normal probability plots. The result shows the intensity of the sun light is high in afternoon and lower in the early hours of mornings and late hours of evenings. The average solar intensity of extension site in Federal Polytechnic Oko, is 356,644w/m^2. The result will help in positioning solar panels, in order to determine the efficiency of solar panel, being critical in the selection of solar panels that will be necessary and more effective in that particular geographical area.

Keywords: Sun, Solar, Radiation, Intensity, Temperature, Solarimeter, Photovoltaic.

1. INTRODUCTION

Solar radiation is the radiant energy or radiation emitted by the sun. It is also called electromagnetic energy or short-wave radiation. Solar radiation is a general term for the electromagnetic radiation emitted by the sun. Solar radiation can be captured and turned into useful forms of energy, such as heat and electricity, using a variety of technologies. However, the technical feasibility and economical operation of these technologies at a specific location depends on the available solar resource [24, 25].

1.1 Basic Principles

Every location on Earth receives sunlight at least part of the year. The amount of solar radiation that reaches any one spot on the Earth's surface varies according to geographic location, time of day, season, local landscape, and local weather. Because the Earth is round, the sun strikes the surface at different angles, ranging from 0° (just above the horizon) to 90° (directly overhead). When the sun's rays are vertical, the Earth's surface gets all the energy possible. The more slanted the sun's rays are, the longer they travel through the atmosphere, becoming more scattered and diffuse. Because the Earth is round, the frigid polar regions never get a high sun, and because of the tilted axis of rotation, these areas receive no sun at all during part of the year.

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The Earth revolves around the sun in an elliptical orbit and is closer to the sun during part of the year. When the sun is nearer the Earth, the Earth's surface receives a little more solar energy. The Earth is nearer the sun when it is summer in the southern hemisphere and winter in the northern hemisphere. However, the presence of vast oceans moderates the hotter summers and colder winters one would expect to see in the southern hemisphere as a result of this difference.

The 23.5° tilt in the Earth's axis of rotation is a more significant factor in determining the amount of sunlight striking the Earth at a particular location. Tilting results in longer days in the northern hemisphere from the spring (vernal) equinox to the fall (autumnal) equinox and longer days in the southern hemisphere during the other 6 months. Days and nights are both exactly 12 hours long on the equinoxes, which occur each year on or around March 23 and September 22.

Countries such as the United States, which lie in the middle latitudes, receive more solar energy in the summer not only because days are longer, but also because the sun is nearly overhead. The sun's rays are far more slanted during the shorter days of the winter months. Cities such as Denver, Colorado, (near 40° latitude) receive nearly three times more solar energy in June than they do in December.

The rotation of the Earth is also responsible for hourly variations in sunlight. In the early morning and late afternoon, the sun is low in the sky. Its rays travel further through the atmosphere than at noon, when the sun is at its highest point. On a clear day, the greatest amount of solar energy reaches a solar collector around solar noon.

1.2 Diffuse and Direct Solar Radiation

As sunlight passes through the atmosphere, some of it is absorbed, scattered, and reflected by air molecules, water vapor, clouds, dust, pollutants, forest fires, and volcanoes. This is called diffuse solar radiation. The solar radiation that reaches the Earth's surface without being diffused is called direct beam solar radiation. The sum of the diffuse and direct solar radiation is called global solar radiation. Atmospheric conditions can reduce direct beam radiation by 10% on clear, dry days and by 100% during thick, cloudy days.

1.3 Measurement of Sun Intensity

Scientists measure the amount of sunlight falling on specific locations at different times of the year. They then estimate the amount of sunlight falling on regions at the same latitude with similar climates. Measurements of solar energy are typically expressed as total radiation on a horizontal surface or as total radiation on a surface tracking the sun. Radiation data for solar electric (photovoltaic) systems are often represented as kilowatt-hours per square meter (kWh/m^2). Direct estimates of solar energy may also be expressed as watts per square meter (W/m^2).

1.4 Distribution of Sun Intensity

The solar resource across the Nigeria is ample for photovoltaic (PV) systems because they use both direct and scattered sunlight. Other technologies may be more limited. However, the amount of power generated by any solar technology at a particular site depends on how much of the sun's energy reaches it. Thus, solar technologies function most efficiently in the southwestern United States, which receives the greatest amount of solar energy [26].

2. Photovoltaics

The term "photovoltaic" comes from the Greek meaning "light", and from "volt", the unit of electro-motive force, the volt, which in turn comes from the last name of the Italian physicist Alessandro Volta, inventor of the battery (electrochemical cell). The term "photo-voltaic" has been in use in English since 1849 [13]. Photovoltaic (PV) is a term which covers the conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect, a phenomenon studied in physics, photochemistry, and electrochemistry. A typical photovoltaic system employs solar panels, each comprising a number of solar cells, which generate electrical power. PV installations may be ground-mounted, rooftop mounted or wall mounted. The mount may be fixed, or use a solar tracker to follow the sun across the sky.

Solar PV has specific advantages as an energy source: its operation generates no pollution [1] and no greenhouse gas emissions once installed; it shows simple scalability in respect of power needs and silicon has large availability in the earth's crust [2]. PV systems have the major disadvantage that the power output is dependent on direct sunlight, so about 10-25% is lost if a tracking system is not used, since the cell will not be directly facing the sun at all times [3]. Dust, clouds, and other things in the atmosphere also diminish the power output [4, 5]. Another main issue is the concentration of the production in the hours corresponding to main insolation, which don't usually match the peaks in demand in human activity cycles [2]. Unless current societal patterns of consumption and electrical networks mutually adjust to this scenario, electricity still needs to be made up by other power sources, usually hydrocarbon. Photovoltaic systems have long been used in specialized applications, and standalone and grid-connected PV systems have been in use since the 1990s [6]. They were first mass-produced in 2000, when German environmentalists and the Eurosolar organization got government funding for a ten thousand roof program [7]. Advances in technology and increased manufacturing scale have in any case reduced the cost, increased the reliability, and increased the efficiency of photovoltaic installations [6, 8]. Net metering and financial incentives, such as preferential feed-in tariffs for solar-generated electricity, have supported solar PV installations in many countries [9]. After hydro and wind powers, PV is the third renewable energy source in terms of globally capacity. In 2014, worldwide installed PV capacity increased to 177 gig watts (GW), which is two percent of global electricity demand [10]. China, followed by Japan and the United States, is the fastest growing market, while Germany remains the world's largest producer, with solar PV providing seven percent of annual domestic electricity consumption [11]. With current technology (as of 2013), photovoltaic recoups the energy needed to manufacture them in 1.5 years in Southern Europe and 2.5 years in Northern Europe [12].

2.1 Solar cells

Photovoltaic is best known as a method for generating electric power by using solar cells to convert energy from the sun into a flow of electrons by the photovoltaic effect [14, 15].

Solar cells produce direct current electricity from sunlight which can be used to power equipment or to recharge a battery. The first practical application of photovoltaic was to power orbiting satellites and other spacecraft, but today the majority of photovoltaic modules are used for grid connected power generation. In this case an inverter is required to convert the DC to AC. There is a smaller market for off-grid power for remote dwellings, boats, recreational vehicles, electric cars, roadside emergency telephones, remote sensing, and cathodic protection of pipelines. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material [16]. Copper solar cables connect modules (module cable), arrays (array cable), and sub-fields. Because of the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years [17, 18, 19]. Solar photovoltaic power generation has long been seen as a clean energy technology which draws upon the planet's most plentiful and widely distributed renewable energy source the sun. Cells require protection from the environment and are usually packaged tightly in solar panels. Photovoltaic power capacity is measured as maximum power output under standardized test conditions (STC) in watts peak [20]. The actual power output at a particular point in time may be less than or greater than this standardized, or "rated," value, depending on geographical location, time of day, weather conditions, and other factors [21]. Solar photovoltaic array capacity factors are typically under 25%, which is lower than many other industrial sources of electricity [22]. Electrical efficiency (also called conversion efficiency) is a contributing factor in the selection of a photovoltaic system. However, the most efficient solar panels are typically the most expensive, and may not be commercially available. Therefore, selection is also driven by cost efficiency and other factors. The electrical efficiency of a PV cell is a physical property which represents how much electrical power a cell can produce for a given insolation. The basic expression for maximum efficiency of a photovoltaic cell is given by the ratio of output power to the incident solar power (radiation flux time's area) [23].

3. RESEARCH METHOD

The research method adopted is the analysis of the sun intensity and its temperature variability in the selected case study area using statistical tools and design of expert tool to experiment the analysis of the data and the intensity of the Sun in the geographical area. The tools applied are chart analysis, correlations analysis, Probability analysis and main effect analysis. The results will portray the influence of Sun intensity and temperature variations in the case study area.

4. ANALYSIS AND RESULTS

Table 1: The values of solar intensity for five days in February 2016

S/N	Time	Intensity of the sun day 1 (W/M^2)	Intensity of the sun day 2 (W/M^2)	Intensity of the sun day 3 (W/M^2)	Intensity of the sun day 4 (W/M^2)	Intensity of the sun day 5 (W/M^2)
1	6:00	2.1	3.1	1.9	1.2	1.7
2	6:30	6.4	4.3	9.3	7.7	4
3	7:00	25.1	37.7	21.4	26.5	27.8
4	7:30	75.6	85.4	79.6	43.2	57.8
5	8:00	142.5	106.5	147.5	88.2	207.9
6	8:30	224.3	334.6	264.2	181.6	239.4
7	9:00	438.3	380.5	371.2	3 46. 2	351.6
8	9:30	436.5	339.4	475	316.7	410.6
9	10:00	226.1	271.5	612.1	195.2	602.6
10	10:30	237.5	636.1	255.2	193.2	718.9
11	11:00	741.2	476.4	394.3	856.1	819.3
12	11:30	898.6	959.6	459.7	861.3	908
13	12:00	986	898.1	616	992	986
14	12:30	858.4	491.6	917.6	944.6	1013.3
15	1:00	856.1	318.3	960.9	843.9	998.5

S/N	Time	Intensity of the sun day 1 (W/M^2)	Intensity of the sun day 2 (W/M^2)	Intensity of the sun day 3 (W/M^2)	Intensity of the sun day 4 (W/M^2)	Intensity of the sun day 5 (W/M^2)
16	1:30	474.2	963.5	339	717.2	934.2
17	2:00	265.4	814.3	818.2	751.9	876.8
18	2:30	264	230.7	473.1	371.8	789.6
19	3:00	374.7	554.9	572.5	374.8	686.2
20	3:30	207.4	413	215.6	318.3	547.7
21	4:00	211.8	180.4	154.1	249.7	449.3
22	4:30	153.6	111.8	134	173.1	130.2
23	5:00	86.5	127.1	104	149	160.7
24	5:30	47.1	43.9	57.7	80.1	52.2
25	6:00	13.3	8.6	18.7	30.9	21.2

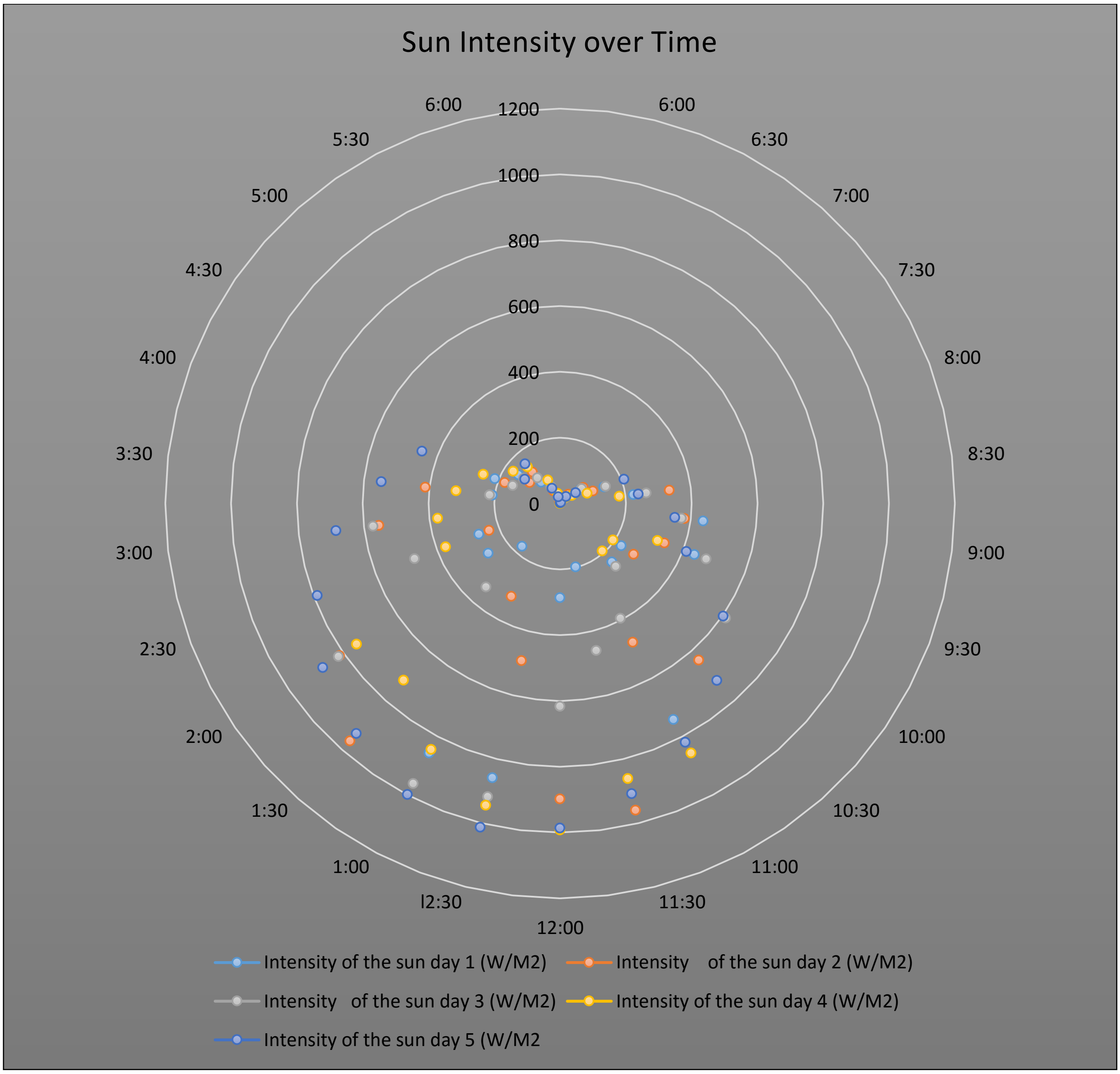

Figure 1: Radial Plot of Sun Intensity over Time

Figure 1 uses a polar coordinate system to visualize daily cycles. While it effectively shows the cluster of intensity during daylight hours, the overlap of five different colored series in a small area makes it difficult to distinguish specific trends for individual days. A standard line graph might provide a clearer comparison of the intensity curves for each day.

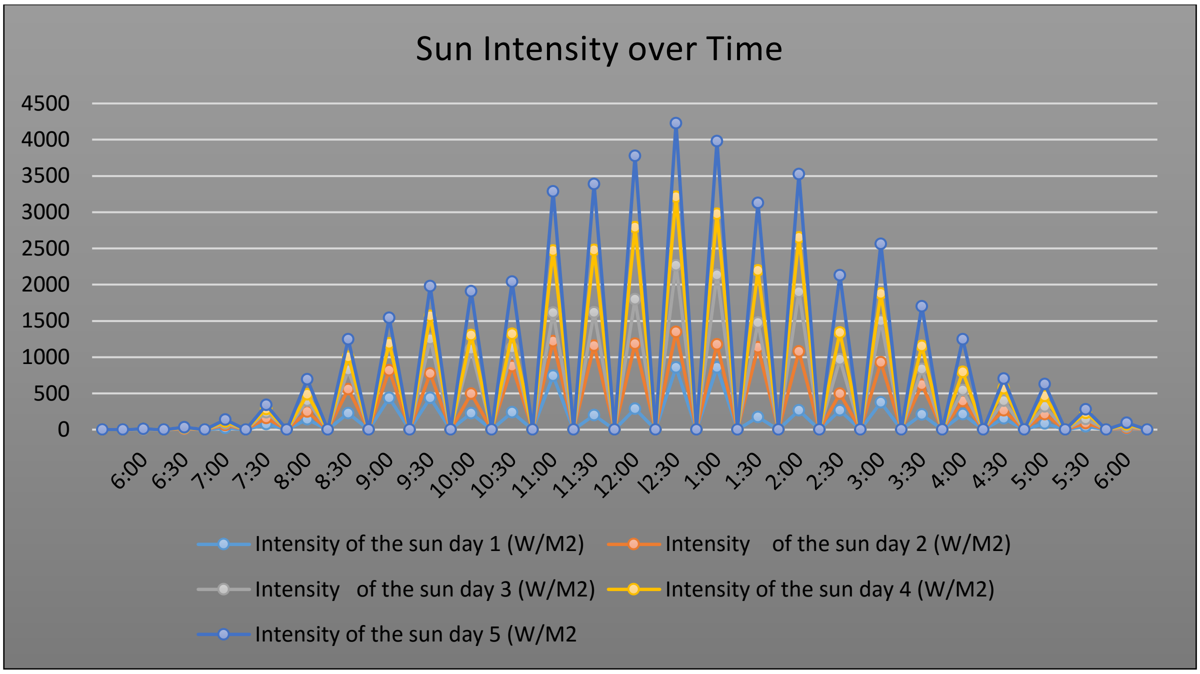

Figure 2: Line Plot of Sun Intensity over Time

Figure 2 is the radar chart that showed the cluster of midday data, this line plot highlights the rate of change and the specific magnitude of solar energy throughout the day. It effectively demonstrates that while the timing of peak sun is consistent, the actual energy output varies greatly day-to-day based on environmental conditions.

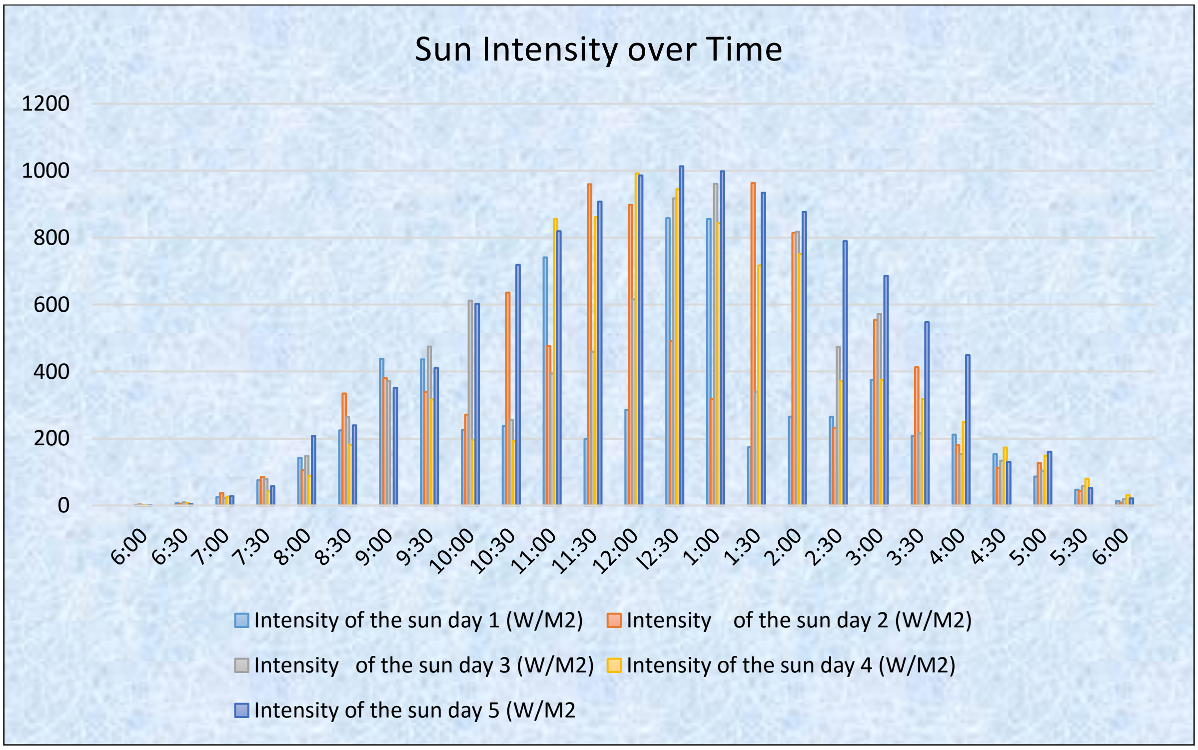

Figure 3: Column Plot for Sun Intensity over Time

Figure 3 presents the solar irradiance data using a grouped bar chart, which allows for a direct side-by-side comparison of sun intensity across the five days at specific time intervals. Figure 3 is the most effective format for cross-sectional analysis. It highlights that while Day 5 is often the strongest, other days occasionally outperform or match it at specific times.

Table 2: Pearson Correlations of Sun Intensity

		SunIntensity1	SunIntensity2	SunIntensity3	SunIntensity4	SunIntensity5	Yield
SunIntensity1	Pearson Correlation	1	.347*	.793**	.718**	.636**	.768*
	Sig. (1-tailed)		.045	.000	.000	.000	.000
	N	25	25	25	25	25	25
SunIntensity2	Pearson Correlation	.347*	1	.600**	.798**	.804**	.823**
	Sig. (1-tailed)	.045		.001	.000	.000	.000
	N	25	25	25	25	25	25
SunIntensity3	Pearson Correlation	.793**	.600**	1	.804**	.819**	.903**
	Sig. (1-tailed)	.000	.001		.000	.000	.000
	N	25	25	25	25	25	25
SunIntensity4	Pearson Correlation	.718**	.798**	.804**	1	.880**	.956**
	Sig. (1-tailed)	.000	.000	.000		.000	.000
	N	25	25	25	25	25	25
SunIntensity5	Pearson Correlation	.636**	.804**	.819**	.880**	1	.949**
	Sig. (1-tailed)	.000	.000	.000	.000		.000
	N	25	25	25	25	25	25
Yield	Pearson Correlation	.768**	.823**	.903**	.956**	.949**	1
	Sig. (1-tailed)	.000	.000	.000	.000	.000	
	N	25	25	25	25	25	25

Table 2 presents a Pearson correlation matrix analyzing the relationships between sun intensity across five different days and the resulting yield. With a sample size of 25 for each variable, the table uses one-tailed significance tests to validate these relationships. The table confirms that Sun Intensity is a high-confidence predictor of yield. Because the coefficients (r) for sun intensity 3, 4, and 5 are all above 0.90 when measured against yield, we can conclude that these days likely represented the peak or most influential solar conditions for the production cycle being studied.

Table 3: Nonparametric Correlations of Sun Intensity

			SunIntensity1	SunIntensity2	SunIntensity3	SunIntensity4	SunIntensity5	Yield
Kendall's tau_b	SunIntensity1	Correlation Coefficient	1.000	.540**	.760**	.687**	.567**	.740**
		Sig. (1-tailed)	.	.000	.000	.000	.000	.000
		N	25	25	25	25	25	25
	SunIntensity2	Correlation Coefficient	.540**	1.000	.607**	.733**	.667**	.733**
		Sig. (1-tailed)	.000	.	.000	.000	.000	.000
		N	25	25	25	25	25	25
	SunIntensity3	Correlation Coefficient	.760**	.607**	1.000	.740**	.660**	.820**
		Sig. (1-tailed)	.000	.000	.	.000	.000	.000
		N	25	25	25	25	25	25
	SunIntensity4	Correlation Coefficient	.687**	.733**	.740**	1.000	.733**	.867**
		Sig. (1-tailed)	.000	.000	.000	.	.000	.000
		N	25	25	25	25	25	25
	SunIntensity5	Correlation Coefficient	.567**	.667**	.660**	.733**	1.000	.827**
		Sig. (1-tailed)	.000	.000	.000	.000	.	.000
		N	25	25	25	25	25	25
	Yield	Correlation Coefficient	.740**	.733**	.820**	.867**	.827**	1.000
		Sig. (1-tailed)	.000	.000	.000	.000	.000	.
		N	25	25	25	25	25	25
Spearman's rho	SunIntensity1	Correlation Coefficient	1.000	.696**	.902**	.835**	.680**	.852**
		Sig. (1-tailed)	.	.000	.000	.000	.000	.000
		N	25	25	25	25	25	25
	SunIntensity2	Correlation Coefficient	.696**	1.000	.762**	.875**	.795**	.873**
		Sig. (1-tailed)	.000	.	.000	.000	.000	.000
		N	25	25	25	25	25	25
	SunIntensity3	Correlation Coefficient	.902**	.762**	1.000	.889**	.812**	.934**
		Sig. (1-tailed)	.000	.000	.	.000	.000	.000
		N	25	25	25	25	25	25
	SunIntensity4	Correlation Coefficient	.835**	.875**	.889**	1.000	.875**	.967**
		Sig. (1-tailed)	.000	.000	.000	.	.000	.000
		N	25	25	25	25	25	25
	SunIntensity5	Correlation Coefficient	.680**	.795**	.812**	.875**	1.000	.925**
		Sig. (1-tailed)	.000	.000	.000	.000	.	.000
		N	25	25	25	25	25	25
	Yield	Correlation Coefficient	.852**	.873**	.934**	.967**	.925**	1.000
		Sig. (1-tailed)	.000	.000	.000	.000	.000	.
		N	25	25	25	25	25	25

Table 3 presents the non-parametric correlation analysis for the relationship between sun intensity across five days and total yield. Unlike the Pearson correlation, Kendall's and Spearman's measure monotonic relationships, making them more robust against outliers and non-normal data distributions. Spearman's rank correlation shows an extremely strong positive relationship between all sun intensity measures and yield. Sun Intensity 4 shows a nearly perfect correlation with Yield with coefficient of 0 .967. Sun Intensity 3 and yield has correlation coefficient of 0.934, while and Sun Intensity 5 and yield has correlation coefficient of 0.925 also show very high coefficients. All relationships are significant at the 0.001 level, meaning there is less than a 1% probability that these results are due to random chance. Kendall's is typically more conservative yielding lower numerical values but often more reliable for smaller sample sizes. The relationship between sun intensity and yield remains high and statistically significant. The results of Table 3 confirm the findings of previous analyses: Sun intensity is a highly significant and reliable predictor of yield. The fact that both Spearman and Kendall tests yield high coefficients reinforces the conclusion that as sun intensity increases, yield increases in a highly predictable, monotonic fashion. The stability of these results across different statistical methods suggests a very high degree of confidence in the data.

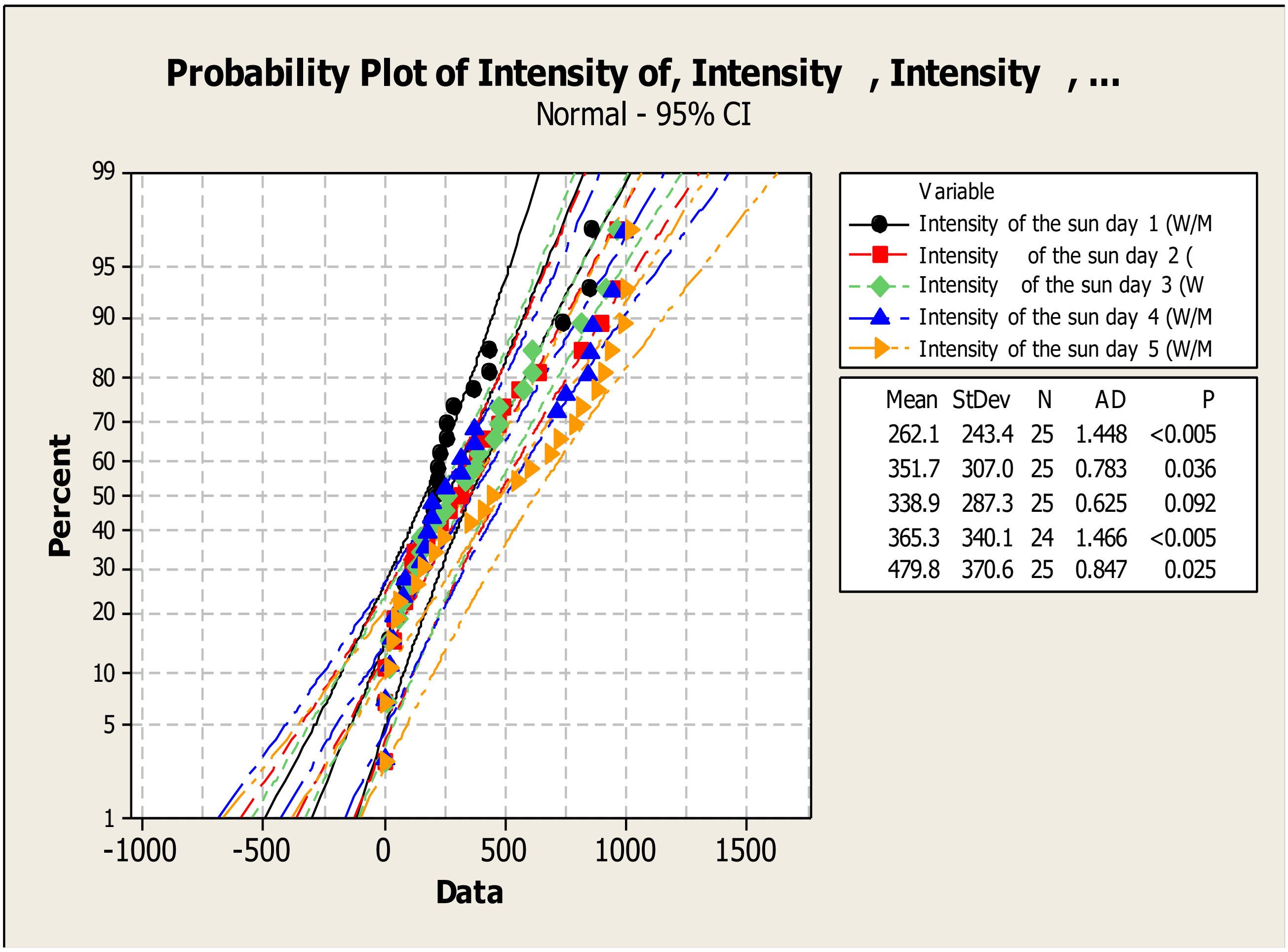

Figure 4: Normal Probability Plot of Sun Intensity over the Experimental Period

Figure 4 is a normal probability plot used to assess whether the sun intensity data for each of the five days follows a normal distribution. In a normal probability plot, if the data points fall closely along the center straight line, the distribution is considered normal. The plot justifies why non-parametric tests were appropriate for this study. Since most of the days (1, 4, and 5) failed the normality test, standard linear assumptions like Pearson's is less reliable than rank-based methods for this specific dataset.

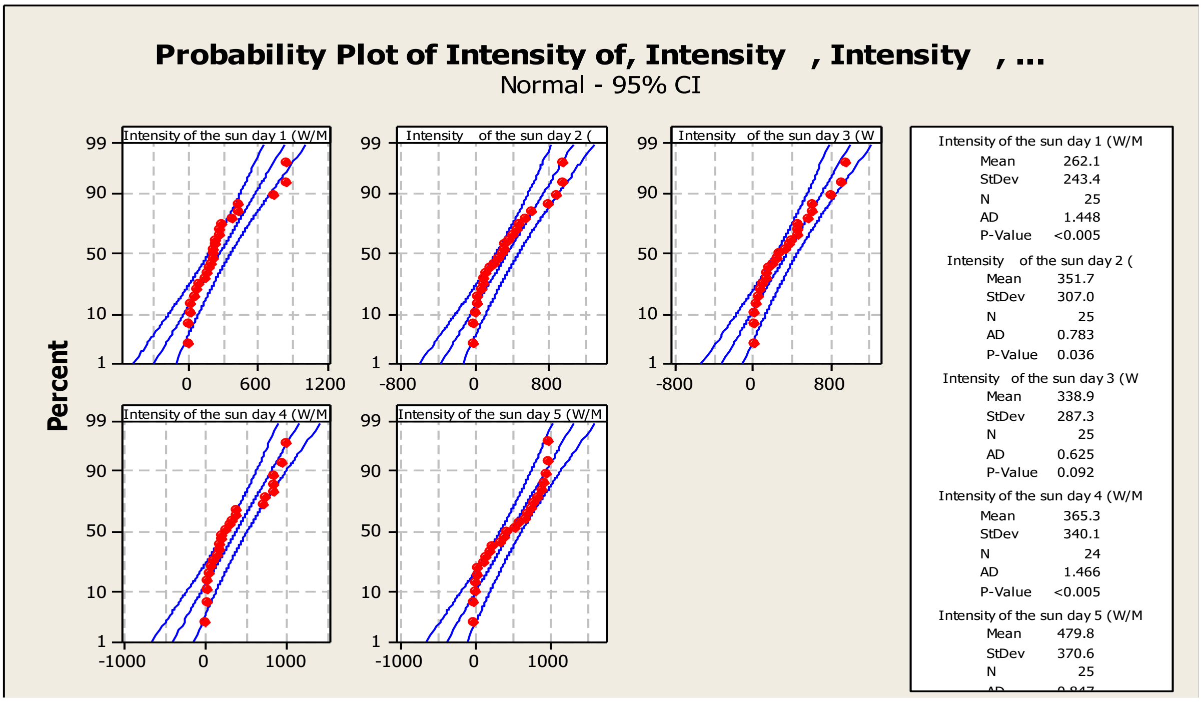

Figure 5: Individual Normal Probability Plot of Sun Intensity over the Period

Figure 5 displays individual Normal Probability Plots for sun intensity across five separate days. This format (small multiples) allows for a clearer view of how each specific day's data points align with the expected normal distribution curve. While the combined plot (Figure 4) showed overlapping lines, these individual charts highlight the specific "S-curve" shapes or outliers for each day. This figure provides the statistical justification for choosing specific data analysis methods. Since the majority of the days do not follow a normal distribution, the use of non-parametric correlations (Spearman and Kendall) mentioned in your earlier tables is the correct and most rigorous approach for this study.

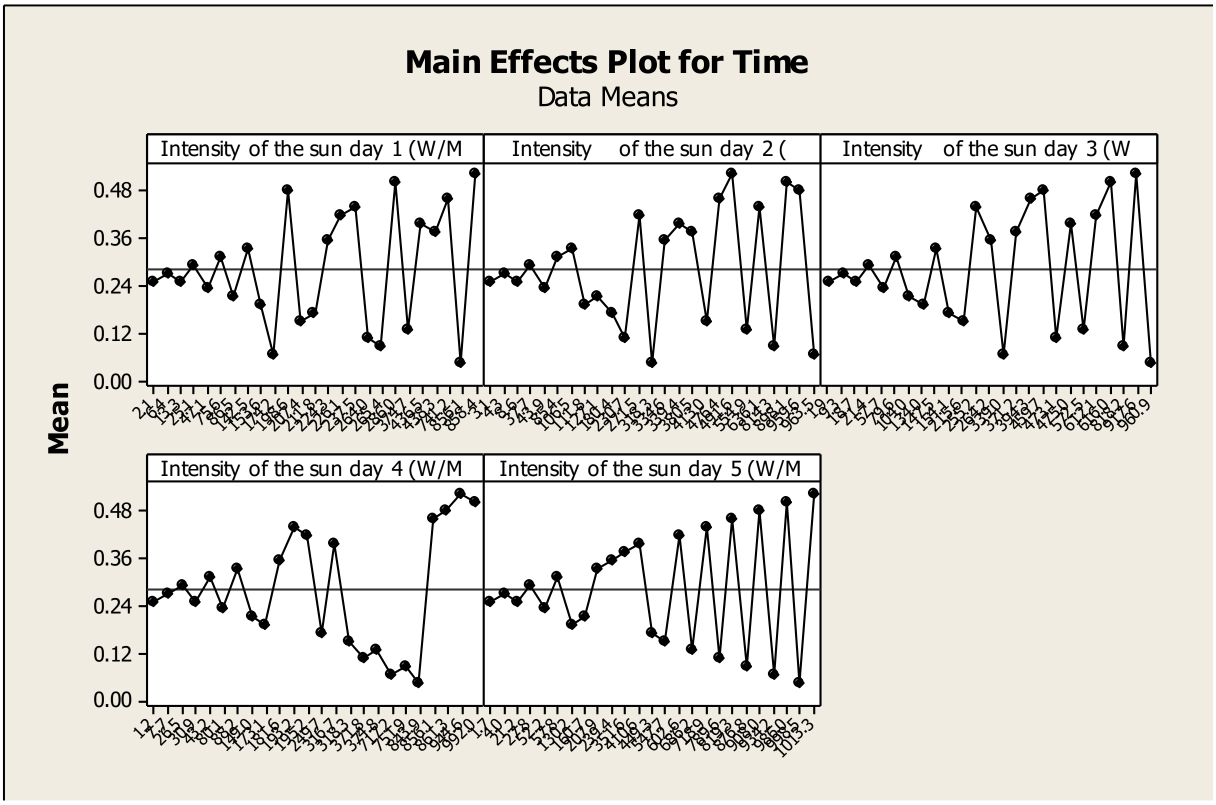

Figure 6: Main Effects Plot for Time

Figure 6 is a main effects plot for time, which illustrates how the mean sun intensity changes across various time-stamped observations for each of the five days. In experimental design, a main effect exists when different levels of a factor (Time) result in different mean responses. These plots clearly show that Time has a substantial main effect on sun intensity, as the means are rarely stable. This figure visualizes the "noise" or variance in the data. While previous charts showed the smooth "bell curve" of a day, the Main Effects Plot reveals the actual instability of solar radiation at a granular level, emphasizing that "time of day" is the most influential factor on the intensity means.

Table 4: Showing the values of temperature for five days

S/N	Time	Temperature Day 1 ("C)	Temperature Day 2 ("C)	Temperature Day 3 ("C)	Temperature Day 4 ("C)	Temperature Day 5 ("C)
1	6:00	19.4	21.1	17.9	17.5	18.1
2	6:30	20.2	21.6	19.8	18.4	19.3
3	7:00	21.5	24.3	20.2	21	20.5
4	7:30	22.3	26.8	20.7	22.3	21.4
5	8:00	22.8	23.2	23.1	23.5	23.1
6	8:30	23.2	23.8	24.3	24.6	22.6
7	9:00	23.7	25.3	24.9	25.3	24.2
8	9:30	24.6	27.3	25.1	26.3	23.9
9	10:00	26.9	28.5	27.8	26.1	27.3
10	10:30	27.4	29.1	27.1	27.5	30.4
11	11:00	27.6	31.4	30.1	31.4	32.6
12	11:30	28.2	32.1	33.1	31.2	34.6
13	12:00	29.7	34.5	34.5	34.5	37.9
14	12:30	34.2	34.7	38.7	36.7	40.1
15	1:00	38.6	39	36.9	35.2	40.6
16	1:30	40.8	37.7	37.5	37.3	38.7
17	2:00	39.5	35.2	34.2	32.2	41.2
18	2:30	37.4	37.1	36.4	28.8	37.5
19	3:00	35.2	35.3	34.3	25.6	33.7
20	3:30	33.9	34.5	32.5	24.3	26.4
21	4:00	34	31.4	30.9	23.9	22.2
22	4:30	32.7	29.6	28.1	22.6	23.9
23	5:00	31.5	29.7	25.6	22.3	20.1
24	5:30	29.6	26.8	22.2	19.6	19.7
25	6:00	23.4	23.9	20.4	20.9	18.8

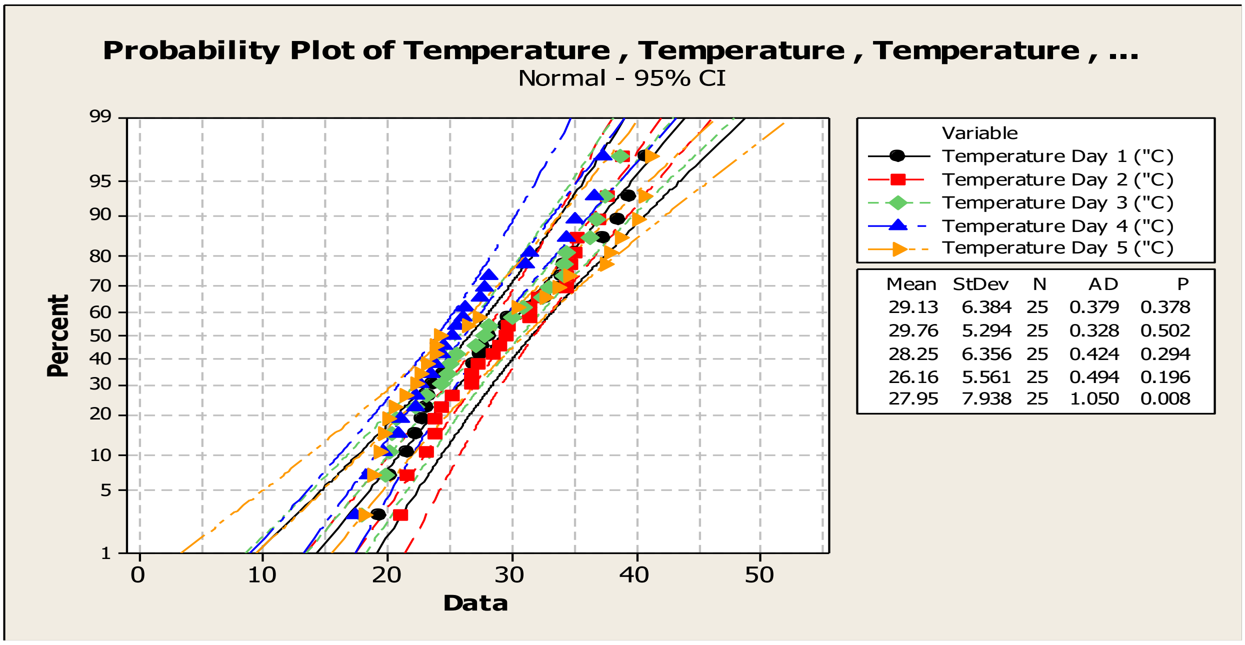

Figure 7: Normal Probability Plot of Temperature over the Experimental Period

Figure 7 is a Normal Probability Plot for temperature data (^{0}C) collected over five days. This chart is used to determine if the temperature variations on each day follow a normal (Gaussian) distribution. The solar intensity data was mostly non-normal; the temperature data is predominantly normal. This suggests that while sun intensity might fluctuate wildly due to clouds, the ambient temperature changes in a more gradual, predictable "bell-curve" fashion for most of the days studied. This allow for the use of more traditional parametric statistics for temperature analysis that wouldn't be appropriate for sun intensity.

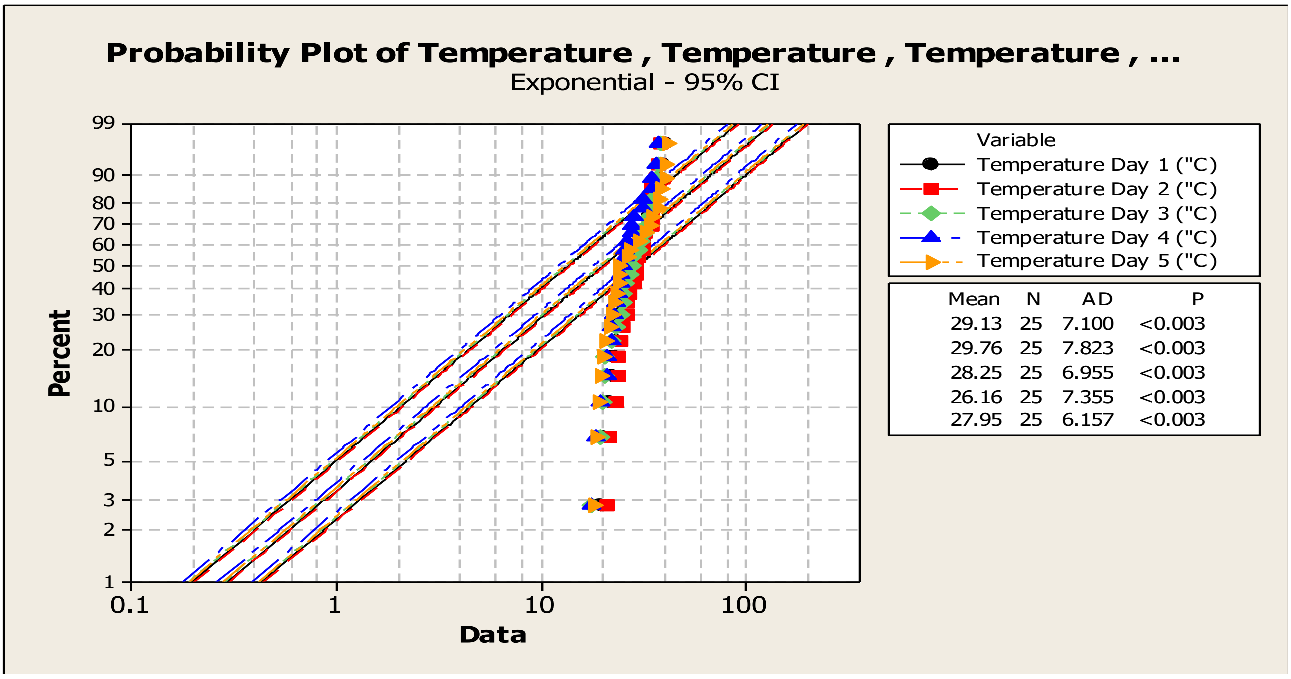

Figure 8: Exponential Probability Plot of Temperature over the Experimental Period

Figure 8 is an Exponential Probability Plot for the temperature data across the five days. While Figure 7 tested for a normal distribution, this chart specifically evaluates whether the data follows an exponential distribution. The vertical alignment of the data points suggests that the temperatures are clustered around a specific range (roughly 20 ^{0}C to 40 ^{0}C) with very little tail, which is the opposite of what an exponential distribution would look like. Comparing Figure 8 to Figure 7 proves that Normal distribution is a much better model for temperature than an Exponential distribution. This is expected for environmental temperature data, which tends to hover around a mean rather than starting high and dropping off rapidly. This validation ensures that researchers don't use the wrong statistical models when predicting temperature trends.

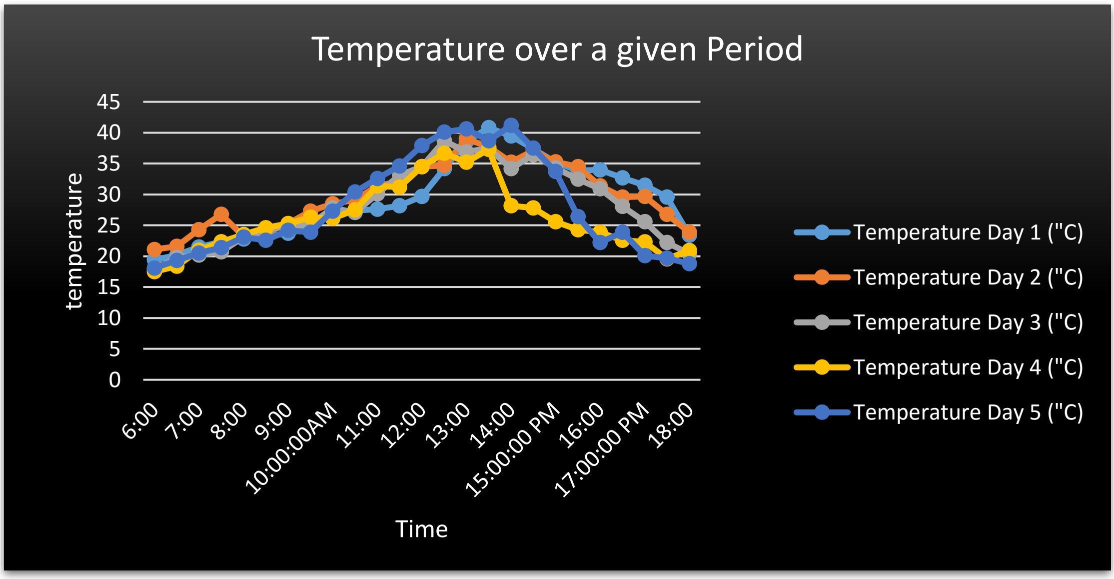

Figure 9: Line Plot of Temperature in the Given Metropolis

Figure 9 is a line plot of temperature over a given period, tracking the ambient temperature (^{0}C) from 6:00 AM to 6:00 PM across five different days. This chart provides a temporal view of thermal energy shifts throughout the daylight hours. Similar to the sun intensity data, temperature peaks in the early afternoon, specifically between 1:00 PM and 2:00 PM. During this window, temperatures reach their maximum of approximately 40 ^{0}Cto 42^{0}C, notably on Day 1 (light blue) and Day 5 (dark blue). Figure 9 shows the result (heat), the Radar Chart (Figure 1) visualizes the input (sun intensity) on a circular 24-hour scale. The radar chart highlights that the solar "thrust" is concentrated at the bottom of the dial (midday), explaining why the temperature curves in Figure 9 all converge toward a peak in that same timeframe. Figure 9 illustrates the direct relationship between time and heat accumulation. It proves that while the sun is most intense at solar noon, the "hottest" part of the day often lags slightly behind, peaking an hour or two later. The consistency between most days suggests a stable climate, with Day 4 serving as a clear example of how atmospheric changes can disrupt the standard daily thermal cycle.

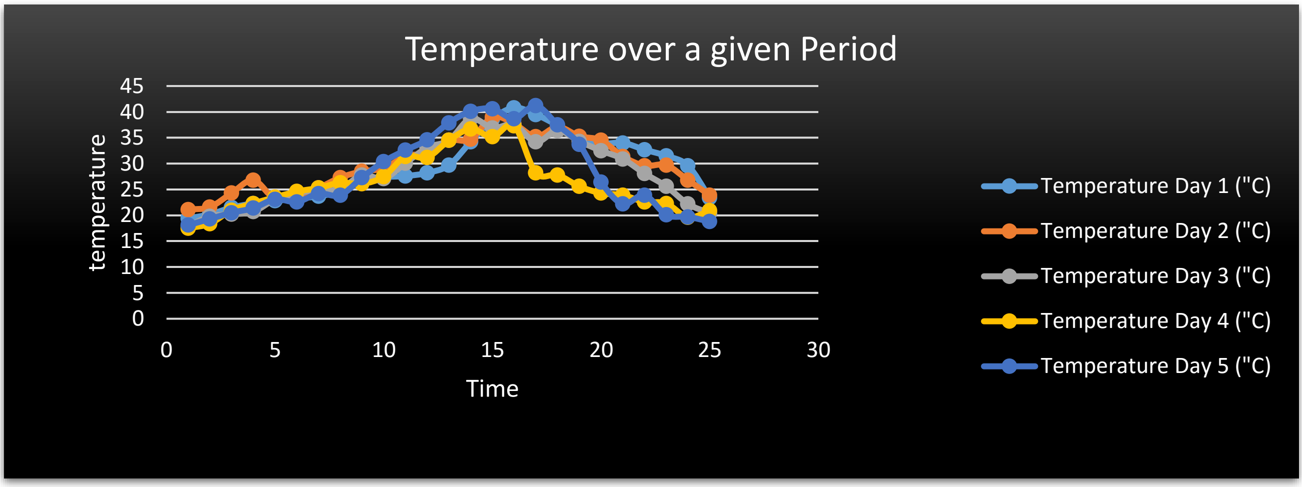

Figure 10: Scatter Plot of Temperature Variations on the Case Study

Figure 10 presents a line plot of temperature over a given period, which effectively replicates the thermal data from Figure 9 but uses a numerical index (1 to 25) on the X-axis instead of specific clock times. Figure 10 serves as a sequential analysis of the temperature data. By stripping away the specific timestamps and focusing on the progression of measurement points, it emphasizes the consistent rate of heating in the morning and the varied, day-specific cooling patterns in the afternoon. This format is particularly useful for statistical modeling where "time" is treated as a continuous sequence of events.

Table 5: Pearson Correlations of Temperature

		Temp.1	Temp.2	Temp.3	Temp.4	Temp.5	Yield
Temp.1	Pearson Correlation	1	.926**	.877**	.616**	.743**	.888**
	Sig. (1-tailed)		.000	.000	.001	.000	.000
	N	25	25	25	25	25	25
Temp.2	Pearson Correlation	.926**	1	.953**	.778**	.867**	.965**
	Sig. (1-tailed)	.000		.000	.000	.000	.000
	N	25	25	25	25	25	25
Temp.3	Pearson Correlation	.877**	.953**	1	.854**	.913**	.983**
	Sig. (1-tailed)	.000	.000		.000	.000	.000
	N	25	25	25	25	25	25
Temp.4	Pearson Correlation	.616**	.778**	.854**	1	.895**	.886**
	Sig. (1-tailed)	.001	.000	.000		.000	.000
	N	25	25	25	25	25	25
Temp.5	Pearson Correlation	.743**	.867**	.913**	.895**	1	.951**
	Sig. (1-tailed)	.000	.000	.000	.000		.000
	N	25	25	25	25	25	25
Yield	Pearson Correlation	.888**	.965**	.983**	.886**	.951**	1
	Sig. (1-tailed)	.000	.000	.000	.000	.000	
	N	25	25	25	25	25	26

This table presents a Pearson Correlation Matrix analyzing the relationship between temperature across five different days (Temp 1–5) and the final Yield. Much like the sun intensity data, these results demonstrate how thermal conditions directly influence production outcomes. The data shows an incredibly strong, positive linear correlation between temperature and Yield across all observations. The peak correlations of temperature 3, with correlation coefficient (r) of 0.983 and temperature 2 with correlation coefficient (r) of 0 .965 show the strongest relationships with Yield. This suggests that the temperature conditions on these specific days were nearly perfect predictors of the final output. All five temperature variables have correlation coefficients above 0.88 with the exception of Temperature 4 and 1 being slightly lower but still very high. This indicates that higher temperatures (within the observed range) are consistently associated with higher yields. Table 5 confirms that temperature is a vital driver of yield. The extremely high coefficients (approaching 1.0) suggest that temperature might even be a slightly more stable predictor of yield than sun intensity was in your previous tables, likely because ambient temperature is less prone to the "instantaneous" volatility seen in solar radiation.

Table 6: Nonparametric Correlations of Temperature

			Temp.1	**Temp.2**	**Temp.3**	**Temp.4**	**Temp.5**	**Yield**
Kendall's tau_b	Temp.1	Correlation Coefficient	1.000	.821**	.767**	.538**	.611**	.787**
		Sig. (1-tailed)	.	.000	.000	.000	.000	.000
		N	25	25	25	25	25	25
	Temp.2	Correlation Coefficient	.821**	1.000	.834**	.604**	.678**	.848**
		Sig. (1-tailed)	.000	.	.000	.000	.000	.000
		N	25	25	25	25	25	25
	Temp.3	Correlation Coefficient	.767**	.834**	1.000	.718**	.751**	.927**
		Sig. (1-tailed)	.000	.000	.	.000	.000	.000
		N	25	25	25	25	25	25
	Temp.4	Correlation Coefficient	.538**	.604**	.718**	1.000	.803**	.751**
		Sig. (1-tailed)	.000	.000	.000	.	.000	.000
		N	25	25	25	25	25	25
	Temp.5	Correlation Coefficient	.611**	.678**	.751**	.803**	1.000	.798**
		Sig. (1-tailed)	.000	.000	.000	.000	.	.000
		N	25	25	25	25	25	25
	Yield	Correlation Coefficient	.787**	.848**	.927**	.751**	.798**	1.000
		Sig. (1-tailed)	.000	.000	.000	.000	.000	.
		N	25	25	25	25	25	26
Spearman's rho	Temp.1	Correlation Coefficient	1.000	.937**	.900**	.649**	.739**	.907**
		Sig. (1-tailed)	.	.000	.000	.000	.000	.000
		N	25	25	25	25	25	25
	Temp.2	Correlation Coefficient	.937**	1.000	.951**	.776**	.844**	.961**
		Sig. (1-tailed)	.000	.	.000	.000	.000	.000
		N	25	25	25	25	25	25
	Temp.3	Correlation Coefficient	.900**	.951**	1.000	.869**	.906**	.987**
		Sig. (1-tailed)	.000	.000	.	.000	.000	.000
		N	25	25	25	25	25	25
	Temp.4	Correlation Coefficient	.649**	.776**	.869**	1.000	.942**	.892**
		Sig. (1-tailed)	.000	.000	.000	.	.000	.000
		N	25	25	25	25	25	25
	Temp.5	Correlation Coefficient	.739**	.844**	.906**	.942**	1.000	.931**
		Sig. (1-tailed)	.000	.000	.000	.000	.	.000
		N	25	25	25	25	25	25
	Yield	Correlation Coefficient	.907**	.961**	.987**	.892**	.931**	1.000
		Sig. (1-tailed)	.000	.000	.000	.000	.000	.
		N	25	25	25	25	25	26

Table 6 presents the non-parametric correlation analysis (Kendall's tau-b and Spearman's rho) between temperature across five days and total yield. While the previous Pearson table measured linear strength, these tests evaluate the monotonic relationship. Spearman's rank correlation shows an extraordinarily strong positive relationship between daily temperatures and yield. Temperature 3 stands out with a nearly perfect correlation coefficient of 0.987 with Yield. All other days (Temperature 1, 2, 4, and 5) also show very high coefficients, all above 0.89. All the variables have statistical significance of 0.000, indicating that the results are significant at the 0.01 level. There is virtually no chance this relationship is accidental. Kendall's tau-b is a more conservative measure of association, typically producing lower numerical values than Spearman or Pearson. The yield correlation values remain high, ranging from 0.751 (Temperature 4) to 0 .927 (Temperature 3). Across all statistical methods (Pearson, Spearman, and Kendall), Temp 3 consistently displays the strongest association with Yield. This implies that the thermal conditions on Day 3 were the most influential for the final output. Since Figure 7 previously showed that Day 5 temperature was non-normal, this non-parametric table is the most statistically "honest" way to report the findings, as it does not rely on the assumption of a perfect bell-curve distribution. Table 6 provides the final piece of evidence that temperature is a decisive driver of yield. Whether measured by linear relationship (Pearson) or rank-order association (Spearman and Kendall), the data shows a high-confidence, positive impact: as temperature values climb within the observed range, yield consistently follows.

5. DISCUSSION

This research was carried out carefully to ensure that the solar power meter (solarimeter) was placed vertically with the sensor pointing to the direction of the sun and the temperature where noted down. The difference in the intensities noted from this research work, were as a result of changes in cloud. In this research, the peak value of solar intensity was recorded on the 10th of February, 2017 which was the 5th day of the research work having a value of 1013.3w/m^2 and the same date has the peak temperature on the experiment to the 41.2°C. The research of this experiment shows that increase in temperature, increases the sun intensity and vice versa. From the analysis, it was observed that the Sun radiation is highest from around 12 noon to 2 pm of the day time and lowest around 6AM to 7AM in the morning hours and around 6 PM in the evenings. The high intensity is as a result of high atmospheric temperature in the area. The correlations of the intensity and the temperature reveal that they are correlated to each other. The application of Kendall's and Spearman's rho correlations is to validate Pearson correlations in other to ensure the validity of their correlations. The sun intensity for the period are all significance with less than 0.05 significance level while the temperature of the experimental period are all significance with less than 0.01 significance level. The probability plots show that the exponential probability plots are more significance than normal probability plots. The result shows the intensity of the sun light is high in afternoon and lower in the early hours of mornings and late hours of evenings. The average solar intensity of extension site in Federal Polytechnic Oko is 356,644w/m^2.

6. CONCLUSION

The study explains the importance of sun intensity of Federal Polytechnic Oko, at the extension site using the solar power meter and the temperature of the day was also recorded with mercury -in -glass thermometers. Readings were tabulated and graph where plotted to show the high level of intensity at the extension site and its environment. This research work will be of great value for the researchers, importers and dealers of solar systems, manufacturers of solar systems and federal government documentation of sun intensity and climatic issues for periodic appraisal use of sun intensity and solar systems in the geographical area.

7. RECOMMENDATION

The research is also recommended for researcher, importers of solar system, manufacturers of solar system and federal government documentation of sun intensity and climatic issues in the geographical area. The Solarimeter instrument is also advised to be used for the documentation of the climatic influence and in optimization of solar intensities of Nigerian geopolitical zone. Periodic utilization of the solarimeter instrument will help to observe the effect of climatic conditions at every interval of the year. It will also help the government and individuals both private and companies for periodic appraisal use of sun intensity and solar systems.

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