IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 6, Issue 6 Ver. III (Nov.-Dec. 2014), PP 01-10
www.iosrjournals.org

The Spatial and Temporal Variability of Sunshine Hours in Nigeria (1961 - 2012)

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Abstract: *For the purposes of providing evidence-based knowledge of climate change and assessing solar energy resources in different parts of Nigeria, this paper provides a synopsis of the spatial and temporal variability of sunshine hours on the basis of data records obtained from 20 instrumental series covering the period 1961 – 2012. Basic data comprises monthly mean daily sunshine duration in hours obtained from the Nigerian Meteorological Agency, Oshodi, Lagos. Mann-Kendall's rank correlation tests, least square regression, Pearson's Product moment correlation, Time series plots, Bar charts and descriptive statistics were used for the analysis. The results indicate dominant significant downward trends and few significant upward trends. The months of November to February indicate highest monthly mean daily sunshine hours while July, August and September months indicate minimum sunshine hours. The monthly mean daily sunshine hours show elevation and latitudinal dependence, increasing with altitude and latitudes of the synoptic stations. The stations record high coefficient of variation that shows neither elevation nor latitudinal dependence. The results are consistent with other studies carried out earlier at different temporal and spatial scales across the globe.*

Key words:*Sunshine hours, Trends, variability, Mann-Kendall, Least square regression, Nigeria.*

I. Introduction

For the purposes of assessing evidence of climate change and solar energy resources in different parts of Nigeria, this study examines the spatial and temporal variability of sunshine duration at 20 synoptic stations during the period 1961 – 2012. The seasonal duration of sunshine during the 52 year period is analyzed and the trends during this interval are mapped out. Although evidence of climate change is mainly based upon measurement of rainfall & temperature, other climatic parameters are emerging as strong climate change indicators. A need for more research supported and extended with the use of other climatic variables such as sunshine hours, recorded for a long time period and successfully used as a proxy for solar radiation has been proposed. Thus, in this study, sunshine duration is used for highlighting the trends in climate change and variability.

Some studies have examined the trends in sunshine hours in the context of climate change. Durlo (2006) examined the multiannual variation of the effective sunshine duration in the Beskid Sadecki mountain over 35 year period (1971 – 2005) using the linear regression model for trend testing and estimation. Sanchez-Lorenzo et al, (2009) analyzed trends in sunshine duration and total cloud cover over the Iberian Peninsula for the period 1961 – 2004 using the least square linear fitting and the Mann-Kendall non-parametric test for trend estimation and significance testing respectively. Similar studies have been carried out in different parts of the world over various periods (e.g. Rahimzadeh et al, 2014; Dobesch, 1992; Kitsara et al, 2013; Angell, 1990; Stanhill and Cohen, 2005). The results from these studies indicate existence of trends at different spatial and temporal scales.

Sanchez-Lorenzo et al, (2006) noted that clouds are the leading cause of inter annual and decadal variability of radiation reaching the earth's surface, and that they exert a dominant influence on the global energy balance. Theyfurther observed that there are still large uncertainties about how clouds will respond to climate change, despite important advances in recent years in understanding them. There have been observed increases and decreases in solar radiation reaching the earth's surface (and by extension sunshine hours) in many regions of the world over different time periods. Although causes of these increasing and decreasing phenomena are not fully understood currently, some studies have attributed the likely causes to changes in the transmissivity of the earth's atmosphere due to changes in the concentration and optical properties of aerosols as consequences of anthropogenic emissions (Stanhill and Cohen, 2001; Wild et al, 2005, 2007). Some studies have revealed that the dimming (decrease in solar radiation) period appears more clearly in large urban areas as a consequence of local pollution and consequently could not be a global phenomenon (Alpert et al, 2005; Alpert and Kishcha, 2008). As cloudiness is the greatest modulator of solar radiation reaching the earth's surface, it has also been suggested that the dimming period may be linked to a detected increase in total cloud cover (Dai et al, 1999). Changes in global solar radiation have been detected by some studies under clear skies (e.g. Wild et al, 2005; Ruckstuhl et al, 2008) and cloudy skies (e.g. Liepert, 2002). These changes are presumably due to variations in atmospheric transparency linked to changes in anthropogenic aerosols. Apart from the direct aerosol effects which relate to their capacity to scatter or absorb solar radiation, Sanchez-Lorenzo et al, (2009) mooted the importance to consider their indirect effects as well. According to them, these indirect effects are more uncertain and correspond to aerosol – induced changes in cloud properties such as lifetime and albedo. Other studies (e.g. Ramanathan et al, 2001; Rosenfeld et al, 2008) linked the modification of precipitation forming processes to aerosol indirect effects. A difficulty in establishing the causes of the increase and decrease in surface solar radiation is the limited number of solar radiation series with accurate and calibrated long-term measurements. Thus the analysis could be supported and extended with the use of other climatic variables such as sunshine duration, evaporation or visibility (Stanhill, 2005). According to Sanchez-Lorenzo et al, (2009) sunshine duration is defined as the amount of time, usually expressed in number of hours, that direct solar radiation exceeds a certain threshold (usually taken at 120Wm^{-2}). This variable is considered and used in the present work as an excellent proxy measure of global solar radiation (Stanhill and Cohen, 2008; Liang and Xia, 2005). The main objective of this study is to examine the trends in sunshine duration in Nigeria using sunshine hours records in 20 synoptic stations for the period 1961 – 2012. The second objective is to determine the seasonal variation of sunshine hours in the stations. The third objective is to examine the interstation correlation of the sunshine hours (for the stations).

II. 2.0 The Study Area Location

Nigeria lies between Longitude 2°E and 15°E and between Latitude 4°N and 14°N. Fig 1 is the map of Nigeria indicating the 20 synoptic stations used in the study.

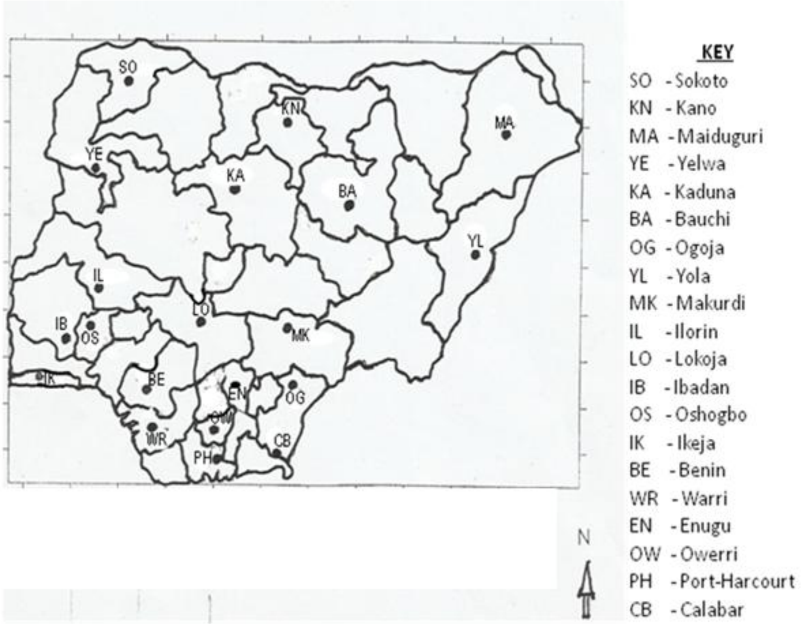


Fig 1. Location map of the study area

III. The Data

The monthly mean daily sunshine duration data in hours were obtained from the Nigerian Meteorological Agency (NIMET), Oshodi, Lagos. The data spanned from 1961 – 2012. Table 1 is the summary of the station data used in the study.

Table 1: Summary of the station data used in the study.

S/N	Station Name	Latitude (^{o}N)	Longitude (^{o}E)	Altitude (m)	Data length	% missing records
1.	Yelwa	10.53	4.45	244	1965 – 2012	4.17
2.	Sokoto	12.55	5.12	251	1961 – 2012	9.62
3.	Kaduna	10.42	7.19	645	1961 – 2012	0.00
4.	Kano	12.03	8.32	476	1961 – 2012	1.92
5.	Bauchi	10.17	9.47	591	1961 – 2012	11.54
6.	Maiduguri	11.51	13.05	354	1961 – 2012	0.00
7.	Ilorin	8.26	4.30	308	1961 – 2012	7.69
8.	Yola	9.16	12.26	191	1961 – 2012	0.00
9.	Ikeja	6.35	3.20	40	1961 – 2012	3.85
10.	Ibadan	7.22	3.59	234	1961 – 2012	1.92
11.	Oshogbo	7.47	4.29	305	1961 – 2012	0.00
12.	Benin	6.19	5.36	77.80	1961 – 2012	11.54
13.	Warri	5.31	5.44	6.00	1961 – 2012	0.00
14.	Lokoja	7.48	6.44	113	1961 – 2012	7.69
15.	P/H	5.01	6.57	18	1961 – 2012	5.77
16.	Owerri	5.25	7.13	91	1976 – 2012	0.00
17.	Enugu	6.28	7.34	142	1961 – 2012	5.77
18.	Calabar	4.58	8.21	62	1961 – 2012	1.92
19.	Makurdi	7.42	8.37	113	1961 – 2012	9.62
20.	Ogoja	6.40	8.48	117	1976 – 2012	0.00

IV. Methodology

The monthly data were subjected to quality control checks. Some missing entries were observed (table 1). The missing records were not replaced. Shongwe et al, (2006) had suggested the use of data from stations with missing records not exceeding 5%. Only 12 stations meet this requirement. This study adopted the recommendation by Hospking and Wallis (1997) of 10% maximum threshold. This was equally adopted by Ngongondo et al, (2011) for data scarce regions. Even though Bauchi and Benin stations exceed this threshold, Helsel and Hirsch (1992) recommended that monotonic trend analysis could be applied if the missing records do not exceed one-third of the total records. The data were tested for homogeneity using the preliminary step in analysis of homogeneity which is to plot the time series on a linear scale. The plots showed that the data are homogenous but long period fluctuations and trends were revealed. According to Syners 1990, these are acceptable within the non-randomness characteristics of series of climatological observations.

The linear trends of the series were calculated over the period by means of least square linear fitting. The significance of the trends were determined using the non-parametric Mann-Kendall's (M-K) rank correlation test at the 1% and 5% significance levels.

To perform the M-K test, the difference between the later measured values and all earlier measured values, (y_j - y_i), where j>i, are computed. The integer value of 1,0, or – 1 are assigned to the positive differences, no differences, and negative differences respectively. The test statistic, S is then computed as the sum of the integer values:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{Sign}\,(y_j - y_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where sign (y_j - y_i), is equal to 1, 0, or -1.

When S is a large positive number, later measured values tend to be greater than earlier measured values and a positive or upward trend is indicated. When S is a large negative number, later values tend to be less than earlier values and a negative or downward trend is indicated. When the absolute value of S is small, no trend is indicated. The test statistic τ can be determined as:

$$\tau = \frac{S}{n(n-1)/2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

τ has a range of -1 to +1, and is analogous to the correlation coefficient in regression analysis. The null hypothesis, H_o, of no trend is rejected when τ is significantly different from zero ($p< \alpha$) and the alternative hypothesis, H_1, of presence of monotonic trend is accepted.

A simple linear regression of Y on time is a test for linear trend:

$$Y = \beta_o + \beta_1 x + \epsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The null hypothesis is that the slope coefficient β_1=0.

If the slope is significantly different from zero, the null hypothesis is rejected and the alternative hypothesis that there is a linear trend in Y over time with rate equal to β_1 is upheld.

V. Results And Discussion

Table 2 is the descriptive statistics of the sunshine hours across the station. A cursory look at the table indicates that the mean daily sunshine hours over the period show latitudinal variations with higher latitudes having higher values. The northern parts of the country show higher values of mean daily sunshine duration than the south. The table also indicates high coefficients of variation across the stations.

Table 3 is the M-K trend test results. The table shows that 16 stations have a downward trend with 10 stations having statistical significance; 8 is significant at the 1% level while 2 is significant at the 5% level. 4 stations show significant upward trends with significance levels of 1% and 5% indicated by 2 stations apiece.

Table 4 is the Pearson's Product moment correlation matrix. The table indicates that almost all the station pairs show positive correlations that are significant at the 1% level.

Table 2: Descriptive statistics for sunshine hours for the period under analysis

Station	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Range**	**C.V (%)**
Yelwa	552	1.6	14.9	7.386	2.2347	13.3	30.00
Sokoto	562	1.0	10.1	7.710	1.5153	9.1	19.65
Kaduna	624	1.7	9.9	7.656	1.5840	8.2	20.69
Kano	612	0.0	13.0	7.886	1.2623	13.0	16.01
Bauchi	552	1.0	10.2	7.023	1.6741	9.2	23.84
Maiduguri	624	4.4	14.6	8.218	1.2995	10.2	15.81
Ilorin	576	2.2	8.6	6.228	1.4927	6.4	23.97
Yola	624	2.5	10.6	7.525	1.3430	8.1	17.85
Ikeja	600	1.3	9.2	5.134	1.4736	7.9	28.70
Ibadan	612	1.2	9.5	5.192	1.6040	8.3	30.89
Oshogbo	624	1.3	8.8	5.355	1.6430	7.5	30.68
Benin	552	1.1	7.7	4.803	1.4269	6.6	29.71
Warri	624	0.0	8.3	4.322	1.5104	8.3	34.95
Lokoja	576	1.6	9.6	6.190	1.4769	8.0	23.86
Port Harcourt	588	0.7	8.7	4.021	1.4989	8.0	37.28
Owerri	444	0.0	8.8	4.454	1.4320	8.8	32.15
Enugu	588	2.5	8.5	5.485	1.3787	6.0	25.14
Calabar	612	0.4	9.0	3.770	1.5209	8.6	40.34
Makurdi	564	0.5	9.9	6.226	1.5016	9.4	24.12
Ogoja	444	1.1	8.4	5.561	1.6011	7.3	28.79

Table 3:Results of M-K trend tests and linear trend estimation

S/N	**Stations**	**Kendall's tau b**	**p-value**	**Trend estimate**		
				(Hours/month)	**Hours/year**	**Hours/decade**
1.	Yelwa	-0.059*	0.041	0.002	-0.024	-0.24
2.	Sokoto	-0.330**	0.000	0.0029	-0.0348	-0.348
3.	Kaduna	-0.008	0.781	0.0007	-0.0084	-0.084
4.	Kano	-0.130**	0.000	0.0014	-0.0168	-0.168
5.	Bauchi	-0.217**	0.000	0.002	-0.024	-0.24
6.	Maiduguri	-0.106**	0.000	0.0004	-0.0048	-0.048
7.	Ilorin	-0.034	0.223	0.0017	-0.0204	-0.204
8.	Yola	-0.122**	0.000	0.0003	-0.0036	-0.036
9.	Ikeja	0.061*	0.026	0.0024	0.0288	0.288
10.	Ibadan	-0.115**	0.000	0.0003	-0.0036	-0.036
11.	Oshogbo	-0.064*	0.018	0.0003	-0.0036	-0.036
12.	Benin	-0.027	0.344	0.0011	-0.0132	-0.132
13.	Warri	0.085**	0.002	0.0040	0.048	0.48
14.	Lokoja	-0.167**	0.000	0.0020	-0.024	-0.24
15.	P/H	0.105**	0.000	0.0025	0.03	0.3
16.	Owerri	0.072*	0.026	0.0007	0.0084	0.084
17.	Enugu	-0.002	0.943	0.0004	-0.0048	-0.048
18.	Calabar	-0.047	0.087	0.0018	-0.0216	-0.216
19.	Makurdi	-0.080**	0.005	0.0001	-0.0272	-0.272
20.	Ogoja	-0.042	0.193	0.0016	-0.0192	-0.192

** Trend significant at the 1% level (2-tailed). * Trend significant at the 5% level (2-tailed).

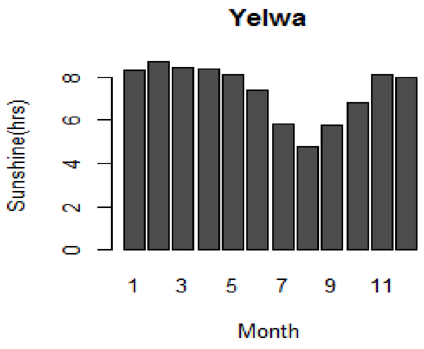
Table 4 – Correlation coefficients for **Sunshine Hours** across the stations

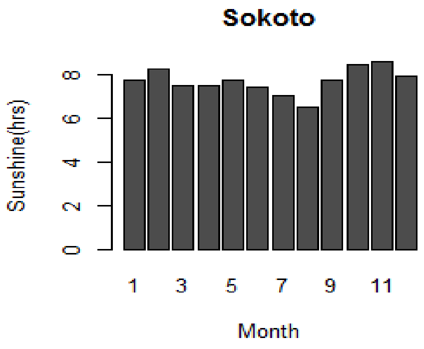
	Stations																			
Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1																			
2	.206**	1																		
3	.412**	.273**	1																	
4	.338**	.289**	.313**	1																
5	.401**	.435**	.393**	.268**	1															
6	.308**	.392**	.548**	.362**	.372**	1														
7	.540**	.316**	.668**	.413**	.416**	.616**	1													
8	.254**	.311**	.514**	.265**	.304**	.500**	.515**	1												
9	.427**	.168**	.603**	.330**	.284**	.465**	.697**	.427**	1											
10	.370**	.327**	.505**	.288**	.419**	.502**	.662**	.430**	.550**	1										
11	.492**	.311**	.675**	.364**	.410**	.548**	.841**	.503**	.696**	.631**	1									
12	.490**	.270**	.643**	.365**	.355**	.510**	.769**	.491**	.711**	.579**	.765**	1								
13	.492**	.158**	.583**	.310**	.279**	.470**	.708**	.431**	.688**	.586**	.683**	.745**	1							
14	.293**	.369**	.501**	.330**	.415**	.488**	.635**	.444**	.469**	.601**	.624**	.581**	.438**	1						
15	.265**	.075	.517**	.174**	.150**	.396**	.570**	.333**	.516**	.384**	.597**	.583**	.555**	.368**	1					
16	.365**	.173**	.458**	.211**	.243**	.403**	.564**	.390**	.549**	.519**	.615**	.582**	.551**	.421**	.480**	1				
17	.485**	.325**	.673**	.306**	.419**	.571**	.757**	.509**	.683**	.617**	.760**	.764**	.675**	.600**	.589**	.588**	1			
18	.395**	.173**	.518**	.276**	.265**	.444**	.669**	.411**	.547**	.513**	.643**	.614**	.551**	.460**	.536**	.542**	.617**	1		
19	.422**	.359**	.615**	.312**	.435**	.527**	.714**	.490**	.580**	.594**	.688**	.638**	.572**	.575**	.485**	.572**	.650**	.560**	1	
20	.335**	.265**	.565**	.207**	.385**	.504**	.662**	.426**	.521**	.587**	.646**	.561**	.468**	.575**	.408**	.533**	.665**	.567**	.642**	1

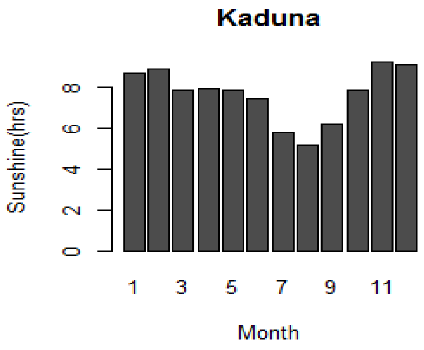
**correlation is significant at the 1% level (2 tailed)

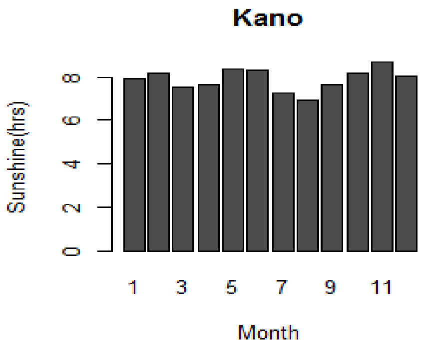
The seasonal variations of sunshine duration for the stations are given in form of Bar charts in fig. 2. The charts indicate that maximum monthly mean daily sunshine hours across all the stations were recorded in late autumn (in November) and during winter (in December, January and February months). The minimum monthly mean daily sunshine hours were recorded during summer (in July and August) and early autumn (in September). However, high sunshine durations exceeding 6 hours per day were observed in April and May in the stations.

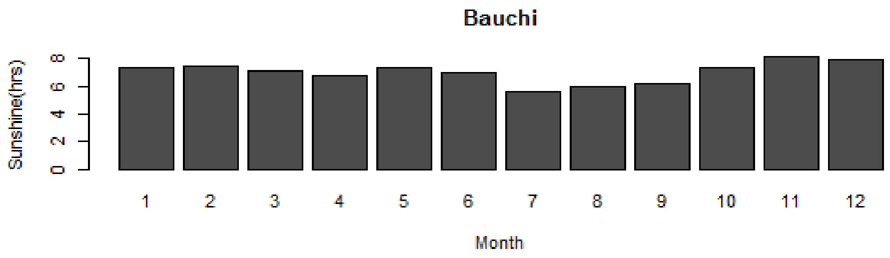
Ikeja, Port Harcourt, Owerri and Warri show surprising significant upward trends in sunshine hours despite expected increase in aerosol concentrations (as a consequence of local pollution in large urban areas) that are expected to cause dimming (decrease in sunshine duration). These observations go to prove that there are still large uncertainties about how clouds will respond to climate change. These phenomena could be linked to the uncertainties of the indirect effects of aerosols on clouds and precipitation, which could result to either induced changes in cloud properties such as life time and albedo or the modifications of precipitation forming processes. In fact, aerosols can interact with clouds and precipitation in many ways, acting either as cloud condensation nuclei (CCN) or ice nuclei (IN), or as absorbing particles, redistributing solar energy as thermal energy inside cloud layers. Sulphates act as CCN, and therefore lead to cloud that have more and smaller cloud droplets. This is known as the cloud-albedo effect. This cloud-albedo effect involves the distribution of the same cloud liquid water content over more and smaller cloud droplets. These clouds reflect solar radiation more efficiently than clouds with fewer and larger droplets, leading to higher cloud reflectivity. Cloud lifetime effect involves the processes that decrease the cloud droplet size (as in cloud-albedo effect) per given liquid water content which also decrease precipitation formation, thereby prolonging cloud life time presumably. In other words, this effect causes droplets to be of more uniform size, which reduces the growth of rain drops and make the cloud more reflective to the incoming solar radiation known as Albrecht effect (Albrecht, 1989). The cloud-albedo and cloud lifetime effects are presumably responsible for the downward trends in the sunshine duration in the urban cities.

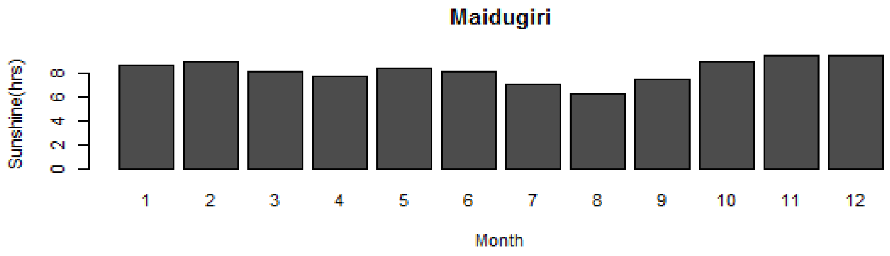


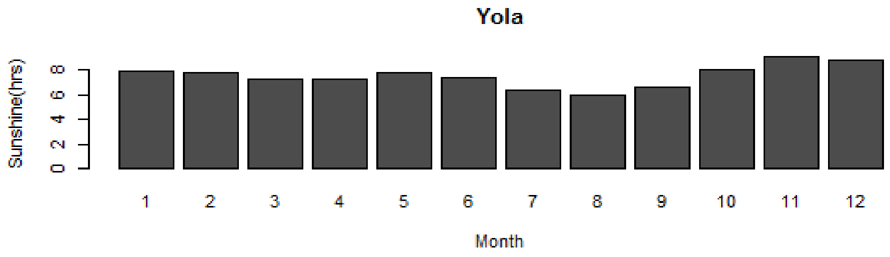


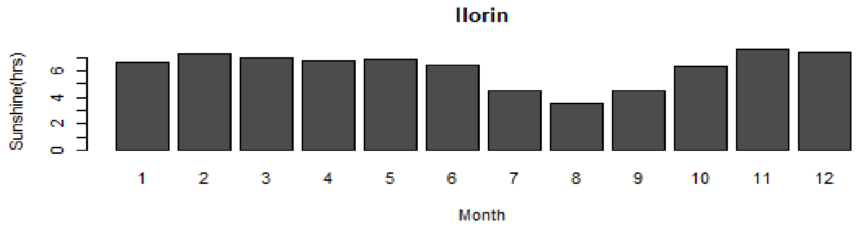











Ilorin
Sunshine(hrs)
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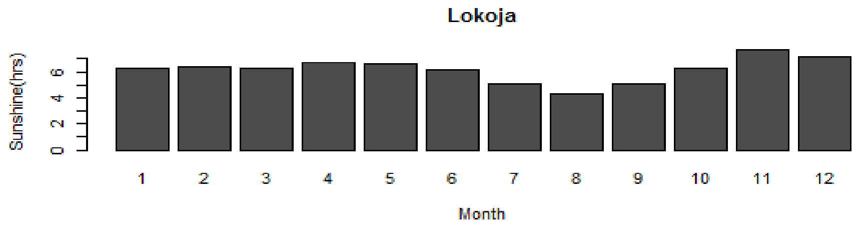
Lokoja
Sunshine(hrs)
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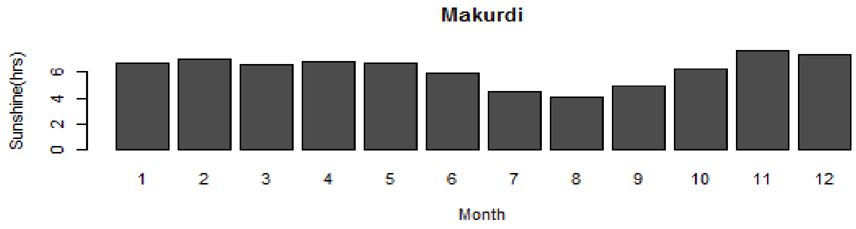
Makurdi
Sunshine(hrs)
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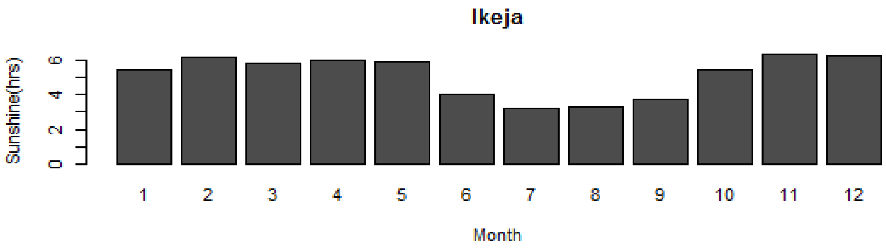
Ikeja
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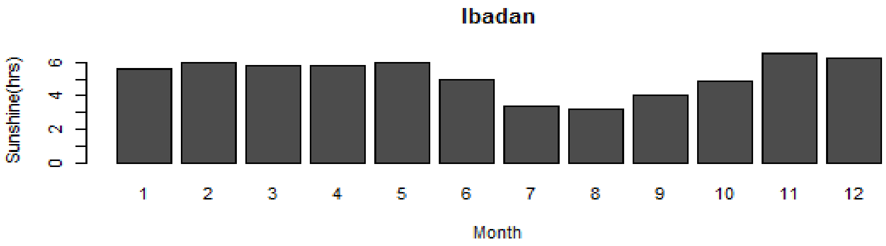
Ibadan
Sunshine(hrs)
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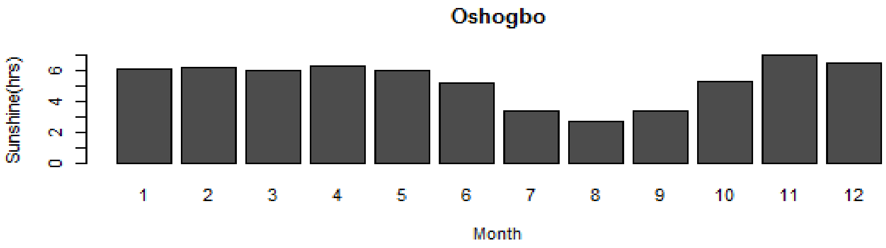
Oshogbo
Sunshine(hrs)
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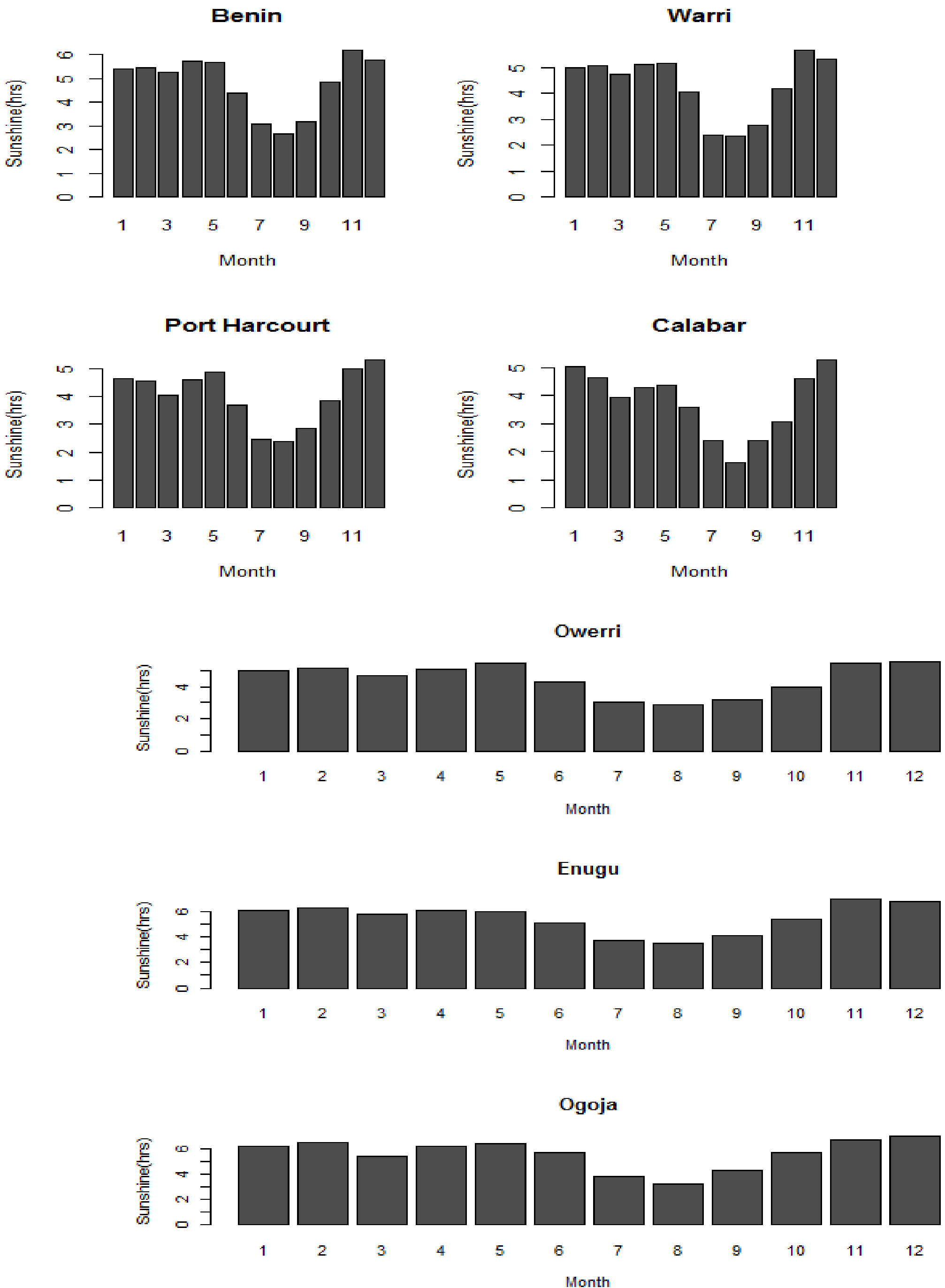

Fig 2 Seasonal variation

The semi-direct effect involves the absorption of solar radiation by soot (particulate black carbon emitted by combustion), re-emission as thermal radiation and subsequent heating of the air mass. This can cause evaporation of cloud droplets. IPCC (2007) observed that aerosol heating within cloud layers reduces cloud fractions, whereas aerosol heating above the cloud layers tends to increase cloud fractions. Ramanathan et al, (2001) equally observed that absorption of solar radiation by aerosols can change the cloud amount. Thus, the semi-direct effect of soot can partly account for the increasing trend in sunshine duration in Port Harcourt, Ikeja, Warri and Owerri. Glaciation effect involves an increase in IN, which results in a rapid and frequent glaciation of a super cooled liquid water cloud due to the difference in vapour pressure over ice and water. These ice crystals grow in an environment of high super saturation with respect to ice (unlike cloud droplets), quickly reaching precipitation size with the potential to turn a non-precipitating cloud into a precipitating cloud (IPCC, 2007), and thus increase the amount of precipitation. Also large aerosols affect the surface energy budget with consequences of precipitation with the formation of fewer and larger droplets known as "Twomey" effect

(Twomey, 1977). This effect also cleanses the atmosphere of aerosols, leading to more sunshine hours and solar radiation. This effect can also be partly responsible for increasing trends in sunshine hours in the urban cities. As Jacob and Winner (2008) observed, particulate matter is efficiently scavenged by precipitation, which is its main atmospheric sink, resulting in atmospheric lifetimes of a few days in the boundary layer and a few weeks in the free troposphere.

Perhaps, a way of investigating possible explanations of decadal variability in sunshine duration and cloudiness would be to analyze their relationships with the regional atmospheric circulation patterns or “teleconnections”. These teleconnections are summarized by indices that simplify the spatial structure of pressure systems and that can be used as time series showing the evolution in amplitude and phase of these modes of atmospheric variability (Hurrell et al, 2003, IPCC, 2007). Thus it is recommended that further studies in this regard should be to analyze the relationships of decadal variability in sunshine hours and cloudiness with the atmospheric circulation patterns. The results of this study is consistent with similar results across the world which show increasing and decreasing trends at various temporal and spatial scales (e.g. Stanhill and Cohen, 2005; Angell, 1990; Kitsara et al, 2013; Dobesch, 1992; Rahimzadehet al, 2014; Durlo, 2006; and Sanchez-Lorenzo et al, 2009).

VI. Conclusion

The spatial and temporal variability of sunshine duration over Nigeria on the basis of data records obtained from 20 instrumental series covering the period 1961 – 2012 has been presented in this paper. We detected both significant downward and upward trends in sunshine duration with dominant downward trends over the period. The highest long-term monthly mean daily sunshine duration occurred in the months of November to February, with April and May months equally recording high values of monthly mean daily sunshine duration above 6 hours. The minimum monthly mean daily sunshine hours were recorded in July, August and September months. The monthly mean daily sunshine duration exhibits latitudinal and elevation dependence with the sunshine hours increasing with elevation and increasing latitude. The records also show high coefficient of variation across the stations. However, no conclusion about a decreasing and increasing trend of this parameter may be made without further analysis of the relationships of decadal variability in sunshine duration and cloudiness with teleconnections. These results have implications for the purposes of assessing solar energy resources in different parts of Nigeria as we try to exploit solar energy as a viable candidate for clean and renewable energy resource for adaptation and mitigation against the adverse impacts of climate change.

References

[1]. Albrecht, B. (1989). Aerosols, Cloud Microphysics, and fractional cloudiness. Science, 245 (4923), 1227 – 1239.
[2]. Alpert, P., and Kishcha, P. (2008). Quantification of the effect of urbanization on solar dimming. Geophys.Res.Lett, 35, doi:10.1029/2007GL033012.
[3]. Alpert, P., Kishcha, P., Kaufman, Y.J., and Schwarzbard, R. (2005). Global dimming or local dimming?: Effect of urbanization on sunshine availability, Geophys.Res.Lett, 32, doi:10.1029/2005GL023320.
[4]. Angell, J.K. (1990). Variation in United States cloudiness and sunshine duration between 1950 and the drought year of 1988. J.Clim, 3, 296 – 308, doi:10.1175/1520 – 044(1990) 003< 0296: VIUSCA> 2.0.co;2.
[5]. Dai, A., Trenberth, K., and Kark, T.R (1999). Effects of clouds, soil moisture, precipitation and water vapour on diurnal temperature range. J.Clim., 12, 2451-2473. Doi:10.1175/1520-0442 (1999) 012 <2451:0ECSMP> 2.0.c;2.
[6]. Dobesch, H. (1992). On the variations of sunshine duration in Austria. Theor.Appl.Climatol., 46(1), 33 – 38, doi:10.1007/B F00866445.
[7]. Durlo, G. (2006). Multiannual variation of the effective sunshine duration in the Beskid Sadecki Mountains. Electronic Journal of Polish Agricultural Universities, 9(4): 12pp.
[8]. Helsel, D.R. and Hirsch, R.M. (1992). Statistical methods in water resources. Studies in environmental Science, 49, New York, Elsevier.
[9]. Hosking, J.R.M. and Wallis, J.R (1997). Regional frequency analysis: an approach based on L-moments. Cambridge University Press, Cambridge.
[10]. Hurrell, J.W., Kushnir, Y., Visbeck, M., and Ottersen, G. (2003). An overview of the North Atlantic Oscillation, in: The North Atlantic Oscillations: Climate significance and Environmental Impact, Geophys. Monogr.Ser., Vol.134, AGU, Washington, D.C, pp.1-35.
[11]. IPCC, (2007). Climate Change 2007: The physical science basis: Contribution of WGI to the Fourth Assessment Report of the IPCC, Cambridge University Press, Cambridge, UK.
[12]. Jacob, D.I. and Winner, D.A. (2009). Effect of Climate change on air quality. Atmospheric Environment, 43(2009), 51-63, doi:10.1016/ j.atmosenv.2008.09.051.
[13]. Kitsara, G., Path., Papaioannou, G., Papathanasiou, A. and Retalis, A. (2013). Dimming/brightening in Athens: Trends in sunshine duration, cloud cover and reference evapotranspiration. Water Resources Management, 27(6), 1623-1633.
[14]. Liang, F., and Xia, X.A. (2005). Long-term trends in solar radiation and the associated climatic factors over China for 1961 – 2000. Ann.Geophys., 23, 2425 – 2432.
[15]. Liepert, B.G. (2002). Observed reductions of surface solar radiations at sites in the United States and worldwide from 1961 – 1990. Geophys.Res.Lett, 29(10), 1421, doi: 10.1029/2002GL014910.
[16]. Ngongondo, C., Xu, C. and Gottschalk, L (2011). Evaluation of spatial and temporal characteristics of rainfall in Malawi: a case of data scarce region. Theor.Appl. Climatol, 106, 79-93, doi: 10.1007/S00704 – 011 – 0413 – 0.
[17]. Rahimzadeh, F., Pedram, M., and Kruk, M.C. (2014). An examination of trend in sunshine hours over Iran. Meteorological Applications, 21(2), 309 – 315, doi:10.1002/met.1334.

[18]. Ramanathan, V., Crutzen, P.J., Kiehl, J.T., and Rosenfeld, D. (2001). Aerosols, climate and the hydrological cycle.Science, 294, 2119 –2124, doi:10.1126/science.1064034.

[19]. Rosenfeld, D., Lohmann, U., Raga, D.B., O'Dowd, C.D., Kulmana, M., Fuzzi, S., Reissell, A., and Andreae, M.O. (2008). Flood or drought: How do aerosols affect precipitation?. Science, 321, 1309 – 1313, doi:10.1126/science. 1160606.

[20]. Ruckstuhl, C. et al, (2008). Aerosols and cloud effects on solar brightening and the recent rapid warming. Geophys.Res.Lett., 35, L12708, doi: 10.1029/2008GL034288.

[21]. Sanchez-Lorenzo, A., Calbo, J., Brunetti, M., and Deser, C. (2009). Dimming/brightening over the Iberian Peninsula: Trends in sunshine duration and cloud cover and their relations with atmospheric circulation. Journal of Geophysical Research, 114, D00D09, doi:1029/2008JD011394.

[22]. Shongwe, M.E., Landman, W.A. and Mason, S.J. (2006). Performance of recalibration systems for GCM forecasts for Southern African. Int.J.Climatol., 17, 1567 – 1585.

[23]. Stanhill, G. (2005). Global dimming: A new aspect of climate change, Weather, 60, 11-14, doi:10.1256/wea.210.03.

[24]. Stanhill, G. and Cohen, S. (2001). Global dimming: A review of the evidence for a widespread and significant reduction in global radiation with discussion of its probable causes and possible agricultural consequences. Agric. For. Meteorol., 107, 255 – 278, doi:10.1016/S0168 – 1923 (00) 00241-0.

[25]. Stanhill, G. and Cohen, S. (2005). Solar radiation changes in the United States during the twentieth century: Evidence from sunshine duration measurements. J.Clim., 18(10), 1503 – 1512, doi:10.1175/jcli3354.1.

[26]. Stanhill, G. and Cohen, S. (2008). Solar radiation changes in Japan during the 20th century: Evidence from sunshine duration measurements. J. Meteorol.Soc.Jpn, 86, 57-76, doi:10.2151/jmsj.86.57.

[27]. Syners, R. (1990). On the statistical analysis of series of observations. WMO Technical Note, 43, World Meteorological Organization, Geneva.

[28]. Twomey, S. (1977). Influence of pollution on short wave albedo of clouds. J.Atmos.Sci., 34(7), 1149 – 1152.

[29]. Wild, M., Gilgen, H., Roesch, A., Ohmura, A., Long, C.L., Dutton, E.G., Forgan, B., Kallis, A., Russak, V., and Tsvetkov, A. (2005). From dimming to brightening: Decadal changes in solar radiation at Earth's surface. Science, 308, 847 – 850, doi:10.1126/science.1103215.

[30]. Wild, M., Ohmura, A., and Makowski, K. (2007). Impact of global dimming and brightening on global warming. Geopys.Res. Lett; 34, L04702, doi:10.1029/2006 GL028031.