TIME SERIES ANALYSIS OF SOLAR RADIATION AND ITS IMPLICATIONS FOR ENERGY GENERATION IN KWARA STATE, NIGERIA

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Abstract:*This study examines the time series analysis of solar radiation and its implications for energy generation in Ilorin. The objective is to examine the trend and seasonality of solar radiation. Data on daily solar radiation were obtained from January to December, 2020 from Nigerian Meteorological Agency, Lagos. Zaitum Time series decomposition method was used in the analysis of seasonality of solar radiation. Seasonal index was used in the measure of the seasonal effects of daily values of solar radiation. The result of the analysis shows that the dispersion characteristics of solar radiation is low and no differential pattern between January – December, 2020. The seasonal indices for periods 2 (February), 3 (March), 4 (April), 6 (June), 8 (August) and 11 (November) shows an above average seasonal effect on the original time series while periods 1 (January) 5 (May), 7 (July), 9 (September) 10 (October) and 12 (December) shows a below average seasonal effect of solar radiation. In term of percentage, the seasonal index indicates that solar radiation in period 3 is 1.19% (1.01192 – 1.0) 100 above the average value and 1.29% (1 – 0.98713)100 below the average solar radiation in period 7. The decrease in solar radiation could be as a result of the effect of cloud, aerosols and pollutant. Furthermore, the result reveals that Ilorin has a rational potential for generating solar energy. Therefore, based on the result of the analysis and the findings, the study recommend that both private sector and the government should take part in the generation of solar energy to compliment the hydroelectric power supply in the area.*

Keywords: *Energy, Nigeria, Radiation, Solar, Variation*

INTRODUCTION

Solar radiation is the basic source of energy that determines biological and physical processes. It is a major requirement in environmental processes. Solar radiation affects virtually all aspects of life because it is pertinent in agriculture, power, water resources, vegetation, soil, animals and even man. Solar radiation supplies the light and heat which are essential conditions needed to maintain life on Earth. Light is critical for photosynthesis to take place. Elements like ozone and oxygen are produced in the atmosphere as a result of chemical reaction produced by solar radiation. According to Gueymard, (2012) the quantity and quality of solar radiation is what totally determines the subtle balance of the Earth's ecosystems, the agricultural and forestry resources needed for human or animal food, and even the development of our civilizations. The amount of solar energy received depends on the amount of solar radiation reaching the Earth's surface. According to Soneye et al. (2019) understanding the incoming solar radiation is very vital in determining its main contributions to the surface radiation energy balance and its usefulness in solar electrical and direct thermal applications, solar voltaic technology, studying of land-surface processes and validation of crop growth stimulation models.

Solar radiation varies from place to place and exhibits both temporal and seasonal variations. This is because there are factors that affect the amount of solar radiation reaching the earth surface. Akpotu and Aruna, (2013) reported that temporal variation of the amount of solar radiation incident at any location on the earth′ s surface basically depends on astronomical, geographical and climatic factors (concentrations of water vapour, aerosols and clouds) in atmosphere. The latitude of the location, the time of day and the season are the major factors that determines solar radiation the reach the earth surface (Oyediran et al., 2001). The amount of solar energy received depends on the amount of solar radiation reaching the Earth's surface. According to Obukhov, et. al. (2018), the amount of solar radiation reaching the surface of solar panels depends on the geographical latitude of the solar power plant location, day of year and time of day, orientation angles of the receiving surface of the solar panel relative to the Sun, the concentration of atmospheric gases, dust, aerosols and water vapor suspended in the air, and the nature of cloud cover and underlying surface. Therefore, these factors that affect the amount of solar radiation reaching the earth surface will definitely affect the amount of energy generated from the sun. The potential solar energy that could be used by humans varies from the amount of solar energy present near the surface of the earth because factors such as geography, time variation, cloud cover, and the land available to humans limits the amount of solar energy that we can acquire. Variation in time affects the potential of solar energy because during the night time there is little solar radiation on the surface of the Earth for solar panels to absorb and this limits the amount of energy that solar panels can absorb in one day. Similarly, cloud cover can affect the potential of solar panels because it blocks incoming light from the sun and reduce the light available for solar cells (UNDP and WEC, 2000). The determination of temporal variation of solar radiation is significant for a reliable assessment of solar energy.

Time series analysis is concerned with the analysis of data collected over time which could be daily, weekly, monthly or yearly. The essential feature to note in time series data is the structure and the nature of the short and long term variations of the data. Time series is used to distinguish whether there is some pattern in the values of a set of data and prediction. It is therefore, against this background that this research study is put forward to examine the time series analysis of solar radiation and its implications for energy generation in Ilorin.

The Study Area

The study was carried out in Ilorin. Ilorin is the State Capital of Kwara State. It is located on latitude $8^0$24'N and $8^0$36'N and longitude $4^0$10E and 4^0 36'E and situated within the North Central geopolitical zone of Nigeria. There are three local Government areas in Ilorin. These are; Ilorin West, Ilorin East, and Ilorin South. Ilorin is positioned at a strategic point between the densely populated South-Western and the sparsely populated middle belt of Nigeria (Ajadi, et, al, 2020). According to 2006 population census, Ilorin had a population of 777,667 (NPC, 2006) and estimated population of 1944,000 as at 2020 (Macro Trend Population Projections).

Figure 1 shows the map of Kwara State and Ilorin, the study area.

The climate of Ilorin exhibits both wet and dry seasons. The wet or rainy season begins towards the end of April and last till October. The dry season begins in November and end in April. Temperature in Ilorin ranges from 33^0C to 35^0C from November to January and from 34^0C to 37^0C from February to April. The total annual rainfall ranges from 990.3mm to 128mm. The rainfall exhibits double maximal pattern. Relative humidity ranges from 75% to 88% from May to October and 35% to 80% during the dry season. The mean monthly sunshine hour ranges between 119hr to 226hr while the mean daily sunshine hours, ranges between 4hr to 8hr (Adeniyi and Abubakar, 2020). Ilorin comprises of Precambrian basement complex rock. The soils are easy to farm and made up of loamy soil with medium and low fertility. There is tendency for lateritic soil to constitute the major soil types in Ilorin due to the leaching of minerals nutrients of the soil as a result of the high seasonal rainfall coupled with the high temperature, (Ajibade and Ojelola, 2004). The elevation of the area varies from 273m to 333m in the western side with isolated hill (Sobi Hill) of about 394m above the sea level while on the eastern side it varies from 273m to 364m (Ajibade and Ojelola, 2004). The lowest level is along the river valley of Asa and Oyun while the highest point is Sobi Hill. According to Olorunfemi, (2001) the socio-economic activities in Ilorin has increased tremendously from agricultural practices of growing food crops to local craft of cloth weaving, leather works, pottery, embroidery, tie and dye, mat making etc. to modern commerce with viable trading industry and administrative activities. Agricultural activities in Ilorin are limited to small garden plots of maize, beans, and vegetables which are cultivated mainly for domestic consumption. according Cultivation of tuber crops like yam and cassava are mainly done at the outskirts of the city. According to Ajadi and Tunde, (2010), the major occupations within Ilorin metropolis, include distributive trading, civil service of varying cadres and persuasions and a host of informal sector services.

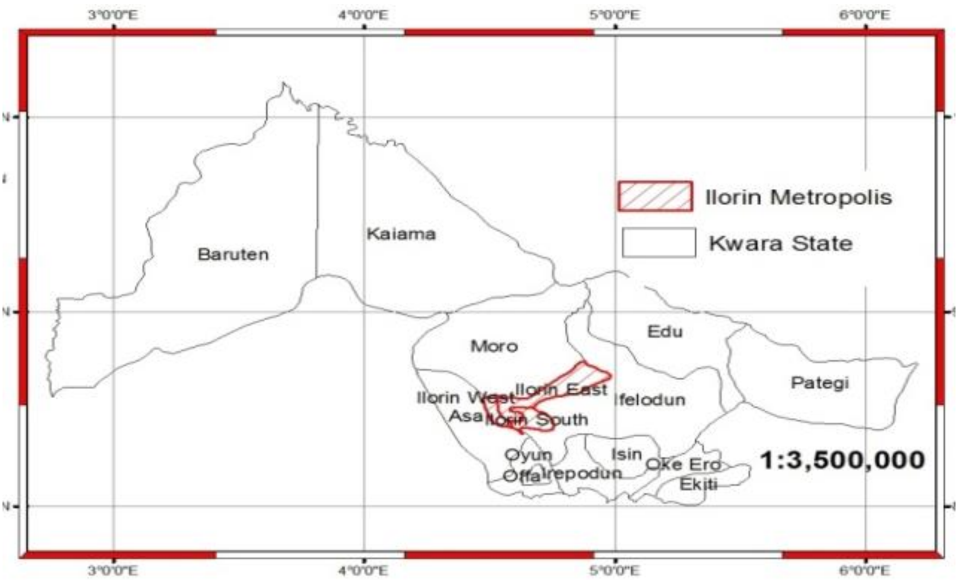

Fig. 1: Map of Kwara State showing the study area.

MATERIAL AND METHODS

Trend, seasonal, cyclical and irregular or random are the major components of time series. The trend is the increase or decrease in values of time series while seasonal is the movements that occur in a time series within a one year. The cyclical and irregular or random components are the nonperiodic fluctuations in time series data and the residuals in a time series that are left after trend, cyclical and seasonal components have been removed. The duration of trend and cyclical is more than one year while that of seasonal component is within one year. However, for this study, the main focus is on trend and seasonal analysis of solar radiation in Ilorin. This is because daily solar radiation data in Ilorin were collected from January to December, 2020. The solar radiation data were collected from the Nigeria Meteorological Agency, Lagos.

Analysis of the data was carried out using Zaitum software. Zaitum Time series decomposition method was used in the analysis of seasonality while seasonal index was used in the measure of the seasonal effects and prediction of daily values of solar radiation. Semi-average method was used to analyse the trend of the data.

RESULTS AND DISCUSSION

Descriptive Analysis of Solar Radiation in Ilorin (January – December, 2020)

Table 1 shows the descriptive analysis of solar radiation data in Ilorin (January – December, 2020). The highest mean value of solar radiation is 24.6 in February and March, 2020 while the lowest mean value is 16.4 in July, 2020. This implies that the highest value of solar radiation was recorded in February and March, 2020. Similarly, the highest standard deviation was recorded in August, 2020 while the lowest deviation value was recorded in November, 2020. The result of the standard deviation reveals that the dispersion characteristics of solar radiation in the study area is low. The coefficient of variation which shows the relative deviation between values of solar radiation showed that solar radiation is homogeneous with values less than 33%. This implies that there is no differential pattern in the values of solar radiation in Ilorin between January – December, 2020.

Table 1: Descriptive Analysis of Solar Radiation in Ilorin
(February, 2020 – January, 2020)

Month	Mean	Standard Deviation	Coefficient of Variation
January 2020	22.2	2.1	9.5
February 2020	24.6	1.5	6.1
March 2020	24.6	2.3	9.3
April 2020	20.7	1.9	9.2
May 2020	19.2	2.3	12.0
June 2020	17.4	1.8	10.3
July 2020	16.4	1.9	11.6
August 2020	16.6	3.0	18.1
September 2020	18.6	1.6	8.6
October 2020	19.5	1.9	9.7
November 2020	22.7	1.4	6.2
December 2020	23.5	2.2	9.4

Source: Authors' Computation, 2020

Trend of Daily Solar Radiation in Ilorin (January – December, 2020)

Fig. 2 (a-l) shows the actual and trend line of daily solar radiation from January to December, 2020 in Ilorin. From the figures, the trend line shows an increase in the values of the daily solar radiation in February, August, September, October, and November. This implies that values of daily solar radiation in these months exhibits an upward trend. On the other hand, the trend line shows a decrease in the values of solar radiation in March, April, May, June, July and December. This also implies that values of solar radiation in these months exhibits a downward trend. Generally, the values of daily solar radiation in the study area shows an increasing trend in six months and decreasing trend in six months.

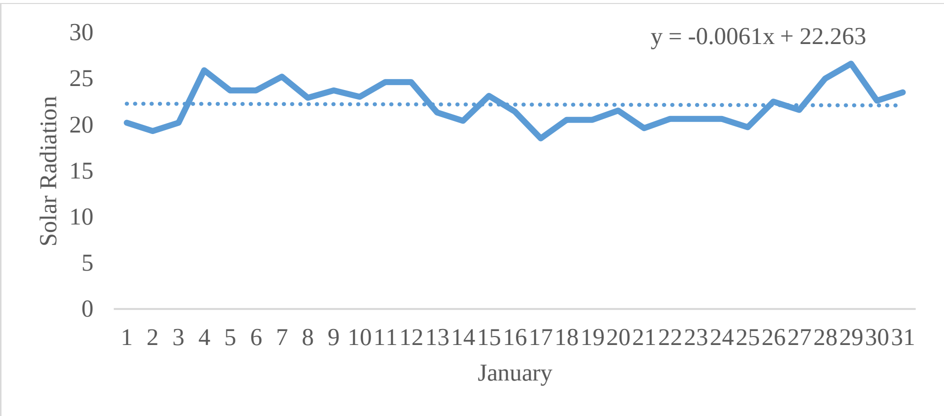

Figure 2a: Trend of Daily Solar Radiation in January 2020 in Ilorin

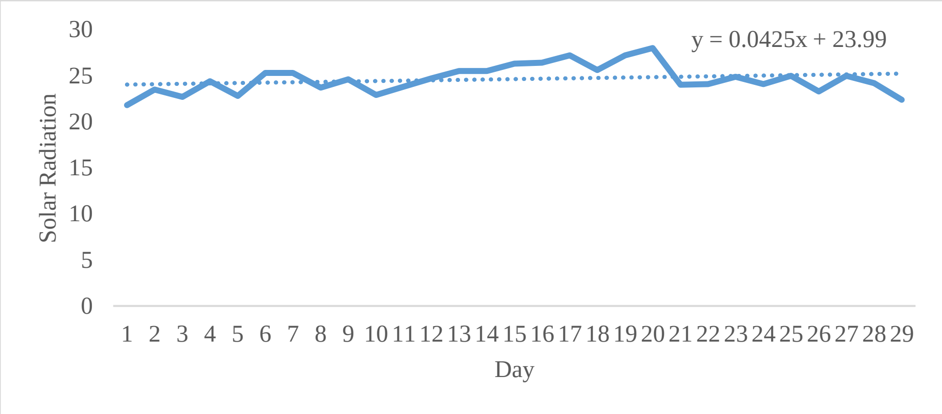

Figure 2b: Trend of Daily Solar Radiation in February 2020 in Ilorin

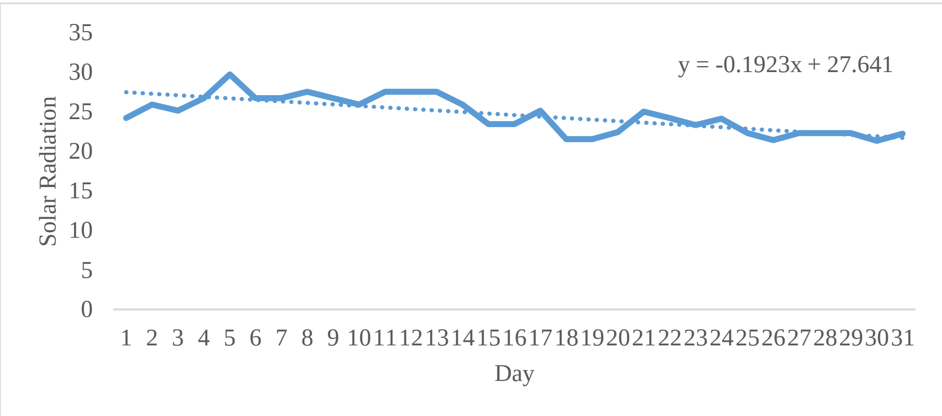

Figure 2c: Trend of Daily Solar Radiation in March 2020 in Ilorin

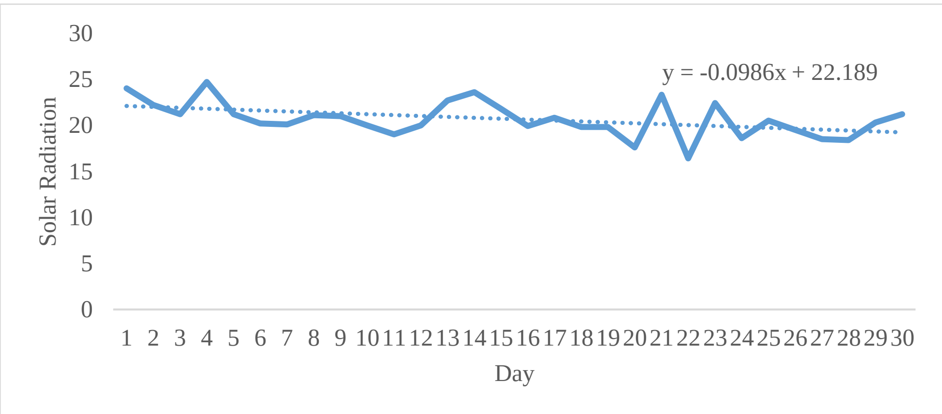

Figure 2d: Trend of Daily Solar Radiation in April 2020 in Ilorin

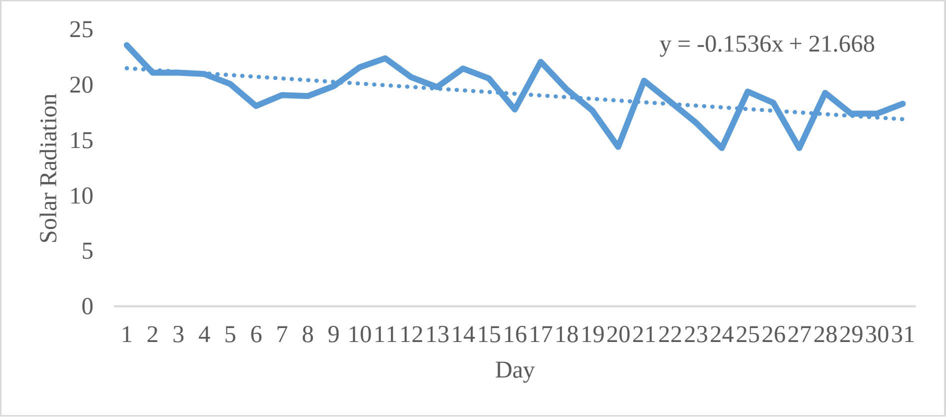

Figure 2e: Trend of Daily Solar Radiation in May 2020 in Ilorin

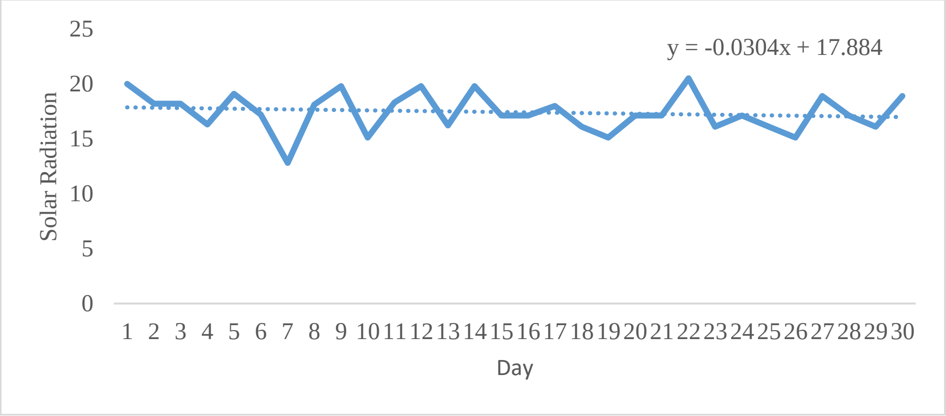

Figure 2f: Trend of Daily Solar Radiation in June 2020 in Ilorin

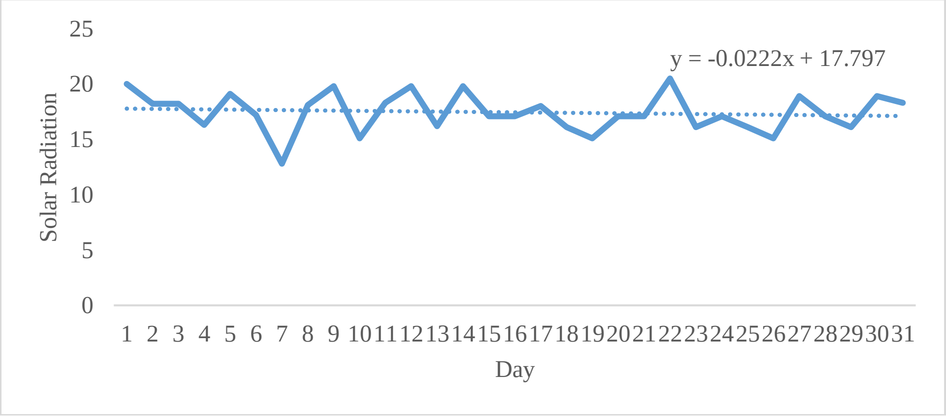

Figure 2g: Trend of Daily Solar Radiation in July 2020 in Ilorin

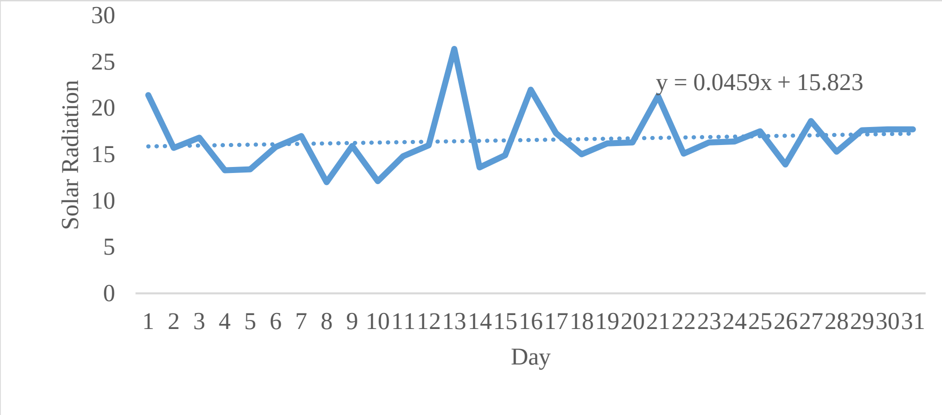

Figure 2h: Trend of Daily Solar Radiation in August 2020 in Ilorin

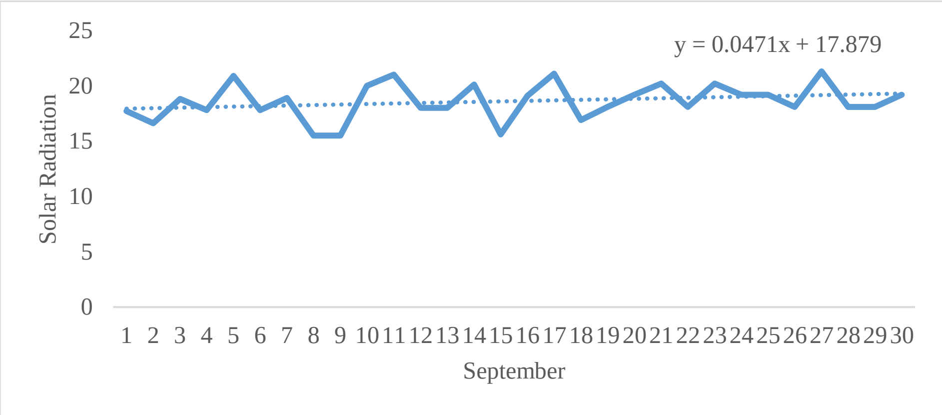

Figure 2i: Trend of Daily Solar Radiation in September 2020 in Ilorin

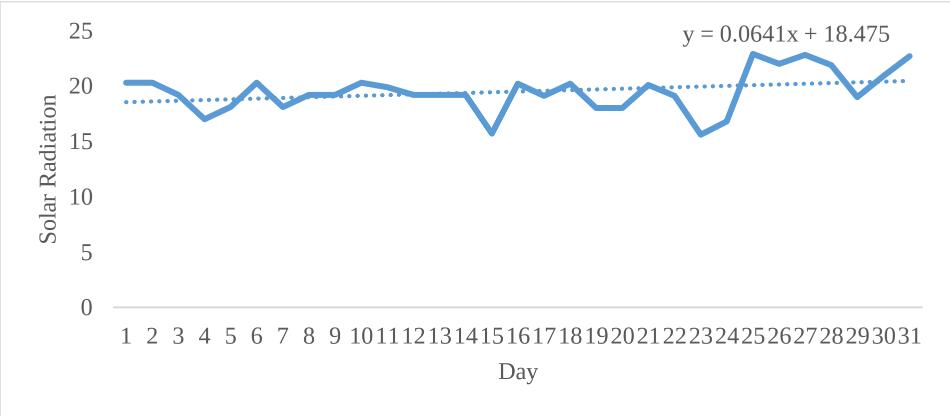

Figure 2j: Trend of Daily Solar Radiation in October 2020 in Ilorin

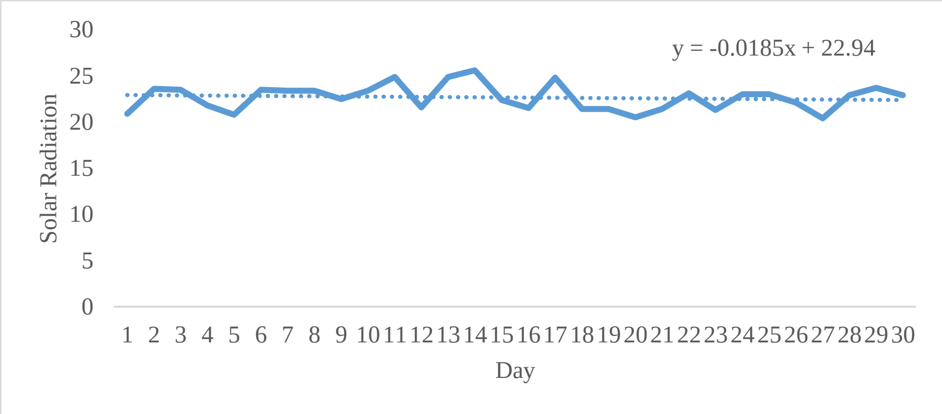

Figure 2k: Trend of Daily Solar Radiation in November 2020 in Ilorin

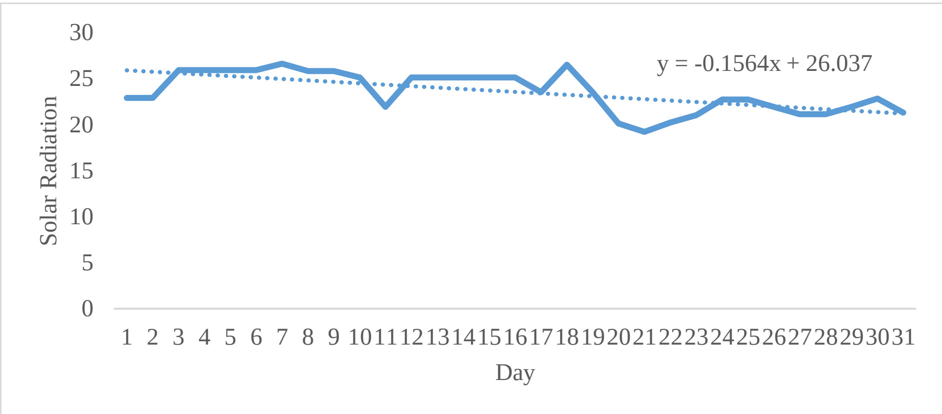

Figure 2l: Trend of Daily Solar Radiation in December 2020 in Ilorin

Trend in Solar Radiation in Ilorin Using Semi-Average Method (January – December, 2020)

The annual value of solar radiation in Ilorin from January to December, 2020 was analysed for trend using semi-average method. The data was divided into two. The first part average was 21.40 while the second part average was 19.55. This shows that the first part average is greater than the second part average. This implies that solar radiation in Ilorin from January to December 2020 exhibits a downward trend. The result suggests that solar radiation declined from January to December, 2020. The decrease in solar radiation could be as a result of the effect of cloud, aerosols and pollutant.

Seasonal Analysis of Solar Radiation in Ilorin (January – December, 2020)

Seasonal indices which attempt to gauge the degree at which the seasons differ from each other was used to measure the seasonal effect of solar radiation. Table 2 shows the seasonal indices of solar radiation in Ilorin. From the table, the seasonal index for periods 2 (February), 3 (March), 4 (April), 6 (June), 8 (August) and 11 (November) shows an above average seasonal effect on the original time series data. This implies that solar radiation in those period was above the average of the original values. On the other hand, the seasonal indices in the periods 1 (January) 5 (May), 7 (July), 9 (September) 10 (October) and 12 (December) shows a below average seasonal effect of solar radiation. This also implies that solar radiation in those period was below the average of the original values. In term of percentage, the seasonal index indicates that solar radiation in period 3 is 1.19% (1.01192 – 1.0) 100 and 2.41% (1.02414 – 1.0) 100 in period 11 above the average value. However, the seasonal index indicates that solar radiation in period 7 is 1.29% (1 – 0.98713) and 0.06% (1 – 0.99938) in period 12 below that average solar radiation. The seasonality indices in the months of January, May, July, September, October and December are low.

The measures of accuracy of the analysis is presented as follows: Sum Square Error (SSE) of 4266.545655, Mean Squared Error (MSE) of 11.657229, Mean Absolute Error (MAE) of 2.81562, Mean Percentage Error (MPE) of -3.024067 and Mean Absolute Percentage Error (MAPE) of 14.549143.

Table 2: Seasonal Indexes of Solar Radiation in Ilorin
(January – December, 2020)

Period	Month	Index
1	January	0.97787
2	February	1.01723
3	March	1.01192
4	April	1.00399
5	May	0.99799
6	June	1.00082
7	July	0.98713
8	August	1.00597
9	September	0.97942
10	October	0.99414
11	November	1.02414
12	December	0.99938

Source: Authors' Computation, 2020

Forecast of Solar Radiation

Seasonal index can also be used for forecasting. Table 3 shows the forecast of seasonality of solar radiation Ilorin (January to December, 2021). The monthly forecast values were determined by finding the product of seasonal index and the trend value of each month. The period represents the month of the year starting from January to December. From the table, the value of solar radiation in March was predicted to be 22W/m^2 while that of November was predicted to be 22.2 W/m^2. ^{s}

Table 3: Forecast of Monthly Solar Radiation in Ilorin (January to December, 2021)

Period	Seasonal Index	Year	Trend value	Forecast (W/m^2)
1	0.97787	2022	21.7	21.2
2	1.01723	2022	21.7	22.1
3	1.01192	2022	21.7	22.0
4	1.00399	2022	21.7	21.8
5	0.99799	2022	21.7	21.7
6	1.00082	2022	21.7	21.7
7	0.98713	2022	21.7	21.4
8	1.00597	2022	21.7	21.8
9	0.97942	2022	21.7	21.3
10	0.99414	2022	21.7	21.6
11	1.02414	2022	21.7	22.2
12	0.99938	2022	21.7	21.7

Source: Authors' Computation, 2020

Irregular or Random Variation of Solar Radiation in Ilorin (January – December, 2020)

The random variation in a time series analysis are referred to as irregular or random variations or fluctuations. They are the variations that are left over after trend, cyclical and seasonal components have been removed. Such variations occur due to unpredictable factors. Therefore, it is not possible to predict the irregular variations. Fig. 3 shows the residua, irregular variations while fig. 4 shows the trend of daily solar radiation in Ilorin.

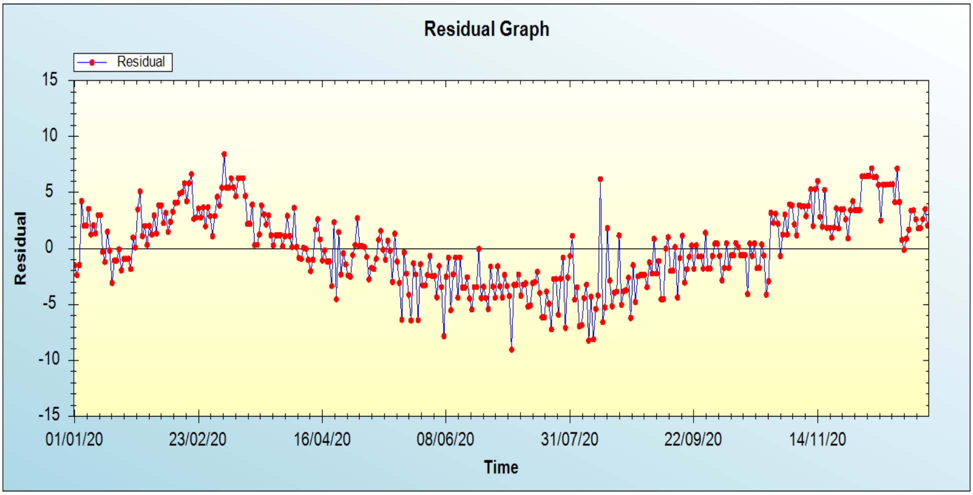

Fig. 3: Irregular Variations Solar Radiation in Ilorin (January – December, 2020)

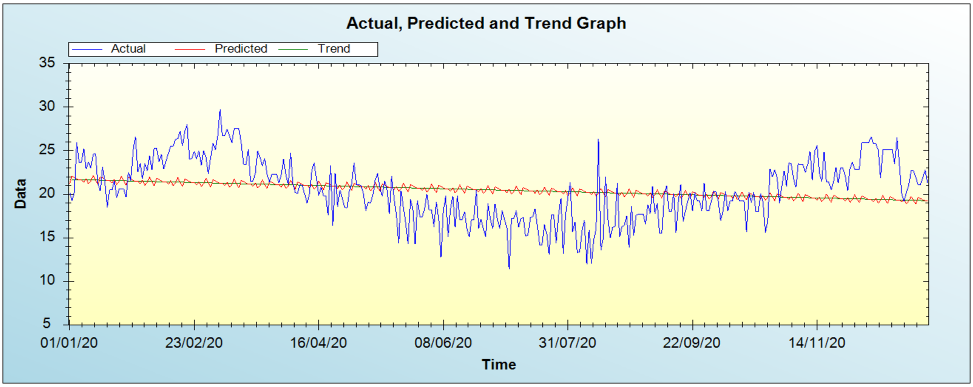

Fig. 4: Trend of daily Solar Radiation in Ilorin (January – December, 2020)

CONCLUSION AND POLICY RECOMMENDATION

The result of the trend analysis showed that solar radiation exhibits both downward and upward trend in Ilorin from January to December, 2020. This implies that reduced solar radiation trend was identified in Ilorin. The downward trend shows a decrease in the values of solar radiation. The decrease in solar radiation could be as a result of the effect of cloud, aerosols and pollutant. On seasonality indices, the seasonal index for periods 2 (February), 3 (March), 4 (April), 6 (June), 8 (August) and 11 (November) shows an above average seasonal effect on the original time series data while the seasonal indices in the periods 1 (January) 5 (May), 7 (July), 9

(September) 10 (October) and 12 (December) shows a below average seasonal effect of solar radiation. In term of percentage, the seasonal index indicates that solar radiation in period 3 is 1.19% (1.01192 – 1.0) 100 and 2.41% (1.02414 – 1.0) 100 in period 11 above the average value. However, the seasonal index indicates that solar radiation in period 7 is 1.29% (1 – 0.98713) and 0.06% (1 – 0.99938) in period 12 below that average solar radiation. The implication of the result is that solar radiation will keep on decreasing. This suggest that potential solar energy generation in the area will keep on decreasing. However, reasonable amount of solar energy could be generated in the area. Therefore, this paper hereby recommends that both private sector and the government should take part in the generation of solar energy to compliment the hydroelectric power supply in the area.

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