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GENERATION OF CLEARNESS INDEX MAPS FOR SELECTED CITIES IN SOUTH WESTERN, NIGERIA USING KRIGING TECHNIQUE

SANUSI, Y. K[1] & OJO, M. O[2]

[1]Department of Pure and Applied Physics, Ladoke Akintola University of Technology Ogbomoso, Nigeria

[2]Department of Physics, Adeyemi College of Education, Ondo, Nigeria

ABSTRACT

In this study, characterization of solar radiation for construction of clearness index maps was carried out to assess the feasibility of solar energy utilization. The materials required for this study are accumulated data of global solar radiation, relative humidity, maximum and minimum temperature which are obtained from the satellite – derived data from the Atmospheric Data Centre of National Aeronautic and Space Administration (NASA) and National Space Research and Development Agency, Abuja. The data obtained covered a period of eleven (11) years, from January 1995 to December, 2005 for six locations in South western Nigeria which lie on the latitudes and longitudes (Lat. 07˚ 03′ N , Long. 03˚ 19′ E) for Abeokuta, (Lat.07˚ 38′ N, Long. 05˚ 12′ E) for Ado Ekiti, (Lat. 07˚ 15′ N Long. 05˚ 05′ E) for Akure, (Lat., 06˚ 25′ N Long. 03˚ 27′ E) for Ikeja, (Lat., 08˚ 01′ N Long. 04˚ 11′ E) for Ogbomoso and (Lat., 07˚ 48′ N Long. 04˚ 42′ E) for Osogbo. Acquired data were used to calculate values of the clearness index K_T , diffuse ratio K_D^1 and diffuse co efficient K_D for each location, these depict the effectiveness of the sky in scattering incoming radiation. A characterization of the sky conditions over the locations based on the calculated clearness index K_T values for the eleven years of data is presented. All monthly irradiance data given as mean monthly radiation sum are transformed into monthly clearness index values through the application of interpolation technique called Kriging method as described by Beryer et al (1997).

The results of this study show the variation of global and diffuse component of solar radiation in summer and winter months. The results revealed that the values of global solar radiation computed vary from 12.248 – 20.844 $MJm^{-2}day^{-1}$ in Abeokuta, 12.880 – 21.744 $MJm^{-2}day^{-1}$ in Ado Ekiti , 12.064 - 21.888 $MJm^{-2}day^{-1}$ in Akure, 12.600 – 19.224 $MJm^{-2}day^{-1}$ in Ikeja , 12.960 – 22.916 $MJm^{-2}day^{-1}$ in Ogbomoso and 12.420 – 21.276 $MJm^{-2}day^{-1}$ in Osogbo. The results showed a seasonal variation of global solar radiation with the highest values corresponding to dry season (November to March) while the least values are observed at the peak of the raining season between (May to October) of the years considered. The clearness index which is availability of global solar radiation varies with geographical location and period of the year. The implications of these results on the effective utilization of solar energy are discussed. The results in this study serve as very useful information for engineers and other renewable energy technologists in the process of designing and estimation of performance of solar application systems.

KEYWORDS: Ado Ekiti, Global Solar Radiation

INTRODUCTION

Clearness index is a measure of solar radiation extinction in the atmosphere, which includes effects due to clouds but also effects due to radiation interaction with other atmospheric constituents. In terms of sky conditions classification, the clearness index is a widely used index since it depends on global solar radiation irradiance Muneer, (1995); Li et al., (2004). Low clearness means low global radiation which usually attributes to a cloudy sky with high portion of diffuse components. Large values of clearness index means high global radiation, which is dominated by the direct component.

Solar radiation is received at the earth's surface under different atmospheric conditions, which clearly affect the amount and quality of radiation obtained at the ground. Turbidity, transparency, air mass, atmospheric water vapour contents layers and distribution of cloud cover have been suggested as the atmospheric conditions that exert influence on solar radiation at the earth's surface through the process of absorption, scattering and reflection of the incoming solar radiation.

Solar radiation at the earth's surface is essential for the development and utilization of solar energy. It is needed for designing collectors for the solar heater and other photovoltaic equipment that depend on solar energy. Knowledge of the global solar radiation is of fundamental importance for all solar energy conversion systems. The solar radiation data are not easily available for many locations in Nigeria. The exploitation of the vast energy of the sun and the performance evaluation of such energy conversion systems within a particular region require relevant information on distribution of the amount of solar energy received and its characteristics (Okogbue et al. 2009). Clearness index (K_T) is expressed as the ratio of the monthly mean daily global solar radiation on horizontal surface to monthly mean daily extraterrestrial horizontal radiation. Clearness index Kt indicates the availability of global solar radiation at a particular location.

Notable researchers that have carried out studies in the estimation of clearness index and related parameters such as diffuse ratio and diffuse co-efficient for the purpose of modeling and study sky conditions in Nigeria are Falayi and Rabiu, (2011); Okogbue et al., (2009); Oj; Augustine and Nnabuchi (2009); Ezekwe et. al, (1981) and Sanusi et al., (2011). Concerning the construction of clearness index maps, very few studies are available but some researchers that carried out studies in this area are Ojosu (1984); falayi and Rabiu (2011); Okogbue (2009). Beryer et al. (1987) assessed the method used to construct clearness index maps for Europe; Zelenka and Lazic (1987) worked on the generation of maps of the METEONORM database for Switzerland..

In this study, Clearness index, diffuse ratio and diffuse co-efficient are calculated from the acquired solar radiation data which are considered as an essential requirement to conduct feasibility studies for solar energy systems. The knowledge of the trends of its variation gained over a long period should be useful for the wider world community. For an energy source to be renewed, it means that its harvesting, conversion and use would occur in a sustainable manner and avoid any negative impacts on the people and natural environment. The present dependence on fossil fuel is not enough to meet the energy needs of the country. Interest in renewable energy development and dissemination in Nigeria is driven by the recent increase in oil prices, unavailability of electricity to majority of the population and high cost and energy losses associated with grid extension. Therefore, the results from this study will serve as useful information for the engineers, designers and other renewable energy technologists in the process of design, analysis and performance estimation of solar energy conversion system. Also, it serves as helpful hint for designers of solar energy photovoltaic devices.

The prime objectives of this study include (i) determination of the clearness index, K_T, diffuse ratio and diffuse co-efficient which depict the effectiveness of the sky in scattering the incoming radiation (ii) generation of the clearness index maps of monthly mean irradiance over six selected cities in south western Nigeria using Kriging technique.

MATERIALS AND METHODS

The materials required for this study are the Satellite-derived data on solar radiation, relative humidity, minimum and maximum temperature which are adopted from the Atmospheric center data of National Aeronautic and Space Administration and National Space and Development Agency, Abuja. The data obtained covered a period of eleven (11) years, from January 1995 to December, 2005 for six locations in South western Nigeria which lie on the latitudes and longitudes (Lat. 07˚ 03′ N , Long. 03˚ 19′ E) for Abeokuta, (Lat.07˚ 38′ N, Long. 05˚ 12′ E) for Ado Ekiti, (Lat. 07˚ 15′ N Long. 05˚ 05′ E) for Akure, (Lat., 06˚ 25′ N Long. 03˚ 27′ E) for Ikeja, (Lat., 08˚ 01′ N Long. 04˚ 11′ E) for Ogbomoso and (Lat., 07˚ 48′ N Long. 04˚ 42′ E) for Osogbo. Acquired data were used to calculate values of the clearness index K_T , diffuse ratio K_D^1 and diffuse co efficient K_D for each location, these depict the effectiveness of the sky in scattering incoming radiation. In the process of data treatment, the global solar radiation data measured in $KWm^{-2}day^{-1}$ was converted to $MJm^{-2}day^{-1}$ using a factor of 3.6 (according to Igbal 1983.).

Table 1: Shows the Geographical Coordinates of the Selected Cities

S/No	Location	Latitude	Longitude	Altitude (Metres)
1	Abeokuta	07˚ 03′ N	03˚ 19′ E	104.1
2	Ado Ekiti	07˚ 38′ N	05˚ 12′ E	541.0
3	Akure	07˚ 15′ N	05˚ 05′ E	353.0
4	Lagos	06˚ 25′ N	03˚ 27′ E	34.0
5	Ogbomoso	08˚ 01′ N	04˚ 11′ E	341.0
6	Osogbo	07˚ 48′ N	04˚ 42′ E	318.0

Plate 1: Map Showing the Selected cities in the South Western, Nigeria

Solar radiation data were presented in dimensionless form as the ratio of global irradiance (H) to extraterrestrial radiation (H_0). Then the clearness index could be expressed as

$$K_T = \frac{H}{H_o} \quad (1)$$

Where K_T is the clearness index, which is a measure of the availability of solar radiation or the transmissivity of the atmosphere.

$$K_d^1 = \frac{H_d}{H} \text{ and } K_d = \frac{H_d}{H_o} \quad (2)$$

(a & b)

Where K_d^1 and K_d represent the diffuse ratio and diffuse co-efficient respectively, which are transmission characteristics of diffuse radiation and hence mirror the effectiveness of the sky in transmitting diffuse solar radiation.

In this study, simple model of the Supit and Van Kappel (1998) was adopted to estimate the monthly mean of daily total terrestrial solar radiation falling on horizontal surface at a particular location. According to Supit and Van Kappel (1998),

$$H = H_0\left[a\sqrt{(T_{max} - T_{min})} + b\sqrt{(1 - C_w/8)}\right] + c \quad (3)$$

Where C_w is the mean of the total cloud cover of the daytime observation in percents, tenths, or in eight of the sky covered by cloud, T_{max} and Tmin are maximum and minimum temperature. H_0 is the monthly mean of daily total extraterrestrial solar radiation on horizontal surface in the absence of atmosphere while a, b and c are empirical constants.

$$H_0 = \frac{24 \times 3600}{\pi} G_{sc}\left(1 + 0.033 Cos\frac{360n}{365}\right)\left(Cos\emptyset Cos\delta Sin\omega_s + \frac{2\pi\omega_s}{360} Sin\emptyset Sin\delta\right) \quad 4$$

Where H_0 is the monthly mean daily extraterrestrial radiation in MJm^{-2}, G_{sc} is the solar constant with a value $1367W/m^2$ while w_s is the sunset hour angle for the typical day n for each month in degrees, then

$$\omega_s = Cos^{-1}(-tan\theta tan\delta) \quad 5$$

θ is the Latitude angle for the location in degrees

δ is the declination angle for the month in degree and n is the mean day of each month and

$$\delta = 23.45\, Sin\left[360\left(\frac{284+n}{365}\right)\right] \quad 6$$

Iqba, 1983.

Generation of Clearness Index Maps

In the process of clearness index contour maps generation, the following relevant information are very pertinent for each location. These are;

- Geographical location of the place, in respect to its longitude and latitude,
- Altitude (the place height above the sea level),
- Associated data such as global, diffuse and direct solar radiation on the horizontal surface,
- Available clearness index for previous years.

There is need for generating the maps for concise and proper interpretation of the availability of solar radiation at the locations for solar energy utilization and efficiency. All monthly irradiance data given as mean monthly radiation sum are transformed into monthly clearness index values through the application of interpolation technique (Beryer et al, 1997. Out of series of these techniques, Kriging method was adopted because in application, it uses trend in the map to extrapolate into areas without data. To adopt kriging method in generation of clearness index contour maps, some pre-treatment of the available data were necessary. The adopted software programme will not accept the units of Longitude and Latitude as degree and minutes, for conformity, the units were converted to Universal Transverse Mercator (UTM).

RESULTS AND DISCUSSION

The input parameters for the estimation of monthly average clearness index , diffuse ratio and diffuse co-efficient at the selected cities are shown in tables 2 -7.

Table 2: Monthly Average Clearness Index K_T, the Diffuse Ratio and the Diffuse Co-Efficient for Abeokuta

Month	H_0	H	H_D	H_D/H	H_D/Ho	$K_T = \frac{H}{H_0}$
JAN	33.09779	19.64291	20.02582	1.019494	0.60505	0.593481
FEB	35.25611	20.31709	20.87673	1.027545	0.592145	0.576272
MAR	37.17388	20.21891	22.22836	1.099385	0.597956	0.543901

Table 2: Contd.,

APR	37.6868	18.76582	23.34436	1.243983	0.619431	0.497941
MAY	36.93472	17.92473	22.56873	1.259083	0.611044	0.485308
JUN	36.21632	15.75491	21.82255	1.385127	0.602561	0.435022
JUL	36.41965	13.84691	22.68982	1.63862	0.62301	0.380204
AUG	37.14437	13.34945	23.87782	1.788674	0.642838	0.359394
SEPT	37.10783	14.148	24.012	1.697201	0.647087	0.381267
OCT	35.60009	16.416	22.572	1.375	0.634043	0.461122
NOV	33.42343	18.09818	19.38436	1.071067	0.579963	0.541482
DEC	32.25023	19.14545	19.33855	1.010085	0.59964	0.593653

Table 3: Monthly Average Clearness Index K_T, the Diffuse Ratio and the Diffuse Co-Efficient for Ado -EKITI

Month	H_0	H	H_D	H_D/H	H_D/H_0	$K_T = \frac{H}{H_0}$
JAN	33.09779	20.25818	20.54945	1.014378	0.620871	0.612071
FEB	35.25611	20.44145	20.92582	1.023695	0.593537	0.579799
MAR	37.17388	20.22218	21.96655	1.08626	0.590913	0.543989
APR	37.6868	18.78545	23.57345	1.254878	0.62551	0.498462
MAY	36.93472	17.93127	22.86655	1.275233	0.619107	0.485486
JUN	36.21632	15.80073	21.99927	1.392295	0.607441	0.436287
JUL	36.41965	13.91891	22.54582	1.619798	0.619056	0.382181
AUG	37.14437	13.24473	23.84509	1.800346	0.641957	0.356574
SEPT	37.10783	14.184	24.21818	1.70743	0.652643	0.382237
OCT	35.60009	16.05273	22.67345	1.412436	0.636893	0.450918
NOV	33.42343	18.81164	19.91127	1.058455	0.595728	0.562828
DEC	32.25023	19.77709	19.83927	1.003144	0.615167	0.613239

Table 4: Monthly Average Clearness Index K_T, the Diffuse Ratio and the Diffuse Co-Efficient for Akure

Month	H_0	H	H_D	H_D/H	H_D/Ho	$K_T = \frac{H}{H_0}$
JAN	33.25308	20.39564	20.54945	1.007542	0.617972	0.613346
FEB	35.36763	20.55927	20.92582	1.017829	0.591666	0.581302
MAR	37.21805	20.11745	21.96655	1.091915	0.590212	0.540529
APR	37.656	18.78545	23.57345	1.254878	0.626021	0.49887
MAY	36.84606	17.94436	22.86655	1.274302	0.620597	0.487009
JUN	36.10218	15.81055	21.99927	1.39143	0.609361	0.437939
JUL	36.31811	13.85673	22.54582	1.627067	0.620787	0.381538
AUG	37.09127	13.22509	23.84509	1.803019	0.642876	0.356555
SEPT	37.12546	14.22	24.21818	1.703107	0.652334	0.383026
OCT	35.69071	16.09527	22.67345	1.408703	0.635276	0.450965
NOV	33.56826	18.90982	19.91127	1.05296	0.593158	0.563324
DEC	32.41789	19.74109	19.83927	1.004973	0.611985	0.608957

Table 5: Monthly Average Clearness Index K_T, the Diffuse Ratio and the Diffuse Co-Efficient for Ikeja

Month	H_0	H	H_D	H_D/H	H_D/Ho	$K_T = \frac{H}{H_0}$
JAN	33.61716	18.88364	20.04873	1.061698	0.596384	0.561726
EB	35.62715	19.76727	21.21382	1.073179	0.59544	0.554837
MAR	37.31728	19.82945	22.5	1.134676	0.602938	0.531375
APR	37.57753	18.45818	23.42291	1.268972	0.623322	0.491203
MAY	36.63096	16.86764	23.07273	1.36787	0.62987	0.460475
JUN	35.82706	13.77164	22.33309	1.621673	0.623358	0.384392
JUL	36.07269	14.19709	22.76836	1.603734	0.63118	0.393569
AUG	36.96014	14.67818	23.26255	1.584838	0.629396	0.397135
SEPT	37.16175	14.80255	24.12655	1.629892	0.649231	0.398327
OCT	35.90048	16.13782	23.82873	1.476577	0.663744	0.449515
NOV	33.90736	18.14073	21.52145	1.186361	0.634713	0.535009
DEC	32.81161	18.86727	20.04218	1.062272	0.610826	0.575018

Table 6: Monthly Average Clearness Index K_T, the Diffuse Ratio and the Diffuse Co-Efficient for Ogbomoso

Month	H_0	H	H_D	H_D/H	H_D/Ho	$K_T = \frac{H}{H_0}$
JAN	33.34135	20.40545	20.52982	1.006095	0.615747	0.612017
FEB	35.43081	20.93891	21.03709	1.004689	0.593751	0.59098
MAR	37.24267	21.57709	22.67345	1.050811	0.608803	0.579365
APR	37.63779	20.28109	23.75673	1.171373	0.631193	0.538849
MAY	36.79485	19.14545	23.24945	1.214359	0.631867	0.52033
JUN	36.03646	16.85455	21.84545	1.296117	0.606204	0.467708
JUL	36.25957	14.48182	22.94509	1.584407	0.632801	0.399393
AUG	37.06034	13.67673	24.00218	1.754965	0.647651	0.369039
SEPT	37.13491	14.85818	23.55055	1.585022	0.634189	0.400114
OCT	35.74192	17.028	21.91745	1.287142	0.613214	0.476415
NOV	33.65053	19.59382	20.74582	1.058794	0.616508	0.582274
DEC	32.51326	20.07818	20.36945	1.014507	0.626497	0.617538

Table7: Monthly Average Clearness Index K_T, the Diffuse Ratio and the Diffuse Co-Efficient for Osogbo

Month	H_0	H	H_D	H_D/H	H_D/Ho	$K_T = \frac{H}{H_0}$
JAN	33.00859	19.93091	20.11745	1.00936	0.609461	0.60381
FEB	35.19183	20.42836	20.89309	1.022749	0.593692	0.580486
MAR	37.14802	20.31709	22.08436	1.086985	0.594496	0.546923
APR	37.70379	18.74291	23.48509	1.253012	0.622884	0.497109
MAY	36.98483	17.77091	22.73236	1.27919	0.61464	0.480492
JUN	36.28104	15.59127	21.71782	1.392947	0.5986	0.429736
JUL	36.47714	13.428	22.95491	1.709481	0.629296	0.368121
AUG	37.17413	12.996	24.264	1.867036	0.652712	0.349598
SEPT	37.09714	14.02364	24.20182	1.725788	0.65239	0.378025
OCT	35.54773	15.98073	23.06291	1.44317	0.648787	0.449557
NOV	33.34019	18.42545	19.59709	1.063588	0.587792	0.55265
DEC	32.154	19.16836	19.24364	1.003927	0.598483	0.596142

The tables 2-7 shown that the contributions of diffuse solar radiation very low throughout the year in all the cities with the exception of monsoon months July - September

Figure 1 displays the plots of monthly average global and diffuse radiation for the cities for the year 1995 -2005.

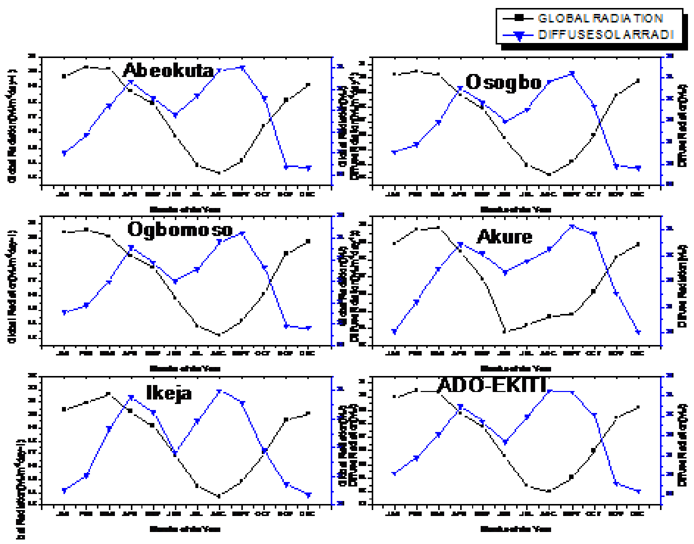

Figure 1: Plots of Monthly Average Global and Diffuse Radiation for the Selected Cities for the Year 1995 - 2005.

From figure 1, it was observed and obvious for Abeokuta that the global radiation is very low during the raining period (between June - October) with values ranging between 13.00 – 15.50MJm^{-2}day^{-1} while the diffuse solar radiation has rather very high value of 24.53 MJm^{-2}day^{-1} during such period (July and August). During the dry period between the months of November to March, the global solar radiation values ranging between 19.50 – 20.5 MJm^{-2}day^{-1}. Also, diffuse radiation showed bi-modal pattern throughout the years under consideration. It was shown in the figure 1 that the global and diffuse solar radiation for Ado – Ekiti portray similar patterns. For the month of July and August which are typical of wet season, the global radiation value is very low (13.20 MJm^{-2}day^{-1}) while the diffuse solar radiation value is 24.40 MJm^{-2}day^{-1}. Generally, other figures displayed have similar patterns except Ogbomoso which has close values for both global and diffuse radiation with a value of 16.45 MJm^{-2}day^{-1}. Also, global solar radiation for Ikeja is very low in the month of August. The slight difference in the patterns may be attributed to the latitudinal difference that existing between the locations.

These results show that there is great availability of solar radiation in all the locations but the values in Abeokuta and Ikeja are relatively low. In application point of view, solar energy devices will function successfully throughout the year in Akure, Ogbomoso, Ado Ekiti and Osogbo. Ikeja and Abeokuta are very close to the sea with cold air flow over them. The air steam flow is characterized by thick stratocumulus cloud cover which inhibit solar radiation from reaching the earth’s surface, then solar devices may find it difficult to function effectively in these two locations.

Also, evidence of high values of diffuse solar radiation during the wet period especially August implies that the solar radiation received at the surface during the periods consists mainly of the diffuse components. This is consistent with the dependence of the diffuse solar radiation reaching the surface on solar elevation and atmospheric turbidity, air mass, atmospheric water vapour content and layer, and distribution of cloud cover in the areas (Okogbue et al, 2009).

The results showed a seasonal variation of global solar radiation with the highest values corresponding to dry season (November to March) while the least values are observed at the peak of the raining season between (May to October) of the years considered. The high values is due to sky that clear off cloud and some aerosol particles that attenuate the incident of solar radiation to the earth’s surface. The low values are due mainly to presence of cloud, rainfall, suspension of water particles that lead to scattering, absorption and reflection of incoming solar radiation to the earth’s surface.

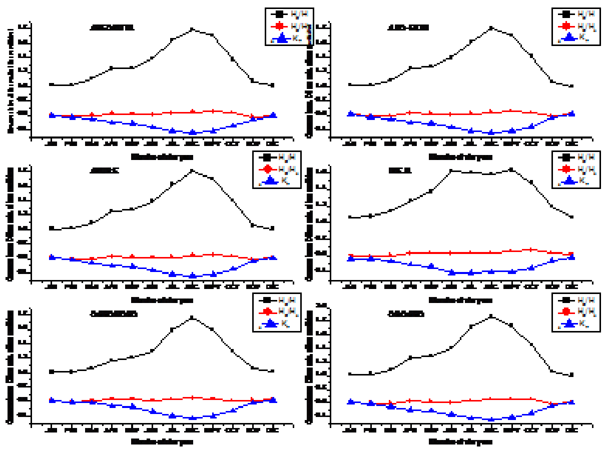

Figure 2: Plots of Monthly Averages of Clearness Index (K_T), Diffuse Ratio (H_D/H) and Diffuse Co- Efficient (H_D/H_0) over the Selected Cities for the Period 1995 – 2005

The plots of the monthly variations of the clearness index (K_T), diffuse ratio (H_D/H), and diffuse coefficient (H_D/H_0) for the locations will serve as useful hints in the course of discussion of the sky conditions in the process of transmitting and scattering of incoming solar radiation. Low clearness means low global radiation which usually attributes to a cloudy sky with high portion of diffuse components. Large values of clearness index means high global radiation, which is dominated by the direct component. In the figures shown above, a pronounced dip was observed in the patterns of the clearness index and rise in diffuse radiation in the months of August throughout the periods considered except in Ikeja (Lagos), that has dip in clearness index and rise in diffuse ratio in the months of June and September of the years. The dip in the values of K_T is in accordance with high values H_D/H for the same months.

Generally, clearness index (K_T) values are varies throughout the year for all the locations under study. In Abeokuta, the highest K_T (0.595) observed in January and December while the lowest K_T (0.351) occurred in August. In Ado Ekiti, the highest value of K_T (0.613) observed in January and December and lowest value K_T (0.382) observed in July. Highest value K_T (0.612) observed in Akure in January while the lowest K_T (0.353) occurred in August. In Ikeja, highest value K_T (0.575) observed in December and lowest value K_T (0.381) in July. In Ogbomoso, the highest value of K_T (0.617) observed in January and December and lowest value K_T (0.369) observed in August. In Osogbo, the highest value of K_T (0.603) occurred in January while the lowest value of K_T (0.342) observed in August. This indicates that the sky is very clear over Akure, Ado Ekiti, Ogbomoso and Osogbo throughout the year except in June to September.

Table 8: Showing Conversion of Latitudes and Longitudes Into Universal Transverse Mercator

Location	Latitude	UTM	Longitude	UTM	Altitude (Metres)
Abeokuta	07˚ 03′ N	779168.70	03˚ 19′ E	535060.80	104.1
Ado Ekiti	07˚ 38′ N	844262.70	05˚ 12′ E	742796.90	541.0
Akure	07˚ 15′ N	801794.30	05˚ 05′ E	730120	353.0
Ikeja	06˚ 25′ N	709166.40	03˚ 27′ E	549850.90	34.0
Ogbomoso	08˚ 01′ N	886209.30	04˚ 11′ E	630494.60	341.0
Osogbo	07˚ 48′ N	862446.20	04˚ 42′ E	687544.30	318.0

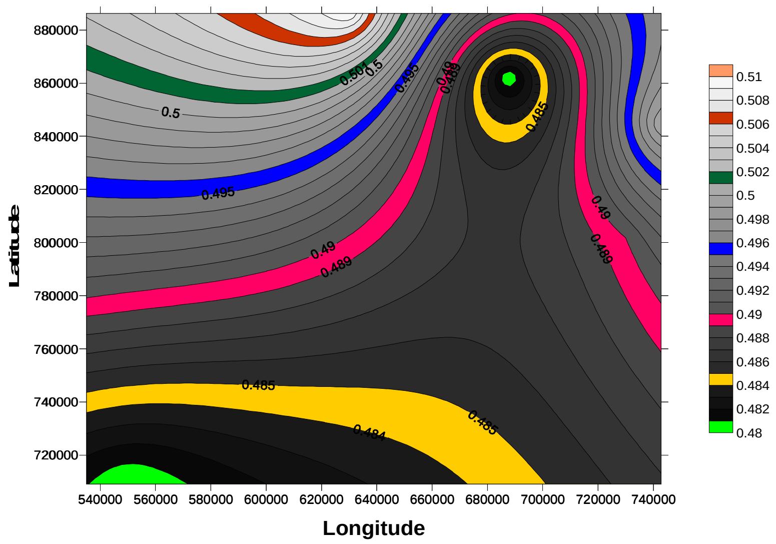

Figure 3.a: Monthly Mean Clearness Index Map for the Location (1999)

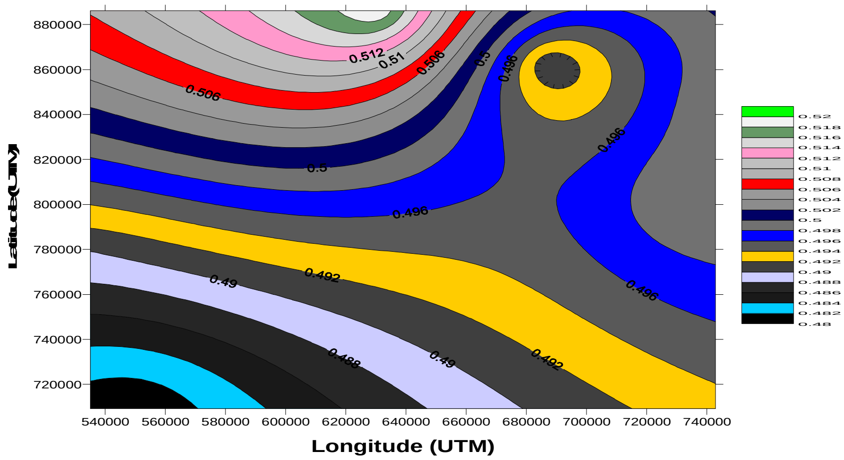

Figure 3.b Monthly Mean Clearness Index Map for the Selected Location (2001)

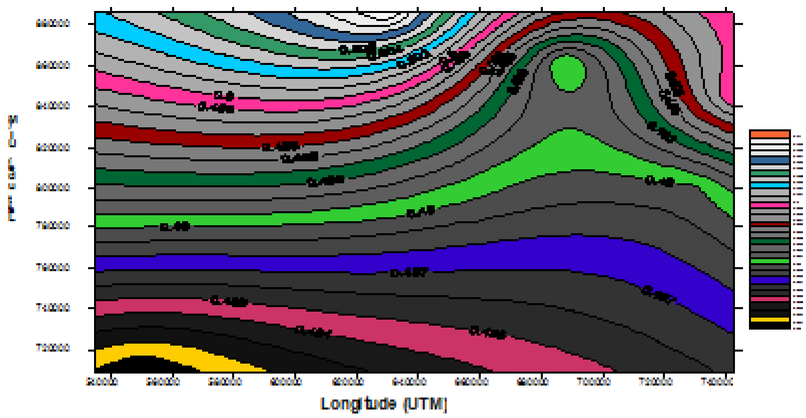

Figure 3.c: Monthly Mean Clearness Index Map for the Selected Locations (2003)

Clearness index data sets were subjected to time-series analysis in order to identify the nature of the variability of the solar radiation over the locations under study. This serves as very useful information to study the potential applicability of solar energy utilization and optimal design for effective prediction of the system performance.

Figures 3 (a,b,c) show the contour maps for monthly mean clearness index maps for the stations for specific years such as, 1999, 2001, and 2003 respectively.

It was observed that all the locations considered showed latitudinal variations of clearness index with high values at Ogbomoso, Akure and Ado Ekiti. The trends of variation patterns are consistent with high values during the dry period and low values during the raining season except in Ikeja and Abeokuta with bimodal distribution in the clearness index, global and diffuse solar radiation values . The results were consistent with those found by Okogbue et al (2002); Beryer et al, (1997); Okogbue and Adedokun, (2009); Chukwuemeka and Nnabuchi, (2009) and Falayi and Rabiu, (2011).

It was generally observed that the global solar radiation increases with latitude. This implies that the locations near the coast are characterized by low values of solar radiation, these values declining with distance from the coast. This might be as a result of the anthropogenic activities that cause pollution from industries and human activities. The situation in Ikeja and Abeokuta are good example of the above explanation.

From the clearness index contour maps shown, it was observed that clearness index were consistent for the locations under study, the values range between 0.35 and 0.58 which was in good agreement as predicted by Falayi and Rabiu (2011). Clearness index increased to about 0.612 in the months of January and December for Ogbomoso, Akure and ado Ekiti. The information serves as useful hints for designers of solar energy devices. Also, solar radiation is readily available to generate electricity except at the peak of the raining season (August and September) of the years considered.

CONCLUSIONS

In this study, characterization of the solar radiation for effective generation of clearness index contour maps was carried out for some selected locations Abeokuta, Ado Ekiti, Akure, Ikeja, Ogbomso and Osogbo, all in South western, Nigeria. This is majorly to work out the feasibility of possible and utilization of solar energy at the selected locations. The mean monthly solar radiation and diffuse radiation were computed so as to determine the clearness index, diffuse ratio and diffuse co-efficient. The monthly and annual mean global and diffuse radiation data spanning between 1995 and 2005 were presented for the locations.

The results showed a seasonal variation of global solar radiation with the highest values corresponding to dry season (November to March) while the least values are observed at the peak of the raining season between (May to October) of the years considered. The global solar radiation in the locations vary from 12.248 – 20.844 $MJm^{-2}day^{-1}$ in Abeokuta, 12.880 – 21.744 $MJm^{-2}day^{-1}$ in Ado Ekiti , 12.064 - 21.888 $MJm^{-2}day^{-1}$ in Akure , 12.600 – 19.224$MJm^{2}day^{-1}$ in Ikeja ,12.960 – 22.916 $MJm^{-2}day^{-1}$ in Ogbomoso ,12.420 – 21.276 $MJm^{-2}day^{-1}$ in Osogbo .

The clearness index values indicate that the sky is very clear over Akure, Ado Ekiti, Ogbomoso and Osogbo throughout the year except June to September. Clearness index maps showed latitudinal variations in clearness index with high values in Ogbomoso, Ado – Ekiti , Akure and Osogbo. Clearness index maps revealed that global solar radiation dependent on latitude, the higher latitudes received more radiation. There is great availability of solar radiation in Akure, Ado Ekiti, Ogbomoso and Osogbo, so solar energy devices will function successfully throughout the year. The results provide a useful source of information in the design and estimation of performance of solar application systems.

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