Use of Relative Sunshine Duration and Cloud Cover for the Prediction of Solar Radiation in Nigeria

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Abstract:- The use of relative sunshine duration and cloud cover for the prediction of solar radiation has been the tool used by researchers. High values of correlation coefficients exist between clearness index with relative sunshine duration and cloud cover in a proposed new model equations. In this work, fourteen meteorological stations: Bauchi, Bida, Enugu, Gusau, Ikom, Jos, Kano, Maiduguri, Minna, Nguru, Yelwa, Yola and Zaria were considered. For most of the stations studied, adjusted coefficient of determination, $R_a^2 \geq 0.998$ was obtained, standard error of estimate Se < 0.005 and largest percentage error, $LPE \approx 0.0\%$ except for Gusau and Zaria which have 0.3% and 2.9% respectively when seasonal variations are considered

Key-words: - New model equation, unavailable solar radiation, cloud cover, relative sunshine duration

1 Introduction

Extensive literature review reveals that model equations used to describe solar radiation is a mathematical equation relating total solar radiation on a horizontal surface, H, clearness index, H/H_0 (H_0 is the total extraterrestrial solar radiation on a horizontal surface) or unavailable solar radiation, $H_0 - H$ to one or more climatological independent variables such as cloud cover, C, relative humidity, R, maximum air temperature, T_m or relative sunshine duration, S/S_0 (S is the bright sunshine duration and S_0 day-length both in hours) [1] – [8]. Ododo *et al.* [1] used both cloud cover and relative sunshine duration to model both H and H/H_0, the equations were applied to three Nigerian stations: Gusau, Potiskum and Yola. The results show that yearly regression parameters do not give satisfactory fits for Yola and Gusau, another difficulty with the model equations was that the usual months of dry season (November – April) and wet season (May – October) were applied to Potiskum and Yola only while for Gusau October – April was used for the dry season and May – September for the wet season [1]. In this study, we have proposed two model equations to be used to solve this problem.

2 Model Equations Relating Relative Sunshine Duration and Cloud Cover

The general model equations which relates H or H/H_0 to cloud cover, C and relative sunshine duration, S/S_0, have been published elsewhere [1], the equations assumes the general form given by:

$$H / H_0 = \sum_{i,j=0}^{2} \alpha_{ij} \left(S / S_0\right)^i C^j \tag{1}$$

Some of the equations explicit in equation (1) are:
The Angstrom-Prescott-Page Equation given by;

$$H / H_0 = \alpha_{00} + \alpha_{10}\left(S / S_0\right) \tag{2}$$

The Ojosu's equations given by;

$$H / H_0 = \alpha_{00} + \alpha_{01} C \tag{3}$$

and

$$H / H_0 = \alpha_{00} + \alpha_{10}\left(S / S_0\right) + \alpha_{01} C \tag{4}$$

However, it was shown by [1] that a more general equations involving cloud cover and relative sunshine duration are given by:

$$H / H_0 = \alpha_{00} + \alpha_{10}\left(S / S_0\right) + \alpha_{11}\left(S / S_0\right) C \tag{5}$$

$$H / H_0 = \alpha_{00} + \alpha_{01} C + \alpha_{11}\left(S / S_0\right) C \tag{6}$$

$$H / H_0 = \alpha_{00} + \alpha_{10}\left(S / S_0\right) + \alpha_{01} C + \alpha_{11}\left(S / S_0\right) C \tag{7}$$

These equations were applied to three stations (Gusau, Potiskum and Yola).
In this paper, two model equations given by:

$$H / H_0 = \alpha_{00} + \alpha_{01}\left(1/C\right) + \alpha_{02}\left(1/C^2\right) + \alpha_{12}\left(S / S_0\right)\left(1/C^2\right) + \alpha_{20}\left(S / S_0\right)^2 \tag{8}$$

and

$$H / H_0 = \alpha_{00} + \alpha_{01}\left(1/C\right) + \alpha_{02}\left(1/C^2\right) + \alpha_{11}\left(S / S_0\right)\left(1/C\right) + \alpha_{12}\left(S / S_0\right)\left(1/C^2\right) + \alpha_{20}\left(S / S_0\right)^2 + \alpha_{21}\left(S / S_0\right)\left(1/C\right) \tag{9}$$

were analyzed and applied to fourteen stations in Nigeria (Bauchi, Bida, Enugu, Gusau, Ikom, Jos, Kano, Maiduguri, Minna, Nguru, Potiskum, Yelwa, Yola and Zaria). Equations (8) and (9) are derivable from a general equation, proposed by J.C. Ododo, given by:

$$H / H_0 = \sum_{i,j=0}^{2} \alpha_{ij} \left(S / S_0\right)^i \left(1/C^j\right) \tag{10}$$

3 Data and Analysis

All the data for the fourteen (14) stations have been tabulated elsewhere [6] – [8].
Simple and multiple regression analysis, where appropriate, was carried out using equations (2) – (9) for both yearly and seasonal variations, the seasonal variation we have used in the analysis are dry season (November - April) and wet season (May - October). The goodness-of-fit indices used are the adjusted coefficient of determination, R_a^2 standard error, Se, Largest Percentage Error (LPE), Absolute Average Percentage Error (AAPE) and Sum of Percentage Errors (SPE). These goodness-of-fit indices have been defined elsewhere [6] – [8]

4 Results and Discussion

Tables of parameters of regression analysis for fits using cloud cover and relative sunshine duration for each of the fourteen stations are presented in appendix A. also shown in appendix B (Fig. 1) are plots of observed and fitted clearness index versus months of the year

4.1 Bauchi (10.6371^0N, 10.0807^0E)

The regression parameters are shown in Table 1. The yearly fit with equation (8) is not very satisfactory, the values of Se (0.164), LPE (5.2%), AAPE (2.2%) and SPE (0.8%) are relatively high. For seasonal variation the fits are satisfactory, LPE = 2.1 % and 1.8% respectively.

4.2 Bida (9.0797^0N, 6.0097^0E)

The parameters for yearly and seasonal fits are shown in Table 2. The yearly fit using equation (9) is not satisfactory since the values of Se (0.0251), LPE (9.5%), AAPE (2.7%) and SPE (1.8) are relatively high. However, if we consider seasonal fits, R_a^2 is 0.5795 for dry season and 0.866 for the wet season, the values of Se, LPE and AAPE are not significantly different from those of yearly fit, thus, it appears that with only cloud cover and relative

sunshine duration as parameters are not sufficient to predict solar radiation for the data of Bida.

4.3 Enugu (6.458^{0}N, 7.546^{0}E)

Result of regression analysis for yearly and seasonal fits are presented in Table 3. The result for yearly fit is quite satisfactory with R_a^2 = 0.9767, Se = 0.0083 and LPE = 2.6%. Thus, seasonal fit is not necessary, equation (9) could be used to obtain good estimates of solar radiation for Enugu.

4.4 Gusau (12.1628^{0}N, 6.6745^{0}E)

The corresponding parameters for Gusau are listed in Table 4. The yearly fit given by equation (4) where R_a^2 = 0.0371, Se = 0.0199, LPE = 4.4% and AAPE = 1.8% is satisfactory. However, if we consider seasonal variation, excellent fits given by equations (8) and (7) for both dry and wet seasons.

4.5 Ikom (5.9617^{0}N, 8.7206^{0}E)

Results of regression analysis for yearly and seasonal fits are shown in Table 4. The fit given by equation (8) with Se (= 0.012), R_a^2 (= 0.9628) and LPE (= 5%) is quite satisfactory, thus, there is no need for seasonal fits. Figure 1 (e) shows the plot of observed and fitted yearly clearness index versus months of the year for Ikom.

4.6 Jos (9.8965^{0}N, 8.8583^{0}E)

Regression parameters for both yearly and seasonal fits are shown in Table 6. The yearly fit given by equation (9) with R_a^2 = 0.9922, Se = 0.0089 and LPE = 2.5% is satisfactory. However, if we consider seasonal fits, equation (8) gives best-fit-equation for the two seasons, LPE is 0.3% for the dry season and 0.9% for wet season, R_a^2 > 0.992 for both seasons.

4.7 Kano (12.0022^{0}N, 8.5920^{0}E)

Table 7 shows regression parameters for both yearly and seasonal fits, the yearly fit given by equation (9) with R_a^2 = 0.9012 is satisfactory, if we take seasonal fits into consideration, as can be seen from the Table, the values of LPE, AAPE and SPE do not vary significantly from the corresponding values of yearly fit, therefore, one does not need seasonal fits for the estimation of solar radiation for the data of Kano. Shown in.

4.8 Maiduguri (11.8311^{0}N, 13.1510^{0}E)

The regression data for both yearly and seasonal variations are shown in Table 8, it can be seen that yearly fit given by equation (8) in which R_a^2 = 0.9405 is quite satisfactory. From the Table, it is also apparent that seasonal fits have relatively improved values of Se, LPE, with R_a^2 = 0.8911 and 0.9855 for dry and wet seasons respectively. Figure 1 (h) is the plot of observed and fitted yearly clearness index versus months of the year for Maiduguri

4.9 Minna (9.5836^{0}N, 6.5463^{0}E)

Shown in Table 9 is the regression parameters for yearly and seasonal fits, for yearly fit, equation (9) with R_a^2 = 0.9253 gives the best model equation but LPE (6.1%) is high. If we consider seasonal fits, equations (6) and (7) gives the best-fit-equations for dry and wet seasons respectively. The values of LPE (5.4%) and AAPE (2.5%) for dry season do not vary appreciably from those of yearly fit, R_a^2 (0.5387 for the dry season and 0.9595 for the wet season). Like for Bida, it appears use of only cloud cover and relative sunshine duration is not sufficient to predict solar radiation for Minna.

4.10 Nguru (12.878^{0}N, 10.457^{0}E)

The entries in Table 10 are the regression parameters for both yearly and seasonal fits, for yearly fit, equation (8) with R_a^2 = 0.7759 , LPE = 4.4% gives the best-model-equation, this is just satisfactory. The result of seasonal fits shows that equation (3) gives best-fit-equation for the two seasons and R_a^2 (-0.2066) for dry season, thus, seasonal fit is not satisfactory.

4.11 Potiskum (11.7072^{0}N, 11.0825^{0}E)

The regression parameters for Potiskum shown in Table 11 indicates that for yearly fit equation (7) with R_a^2 = 0.9621, Se = 0.0109, LPE = 2.7% gives the best-fit-equation for the data. However, if we consider seasonal fits, the values of LPE ($\leq$1.2%), AAPE ($\leq$0.6%) do not vary appreciably from the corresponding yearly fit, therefore, there is no need for seasonal fits could be used to estimates of solar radiation for Potiskum.

4.12 Yelwa (10.8370^{0}N, 4.7433^{0}E)

Results of regression analysis for yearly and seasonal fits are listed in Table 12 from which it can be seen that yearly fits given by equation (9), where, R_a^2 = 0.9408, LPE = 3.3% and SPE = 0.5% is satisfactory, hence there is no need for seasonal fits.

4.13 Yola (9.2035^0N, 12.4954^0E)

Parameters of regression analysis are listed in Table 11, yearly fits given by equation (9) gives satisfactory result with R_a^2 = 0.9499, LPE (= 4%), and AAPE (= 1.7%), when seasonal fits are considered, LPE $\leq$2.5%, AAPE $\leq$1.7% and R_a^2 (= 0.3818 for dry season and 0.9749 for wet season), thus there is no need for seasonal fit.

4.14 Zaria (11.0855^0N, 7.7199^0E)

The result of regression analysis for both yearly and seasonal fits are shown in Table 12, the result for yearly fit is not satisfactory due to relatively high values of Se (0.0398), LPE (9.7%), AAPE (4.1%) and SPE(3.5%). From the Table, it can be seen that for seasonal fits, equation (8) gives the best-fit-equation for the two seasons, with R_a^2 (= 0.7174 for dry season and 0.9946 for wet season). For the two seasons; LPE $\leq$ 1.6%, AAPE $\leq$0.6% and SPE$\leq$0.1%. Therefore seasonal fit is quite satisfactory.

5 Conclusion

This work clearly indicate the relevance of cloud cover in relation to relative sunshine duration in a new model equation of the forms given by (8) and (9) for the prediction of clearness index, H/H_0, the result indicated an extremely high correlation between the variables and very low percentage errors, the work is intended to cover other meteorological stations and to see if correlation exists with other dependent variables such as unavailable solar radiation, H_0-H and total global solar radiation H.

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Appendix A

Regression parameters for fits using cloud cover and relative sunshine duration

Table 1. Regression parameters for fits using cloud cover and relative sunshine duration (Bauchi)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly Variation								
α_{00}	0.2093	0.7827	0.6662	0.3195	0.6401	1.7622	-0.0999	-1.4223
α_{01}	…	-0.0465	-0.0375	…	-0.0597	-0.2366	1.4038	19.6427
α_{10}	0.5113	…	0.1070	0.4677	…	-1.5143	…	…
α_{11}	…	…	…	-0.0249	0.0642	0.3012	…	23.5362
α_{02}	…	…	…	…	…	…	19.1953	-127.3976
α_{12}	…	…	…	…	…	…	-30.1032	123.5602
α_{20}	…	…	…	…	…	…	0.9652	-0.1175
α_{21}	…	…	…	…	…	…	…	-36.0879
Se	0.0271	0.0246	0.0257	0.0280	0.0235	0.0164	0.0202	0.0199
R_a^2	0.7412	0.7869	0.7666	0.7239	0.8062	0.9053	0.8567	0.8598
MPE(%)	8.1	9.7	8.9	8.1	7.6	5.2	6.4	4.5
AAPE(%)	4.1	3.5	3.6	3.9	3.3	2.2	2.3	2.1
SPE(%)	2.9	2.5	2.4	2.8	2.0	0.8	1.1	0.7
Dry season variation								
α_{00}	0.4789	0.6536	0.7973	0.6676	0.7095	1.0069	0.5972	…
α_{01}	…	-0.0168	-0.0289	…	-0.0113	-0.0805	-4.0545	…
α_{10}	0.1416	…	-0.1280	0.0735	…	-0.4802	…	…
α_{11}	…	…	…	-0.0455	-0.0261	0.0867	…	…
α_{02}	…	…	…	…	…	…	26.6004	…
α_{12}	…	…	…	…	…	…	-24.0958	…
α_{20}	…	…	…	…	…	…	0.8307	…
Se	0.0116	0.0088	0.0092	0.0097	0.0094	0.0107	0.0146	…
R_a^2	0.3990	0.6577	0.6289	0.5861	0.6049	0.4900	0.0584	…
LPE(%)	2.7	2.1	2.0	2.0	2.0	2.1	2.2	…
AAPE(%)	1.4	1.0	0.9	1.1	1.0	0.7	0.8	…
SPE(%)	0.2	0.1	0.1	0.1	0.1	0.1	0.1	…
Wet season variation								
α_{00}	0.1178	0.9648	0.0604	0.0156	0.4418	1.0802	45.9434	…
α_{01}	…	-0.0773	0.0054	…	-0.0647	-0.1637	-809.8375	…
α_{10}	0.6490	…	0.6910	0.6044	…	-0.9489	…	…
α_{11}	…	…	…	0.0366	0.1273	0.2742	…	…
α_{02}	…	…	…	…	…	…	4008.1679	…
α_{12}	…	…	…	…	…	…	-2606.2101	…
α_{20}	…	…	…	…	…	…	60.1004	…
Se	0.0148	0.0202	0.0171	0.0165	0.0146	0.0163	0.0110	…
R_a^2	0.8865	0.7889	0.8491	0.8586	0.8898	0.8621	0.9377	…
LPE(%)	4.9	6.3	4.9	4.7	4.1	3.3	1.8	…
AAPE(%)	1.7	2.5	1.7	1.6	1.4	1.4	0.6	…
SPE(%)	0.4	0.7	0.4	0.3	0.3	0.2	0.0	…

Table 2. Regression parameters for fits using cloud cover and relative sunshine duration (Bida)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly variation								
α_{00}	0.1114	0.6786	0.2377	0.1630	0.5781	0.5480	0.0875	-0.4588
α_{01}	…	-0.0345	-0.0113	…	-0.0698	-0.0649	2.0448	7.7210
α_{10}	0.7426	…	0.6131	0.7328	…	0.0533	…	…
α_{11}	…	…	…	-0.0177	0.1081	0.0994	…	0.1601
α_{02}	…	…	…	…	…	…	-2.5533	-25.4925
α_{12}	…	…	…	…	…	…	-1.6418	34.9751
α_{20}	…	…	…	…	…	…	0.5555	1.8695
α_{21}	…	…	…	…	…	…	…	-14.3764
Se	0.0320	0.0533	0.0301	0.0311	0.0276	0.0293	0.0311	0.0251
R_a^2	0.8206	0.5022	0.8412	0.8306	0.8659	0.8494	0.8306	0.8891
LPE(%)	11.7	23.6	11.5	11.9	9.4	9.6	12.5	9.5
AAPE(%)	4.8	9.0	3.9	4.1	4.1	4.1	3.5	2.7
SPE(%)	4.8	13.2	4.0	4.3	3.0	3.0	3.7	1.8
Dry season variation								
α_{00}	0.3275	0.5483	0.2922	0.3158	0.5247	0.1354	0.3303	…
α_{01}	…	0.0020	0.0062	…	-0.0535	0.0482	2.6705	…
α_{10}	0.3960	…	0.4157	0.3744	…	0.6972	…	…
α_{11}	…	…	…	0.0109	0.1074	-0.0757	…	…
α_{02}	…	…	…	…	…	…	-10.3821	…
α_{12}	…	…	…	…	…	…	9.9220	…
α_{20}	…	…	…	…	…	…	-0.3881	…
Se	0.0238	0.0373	0.0259	0.0260	0.0271	0.0314	0.0217	…
R_a^2	0.4952	-0.2440	0.4007	0.3971	0.3426	0.1186	0.5795	…
LPE(%)	5.5	8.0	5.5	5.5	5.6	5.4	2.5	…
AAPE(%)	3.2	4.7	2.8	2.8	2.9	2.8	1.3	…
SPE(%)	0.7	1.8	0.7	0.7	0.7	0.6	0.2	…
Wet season variation								
α_{00}	0.1347	1.4658	-0.1698	0.0591	0.2776	5.1938	-12.5597	…
α_{01}	…	-0.1566	0.0366	…	-0.0300	-0.7486	180.9816	…
α_{10}	0.6581	…	0.7977	0.2692	…	-8.2115	…	…
α_{11}	…	…	…	0.0849	0.1190	1.3131	…	…
α_{02}	…	…	…	…	…	…	-681.1871	…
α_{12}	…	…	…	…	…	…	208.8765	…
α_{20}	…	…	…	…	…	…	-4.5917	…
Se	0.0223	0.0307	0.0253	0.0249	0.0247	0.0263	0.0387	…
R_a^2	0.8660	0.7456	0.8268	0.8321	0.8352	0.8136	0.5951	…
LPE(%)	9.0	12.4	8.5	8.3	8.4	8.0	8.4	…
AAPE(%)	3.2	5.0	3.4	3.4	3.3	2.9	3.0	…
SPE(%)	1.3	2.4	1.3	1.2	1.2	0.9	1.0	…

Table 3. Regression parameters for fits using cloud cover and relative sunshine duration (Enugu)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly variation								
α_{00}	0.2186	0.5982	0.2238	0.2187	0.4904	0.3425	0.1935	0.6784
α_{01}	…	-0.0288	-0.0005	…	-0.0445	-0.0204	0.6205	-6.0819
α_{10}	0.5107	…	0.5054	0.5107	…	0.2785	…	…
α_{11}	…	…	…	0.0000	0.0845	0.0387	…	11.1880
α_{02}	…	…	…	…	…	…	2.7475	17.6090
α_{12}	…	…	…	…	…	…	-7.4323	-36.9184
α_{20}	…	…	…	…	…	…	0.7968	-1.1305
α_{21}	…	…	…	…	…	…	…	4.2745
Se	0.0084	0.0384	0.0088	0.0088	0.0091	0.0086	0.0085	0.0083
R_a^2	0.9763	0.5014	0.9737	0.9736	0.9720	0.9747	0.9757	0.9767
LPE(%)	2.4	13.7	2.5	2.4	2.8	2.5	3.5	2.6
AAPE(%)	1.6	6.6	1.6	1.6	1.4	1.5	1.1	1.0
SPE(%)	0.4	7.8	0.4	0.4	0.2	0.3	0.4	0.2
Dry season variation								
α_{00}	0.2471	0.5102	0.2427	0.2450	0.4822	0.5649	0.2059	…
α_{01}	…	-0.0045	0.0007	…	-0.0559	-0.0748	0.7015	…
α_{10}	0.4591	…	0.4623	0.4556	…	-0.1590	…	…
α_{11}	…	…	…	0.0019	0.1100	0.1467	…	…
α_{02}	…	…	…	…	…	…	1.9056	…
α_{12}	…	…	…	…	…	…	-6.0244	…
α_{20}	…	…	…	…	…	…	0.6985	…
Se	0.0086	0.0301	0.0099	0.0099	0.0075	0.0089	0.0003	…
R_a^2	0.9010	-0.2053	0.8694	0.8707	0.9263	0.8953	0.9999	…
LPE(%)	1.6	8.4	1.8	1.8	1.5	1.5	0.0	…
AAPE(%)	1.4	4.2	1.4	1.4	1.0	0.9	0.0	…
SPE(%)	0.1	1.5	0.1	0.1	0.1	0.1	0.0	…
Wet season variation								
α_{00}	0.2180	1.3402	1.0503	0.2835	1.0631	1.9691	-2.5023	…
α_{01}	…	-0.1508	-0.1120	…	-0.1154	-0.2568	41.6029	…
α_{10}	0.5099	…	0.1340	1.1697	…	-1.9324	…	…
α_{11}	…	…	…	-0.1363	0.0255	0.3265	…	…
α_{02}	…	…	…	…	…	…	-178.5443	…
α_{12}	…	…	…	…	…	…	172.3035	…
α_{20}	…	…	…	…	…	…	-5.8985	…
Se	0.0093	0.0075	0.0083	0.0099	0.0082	0.0086	0.0063	…
R_a^2	0.9524	0.9692	0.9621	0.9459	0.9636	0.9593	0.9780	…
LPE(%)	2.6	3.0	2.4	2.5	2.3	2.1	1.3	…
AAPE(%)	1.7	1.3	1.2	1.6	1.2	1.1	0.6	…
SPE(%)	0.2	0.2	0.1	0.2	0.1	0.1	0.0	…

Table 4. Regression parameters for fits using cloud cover and relative sunshine duration (Gusau)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly variation								
α_{00}	0.2248	1.0241	0.9032	0.4571	0.9705	2.0395	-1.9257	-9.9706
α_{01}	…	-0.0818	-0.0731	…	-0.0873	-0.2658	25.0910	152.5542
α_{10}	0.6208	…	0.1291	0.8310	…	-1.7598	…	…
α_{11}	…	…	…	-0.1150	0.0274	0.3236	…	-129.6600
α_{02}	…	…	…	…	…	…	-63.9866	-551.2313
α_{12}	…	…	…	…	…	…	7.1711	832.0087
α_{20}	…	…	…	…	…	…	-0.1445	23.2034
α_{21}	…	…	…	…	…	…	…	-147.2613
Se	0.0619	0.0396	0.0408	0.0440	0.0402	0.0390	0.0288	0.0199
R_a^2	0.3942	0.7513	0.7365	0.6934	0.7439	0.7594	0.8689	0.9371
LPE(%)	23.6	12.3	11.0	12.7	10.9	10.0	7.8	4.4
AAPE(%)	9.2	5.2	4.9	5.4	4.9	4.6	3.2	1.8
SPE(%)	13.4	5.9	5.7	6.6	5.5	4.4	2.2	0.8
Dry season variation								
α_{00}	0.4491	0.7344	0.3208	0.3762	0.5440	0.7547	-0.4377	…
α_{01}	…	-0.0203	0.0131	…	-0.0378	-0.0849	18.9960	…
α_{10}	0.3134	…	0.4218	0.3128	…	-0.3925	…	…
α_{11}	…	…	…	0.0256	0.0961	0.1840	…	…
α_{02}	…	…	…	…	…	…	-88.8995	…
α_{12}	…	…	…	…	…	…	75.3489	…
α_{20}	…	…	…	…	…	…	-2.7433	…
Se	0.0114	0.0196	0.0116	0.0115	0.0112	0.0136	0.0001	…
R_a^2	0.7212	0.1746	0.7102	0.7171	0.7311	0.6061	1.0000	…
LPE(%)	2.6	4.6	2.4	2.4	2.4	2.4	0.0	…
AAPE(%)	1.1	1.8	1.0	1.0	1.0	1.0	0.0	…
SPE(%)	0.1	0.4	0.1	0.1	0.1	0.1	0.0	…
Wet season variation								
α_{00}	0.2996	1.3741	1.3037	0.4702	1.3225	4.1734	-7.2108	…
α_{01}	…	-0.1401	-0.1331	…	-0.1375	-0.5998	91.4981	…
α_{10}	0.4031	…	0.0519	1.3376	…	-4.7478	…	…
α_{11}	…	…	…	-0.2058	0.0112	0.7857	…	…
α_{02}	…	…	…	…	…	…	-281.3621	…
α_{12}	…	…	…	…	…	…	38.6631	…
α_{20}	…	…	…	…	…	…	-0.8188	…
Se	0.0588	0.0267	0.0304	0.0380	0.0301	0.0115	0.0230	…
R_a^2	0.2073	0.8362	0.7881	0.6689	0.7928	0.9696	0.8791	…
LPE(%)	15.1	6.3	6.5	8.0	6.5	2.0	3.6	…
AAPE(%)	9.2	3.6	3.5	4.7	3.5	1.0	1.6	…
SPE(%)	5.4	1.3	1.2	1.9	1.2	0.1	0.2	…

Table 5. Regression parameters for fits using cloud cover and relative sunshine duration (Ikom)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly Variation								
α_{00}	0.1773	0.7480	0.3307	0.1925	0.5748	-0.1612	0.5145	-0.7377
α_{01}	…	-0.0488	-0.0200	…	-0.0552	0.0511	0.3378	18.0940
α_{10}	0.6730	…	0.6058	0.9538	…	1.8297	…	…
α_{11}	…	…	…	-0.0508	0.0879	-0.1782	…	-17.7306
α_{02}	…	…	…	…	…	…	-22.5681	-84.5680
α_{12}	…	…	…	…	…	…	58.1788	176.2364
α_{20}	…	…	…	…	…	…	-0.8908	4.2417
α_{21}	…	…	…	…	…	…	…	-34.6775
Se	0.0186	0.0528	0.0125	0.0122	0.0132	0.0127	0.0120	0.0138
R_a^2	0.9103	0.2753	0.9593	0.9611	0.9548	0.9584	0.9628	0.9504
LPE(%)	5.6	31.2	6.0	6.1	5.9	6.3	5.0	5.2
AAPE(%)	3.3	10.2	2.0	2.0	2.1	2.0	1.7	1.6
SPE(%)	2.1	18.0	0.9	0.9	0.9	1.0	0.7	0.6
Dry season Variation								
α_{00}	0.3928	0.4531	0.3110	0.1337	0.5805	-1.0851	2.1121	…
α_{01}	…	0.0046	-0.0256	…	-0.0586	0.2244	-13.5382	…
α_{10}	0.1976	…	0.7239	1.1794	…	3.9032	…	…
α_{11}	…	…	…	-0.0668	0.0933	-0.5652	…	…
α_{02}	…	…	…	…	…	…	-9.9097	…
α_{12}	…	…	…	…	…	…	121.2158	…
α_{20}	…	…	…	…	…	…	-3.0010	…
Se	0.0142	0.0155	0.0135	0.0123	0.0156	0.0074	0.0058	…
R_a^2	0.0169	-0.1797	0.1113	0.2593	-0.1943	0.7322	0.8379	…
LPE(%)	4.7	5.3	3.1	2.9	3.7	1.6	0.8	…
AAPE(%)	1.8	1.8	1.7	1.6	1.8	0.8	0.4	…
SPE(%)	0.3	0.4	0.2	0.2	0.3	0.0	0.0	…
Wet season variation								
α_{00}	0.1812	2.8202	0.5245	0.1946	0.7522	1.6489	-50.9358	…
α_{01}	…	-0.3525	-0.0465	…	-0.0791	-0.2070	694.7370	…
α_{10}	0.6425	…	0.5726	1.2044	…	-2.2045	…	…
α_{11}	…	…	…	-0.0879	0.0820	0.3969	…	…
α_{02}	…	…	…	…	…	…	-2355.1711	…
α_{12}	…	…	…	…	…	…	23.5358	…
α_{20}	…	…	…	…	…	…	-0.3190	…
Se	0.0149	0.0306	0.0166	0.0168	0.0165	0.0199	0.0254	…
R_a^2	0.9432	0.7596	0.9289	0.9271	0.9300	0.8980	0.8345	…
LPE(%)	5.8	9.9	6.2	6.2	6.1	5.6	4.5	…
AAPE(%)	2.5	6.1	2.4	2.3	2.4	2.4	2.2	…
SPE(%)	0.7	2.9	0.7	0.7	0.6	0.6	0.4	…

Table 6. Regression parameters for fits using cloud cover and relative sunshine duration (Jos)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly Variation								
α_{00}	0.1653	0.8685	0.1335	0.1249	0.6468	0.7856	0.2028	-0.4860
α_{01}	…	-0.0655	0.0031	…	-0.0712	-0.0900	-0.4625	9.4967
α_{10}	0.5769	…	0.6021	0.5776	…	-0.1540	…	…
α_{11}	…	…	…	0.0131	0.0825	0.1008	…	5.6836
α_{02}	…	…	…	…	…	…	11.4363	-45.8693
α_{12}	…	…	…	…	…	…	-13.6839	40.3408
α_{20}	…	…	…	…	…	…	0.8198	0.2045
α_{21}	…	…	…	…	…	…	…	-10.4579
Se	0.0153	0.0322	0.0161	0.0152	0.0098	0.0100	0.0165	0.0089
R_a^2	0.9766	0.8971	0.9742	0.9769	0.9905	0.9900	0.9728	0.9922
LPE(%)	5.7	14.0	5.7	5.3	3.4	2.8	5.3	2.5
AAPE(%)	2.2	5.4	2.2	2.0	1.3	1.2	2.2	1.0
SPE(%)	1.5	5.9	1.4	1.1	0.4	0.3	1.3	0.2
Dry season Variation								
α_{00}	0.2749	0.7939	0.1912	0.2027	0.5869	0.4692	0.1301	…
α_{01}	…	-0.0465	0.0079	…	-0.0677	-0.0475	2.7641	…
α_{10}	0.4386	…	0.5069	0.4648	…	0.1406	…	…
α_{11}	…	…	…	0.0178	0.0992	0.0755	…	…
α_{02}	…	…	…	…	…	…	-5.4533	…
α_{12}	…	…	…	…	…	…	0.3138	…
α_{20}	…	…	…	…	…	…	0.2132	…
Se	0.0077	0.0203	0.0084	0.0071	0.0046	0.0046	0.0024	…
R_a^2	0.9799	0.8602	0.9764	0.9829	0.9930	0.9929	0.9981	…
LPE(%)	1.5	4.9	1.4	1.4	0.8	0.7	0.3	…
AAPE(%)	1.0	2.0	0.9	0.8	0.5	0.4	0.1	…
SPE(%)	0.1	0.5	0.1	0.1	0.0	0.0	0.0	…
Wet season variation								
α_{00}	0.1506	1.2764	-0.0835	0.1148	0.4964	1.6551	-0.4006	…
α_{01}	…	-0.1294	0.0275	…	-0.0526	-0.2124	64.1990	…
α_{10}	0.5940	…	0.7094	0.4614	…	-1.4111	…	…
α_{11}	…	…	…	0.0323	0.0911	0.2716	…	…
α_{02}	…	…	…	…	…	…	-530.4406	…
α_{12}	…	…	…	…	…	…	541.5057	…
α_{20}	…	…	…	…	…	…	-11.4997	…
Se	0.0068	0.0231	0.0065	0.0063	0.0062	0.0072	0.0054	…
R_a^2	0.9883	0.8623	0.9893	0.9897	0.9903	0.9866	0.9924	…
LPE(%)	2.1	5.7	1.6	1.6	1.5	1.4	0.9	…
AAPE(%)	1.1	4.4	0.8	0.8	0.8	0.9	0.4	…
SPE(%)	0.2	1.5	0.1	0.1	0.1	0.1	0.0	…

Table 7. Regression parameters for fits using cloud cover and relative sunshine duration (Kano)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly Variation								
α_{00}	0.1755	0.7569	0.6061	0.4570	0.7244	1.3439	0.1590	-1.9861
α_{01}	…	-0.0322	-0.0262	…	-0.0701	-0.1864	1.5735	38.1588
α_{10}	0.6785	…	0.1899	0.3930	…	-0.8756	…	…
α_{11}	…	…	…	-0.0350	0.0704	0.2352	…	-66.6713
α_{02}	…	…	…	…	…	…	2.5492	-41.2453
α_{12}	…	…	…	…	…	…	-6.5363	60.4957
α_{20}	…	…	…	…	…	…	0.4606	5.5423
α_{21}	…	…	…	…	…	…	…	16.0592
Se	0.0340	0.0241	0.0241	0.0264	0.0209	0.0165	0.0182	0.0162
R_a^2	0.5616	0.7801	0.7793	0.7358	0.8342	0.8971	0.8742	0.9012
LPE(%)	9.9	6.7	5.8	6.1	4.9	4.1	4.0	2.8
AAPE(%)	4.2	3.2	2.9	3.1	2.4	1.9	1.8	1.5
SPE(%)	3.0	1.7	1.5	1.8	1.1	0.6	0.6	0.3
Dry season Variation								
α_{00}	0.6080	0.6980	0.7915	0.7460	0.7149	1.0719	0.6710	…
α_{01}	…	-0.0110	-0.0162	…	0.0097	-0.1183	1.4825	…
α_{10}	0.0857	…	-0.1135	-0.0455	…	-0.5362	…	…
α_{11}	…	…	…	-0.0246	-0.0389	0.1560	…	…
α_{02}	…	…	…	…	…	…	-5.3107	…
α_{12}	…	…	…	…	…	…	5.1369	…
α_{20}	…	…	…	…	…	…	-0.6448	…
Se	0.0173	0.0148	0.0164	0.0164	0.0165	0.0199	0.0264	…
R_a^2	-0.1579	0.1506	-0.0395	-0.0461	-0.0509	-0.5299	-1.7026	…
LPE(%)	3.5	2.8	2.6	2.5	2.5	2.8	2.6	…
AAPE(%)	1.9	1.6	1.5	1.6	1.6	1.4	1.3	…
SPE(%)	0.3	0.2	0.2	0.2	0.2	0.2	0.2	…
Wet season variation								
α_{00}	0.0980	0.8801	0.2868	0.2003	0.7324	-1.6154	0.4903	…
α_{01}	…	-0.0565	-0.0150	…	-0.0827	0.2862	7.7492	…
α_{10}	0.7668	…	0.5925	0.7169	…	3.1718	…	…
α_{11}	…	…	…	-0.0216	0.0865	-0.3985	…	…
α_{02}	…	…	…	…	…	…	-73.9515	…
α_{12}	…	…	…	…	…	…	79.7810	…
α_{20}	…	…	…	…	…	…	-1.3676	…
Se	0.0124	0.0203	0.0128	0.0124	0.0142	0.0114	0.0152	…
R_a^2	0.9305	0.8127	0.9261	0.9296	0.9088	0.9413	0.8955	…
LPE(%)	2.2	4.5	2.4	2.3	3.0	2.1	1.8	…
AAPE(%)	1.7	2.4	1.3	1.3	1.5	0.8	0.6	…
SPE(%)	0.2	0.5	0.1	0.1	0.2	0.1	0.1	…

Table 8. Regression parameters for fits using cloud cover and relative sunshine duration (Maiduguri)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly Variation								
α_{00}	0.3395	0.9642	0.0011	0.1820	0.6304	0.5936	-0.5473	-3.2844
α_{01}	…	-0.0527	0.0311	…	-0.0666	-0.0612	12.4746	54.2466
α_{10}	0.5093	…	0.7664	0.5245	…	0.0430	…	…
α_{11}	…	…	…	0.0422	0.1163	0.1103	…	-53.8503
α_{02}	…	…	…	…	…	…	-40.2399	-141.5915
α_{12}	…	…	…	…	…	…	12.7550	173.4041
α_{20}	…	…	…	…	…	…	0.0479	6.5588
α_{21}	…	…	…	…	…	…	…	-17.4925
Se	0.0205	0.0323	0.0192	0.0182	0.0175	0.0185	0.0142	0.0156
R_a^2	0.8749	0.6897	0.8902	0.9014	0.9091	0.8978	0.9405	0.9273
LPE(%)	5.9	9.4	4.5	4.8	4.6	4.6	2.8	2.3
AAPE(%)	2.0	3.2	1.9	1.7	1.6	1.6	1.3	1.4
SPE(%)	0.9	2.3	0.7	0.6	0.5	0.5	0.3	0.2
Dry season Variation								
α_{00}	0.4830	0.8529	-0.0040	0.1739	0.4561	0.5092	-0.7717	…
α_{01}	…	-0.0288	0.0454	…	-0.0671	-0.0795	24.3616	…
α_{10}	0.3177	…	0.6924	0.4152	…	-0.0775	…	…
α_{11}	…	…	…	0.0702	0.1693	0.1876	…	…
α_{02}	…	…	…	…	…	…	-109.6031	…
α_{12}	…	…	…	…	…	…	72.0528	…
α_{20}	…	…	…	…	…	…	-2.0965	…
Se	0.0132	0.0199	0.0093	0.0086	0.0082	0.0100	0.0116	…
R_a^2	0.7194	0.3626	0.8615	0.8795	0.8911	0.8371	0.7839	…
LPE(%)	2.9	4.0	1.6	1.6	1.6	1.6	1.2	…
AAPE(%)	1.0	1.5	0.7	0.7	0.6	0.6	0.4	…
SPE(%)	0.1	0.3	0.0	0.0	0.0	0.0	0.0	…
Wet season variation								
α_{00}	0.2391	1.4213	1.5591	0.5866	1.5465	0.6310	-16.6009	…
α_{01}	…	-0.1293	-0.1441	…	-0.1381	-0.0063	268.8057	…
α_{10}	0.6756	…	-0.0812	1.1179	…	1.0678	…	…
α_{11}	…	…	…	-0.1716	-0.0202	-0.1650	…	…
α_{02}	…	…	…	…	…	…	-1188.4529	…
α_{12}	…	…	…	…	…	…	651.4528	…
α_{20}	…	…	…	…	…	…	-14.9948	…
Se	0.0186	0.0091	0.0103	0.0077	0.0099	0.0095	0.0091	…
R_a^2	0.9164	0.9800	0.9743	0.9855	0.9764	0.9782	0.9799	…
LPE(%)	3.8	2.0	2.1	1.5	2.1	1.6	0.9	…
AAPE(%)	1.9	1.0	1.0	0.8	1.0	0.7	0.5	…
SPE(%)	0.2	0.0	0.0	0.0	0.0	0.0	0.0	…

Table 9. Regression parameters for fits using cloud cover and relative sunshine duration (Minna)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly Variation								
α_{00}	0.2106	0.7833	0.2957	0.2381	0.6308	0.2721	-0.0623	5.2612
α_{01}	…	-0.0477	-0.0084	…	-0.0566	-0.0049	3.6571	-78.2044
α_{10}	0.5241	…	0.4579	0.5367	…	0.4903	…	…
α_{11}	…	…	…	-0.0113	0.0649	-0.0047	…	70.8014
α_{02}	…	…	…	…	…	…	-4.0512	296.9704
α_{12}	…	…	…	…	…	…	-5.8900	-450.0127
α_{20}	…	…	…	…	…	…	0.5199	-11.1527
α_{21}	…	…	…	…	…	…	…	74.3620
Se	0.0227	0.0449	0.0228	0.0228	0.0236	0.0242	0.0223	0.0216
R_a^2	0.9175	0.6774	0.9168	0.9168	0.9112	0.9064	0.9206	0.9253
LPE(%)	9.0	16.4	7.7	7.7	7.7	7.7	7.2	6.1
AAPE(%)	3.6	7.3	3.3	3.3	3.3	3.3	2.6	2.3
SPE(%)	1.7	9.0	1.7	1.7	1.7	1.7	1.4	1.0
Dry season Variation								
α_{00}	0.2340	0.6749	0.1475	0.1637	0.5104	1.4078	-0.1096	…
α_{01}	…	-0.0216	0.0064	…	-0.0869	-0.2986	-3.5289	…
α_{10}	0.4995	…	0.5843	0.5502	…	-1.3979	…	…
α_{11}	…	…	…	0.0118	0.1505	0.4841	…	…
α_{02}	…	…	…	…	…	…	40.2828	…
α_{12}	…	…	…	…	…	…	-50.3193	…
α_{20}	…	…	…	…	…	…	2.5911	…
Se	0.0237	0.0331	0.0269	0.0267	0.0249	0.0280	0.0354	…
R_a^2	0.5833	0.1847	0.4625	0.4691	0.5387	0.4160	0.0671	…
LPE(%)	5.2	7.7	5.5	5.5	5.4	4.7	3.8	…
AAPE(%)	3.0	3.5	2.9	2.9	2.5	2.3	2.2	…
SPE(%)	0.6	1.2	0.6	0.6	0.5	0.4	0.3	…
Wet season variation								
α_{00}	0.2441	1.5595	0.4361	0.2682	0.7212	-12.1168	34.2161	…
α_{01}	…	-0.1655	-0.0249	…	-0.0656	1.7768	-433.0402	…
α_{10}	0.4431	…	0.3881	0.6874	…	18.1032	…	…
α_{11}	…	…	…	-0.0447	0.0544	-2.5117	…	…
α_{02}	…	…	…	…	…	…	1386.0805	…
α_{12}	…	…	…	…	…	…	-75.8840	…
α_{20}	…	…	…	…	…	…	3.2372	…
Se	0.0214	0.0335	0.0243	0.0239	0.0247	0.0126	0.0141	…
R_a^2	0.8828	0.7134	0.8496	0.8534	0.8441	0.9595	0.9489	…
LPE(%)	6.9	9.1	6.2	5.9	6.2	2.5	2.0	…
AAPE(%)	3.2	5.4	3.1	3.0	3.1	1.5	1.2	…
SPE(%)	0.8	2.4	0.8	0.8	0.9	0.2	0.1	…

Table 10. Regression parameters for fits using cloud cover and relative sunshine duration (Nguru)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly Variation								
α_{00}	0.3812	0.8545	0.9085	0.6174	0.8345	2.2300	-1.5779	-4.0485
α_{01}	…	-0.0443	-0.0484	…	-0.0465	-0.3122	25.5709	65.3804
α_{10}	0.3419	…	-0.0459	0.3061	…	-1.9222	…	…
α_{11}	…	…	…	-0.0577	0.0085	0.3783	…	-53.1244
α_{02}	…	…	…	…	…	…	-81.7807	-184.6299
α_{12}	…	…	…	…	…	…	29.1539	199.1507
α_{20}	…	…	…	…	…	…	-0.8651	5.5173
α_{21}	…	…	…	…	…	…	…	-18.7101
Se	0.0326	0.0268	0.0282	0.0302	0.0282	0.0233	0.0189	0.0217
R_a^2	0.3306	0.5475	0.4997	0.4284	0.4994	0.6574	0.7755	0.7038
LPE(%)	9.7	6.5	6.5	7.9	6.4	6.3	4.4	4.6
AAPE(%)	3.8	3.5	3.5	3.7	3.4	2.3	1.9	1.7
SPE(%)	2.9	1.9	1.9	2.2	1.9	1.1	0.6	0.6
Dry season Variation								
α_{00}	0.6581	0.6157	0.4593	0.5696	0.5406	0.6368	-3.0051	…
α_{01}	…	0.0079	0.0232	…	0.0060	-0.0139	46.6914	…
α_{10}	-0.0081	…	0.1135	-0.0397	…	-0.1308	…	…
α_{11}	…	…	…	0.0326	0.0243	0.0516	…	…
α_{02}	…	…	…	…	…	…	-166.6573	…
α_{12}	…	…	…	…	…	…	76.9377	…
α_{20}	…	…	…	…	…	…	-2.3606	…
Se	0.0224	0.0221	0.0247	0.0247	0.0247	0.0302	0.0322	…
R_a^2	-0.2488	-0.2066	-0.5180	-0.5130	-0.5139	-1.2683	-1.5755	…
LPE(%)	4.4	4.8	4.7	4.7	4.7	4.7	3.7	…
AAPE(%)	2.3	2.3	2.3	2.3	2.3	2.3	1.4	…
SPE(%)	0.5	0.5	0.4	0.4	0.4	0.4	0.2	…
Wet season variation								
α_{00}	0.1773	1.0405	0.8255	0.4417	0.8827	1.6793	2.3721	…
α_{01}	…	-0.0781	-0.0595	…	-0.0800	-0.2228	-39.8705	…
α_{10}	0.6157	…	0.1607	0.6367	…	-1.1606	…	…
α_{11}	…	…	…	-0.0724	0.0437	0.2531	…	…
α_{02}	…	…	…	…	…	…	213.2574	…
α_{12}	…	…	…	…	…	…	-140.3133	…
α_{20}	…	…	…	…	…	…	3.4424	…
Se	0.0166	0.0125	0.0137	0.0158	0.0129	0.0126	0.0150	…
R_a^2	0.8357	0.9072	0.8880	0.8509	0.9014	0.9057	0.8665	…
LPE(%)	3.8	3.3	2.6	2.5	2.0	2.3	1.9	…
AAPE(%)	1.9	1.5	1.4	1.7	1.3	0.9	0.9	…
SPE(%)	0.3	0.2	0.2	0.2	0.2	0.1	0.1	…

Table 11. Regression parameters for fits using cloud cover and relative sunshine duration (Potiskum)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly Variation								
α_{00}	0.1915	0.9352	0.6717	0.3696	0.7954	2.0808	-0.3548	-2.5681
α_{01}	…	-0.0606	-0.0407	…	-0.0725	-0.2786	3.1128	39.6429
α_{10}	0.6124	…	0.2292	0.5739	…	-1.7091	…	…
α_{11}	…	…	…	-0.0421	0.0564	0.3303	…	-44.2685
α_{02}	…	…	…	…	…	…	24.7590	-82.1121
α_{12}	…	…	…	…	…	…	-41.3643	122.1668
α_{20}	…	…	…	…	…	…	1.1290	6.3250
α_{21}	…	…	…	…	…	…	…	-17.8711
Se	0.0255	0.0219	0.0214	0.0239	0.0190	0.0109	0.0114	0.0128
R_a^2	0.7905	0.8450	0.8529	0.8166	0.8834	0.9621	0.9578	0.9475
LPE(%)	7.2	6.1	5.4	6.3	5.5	2.7	2.7	2.7
AAPE(%)	3.1	3.0	2.6	2.9	2.3	1.2	1.1	1.1
SPE(%)	1.9	1.6	1.3	1.6	1.0	0.2	0.3	0.2
Dry season Variation								
α_{00}	0.4912	0.7940	0.8124	0.6464	0.7971	1.3192	3.8502	…
α_{01}	…	-0.0307	-0.0323	…	-0.0305	-0.1349	-63.6332	…
α_{10}	0.2167	…	-0.0149	0.2149	…	-0.7440	…	…
α_{11}	…	…	…	-0.0452	-0.0012	0.1490	…	…
α_{02}	…	…	…	…	…	…	310.9979	…
α_{12}	…	…	…	…	…	…	-220.9866	…
α_{20}	…	…	…	…	…	…	6.6968	…
Se	0.0139	0.0098	0.0112	0.0116	0.0113	0.0131	0.0057	…
R_a^2	0.4792	0.7432	0.6587	0.6349	0.6578	0.5380	0.9133	…
LPE(%)	2.5	2.4	2.4	2.4	2.4	2.4	0.7	…
AAPE(%)	1.7	1.0	1.0	1.1	1.0	0.8	0.3	…
SPE(%)	0.2	0.1	0.1	0.1	0.1	0.1	0.0	…
Wet season variation								
α_{00}	0.1070	1.2239	0.5253	0.2354	0.8695	0.8433	-8.9626	…
α_{01}	…	-0.1083	-0.0418	…	-0.0936	-0.0897	154.2711	…
α_{10}	0.7280	…	0.4671	0.8337	…	0.0348	…	…
α_{11}	…	…	…	-0.0513	0.0696	0.0646	…	…
α_{02}	…	…	…	…	…	…	-718.3829	…
α_{12}	…	…	…	…	…	…	405.2992	…
α_{20}	…	…	…	…	…	…	-8.3580	…
Se	0.0087	0.0130	0.0058	0.0065	0.0054	0.0067	0.0066	…
R_a^2	0.9706	0.9342	0.9870	0.9835	0.9885	0.9827	0.9832	…
LPE(%)	2.3	3.5	1.1	1.2	1.2	1.2	1.0	…
AAPE(%)	1.1	1.6	0.6	0.7	0.6	0.6	0.3	…
SPE(%)	0.1	0.3	0.0	0.1	0.0	0.0	0.0	…

Table 12. Regression parameters for fits using cloud cover and relative sunshine duration (Yelwa)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly Variation								
α_{00}	0.1629	0.7927	0.1546	0.1005	0.6131	1.3202	0.0848	-0.0813
α_{01}	…	-0.0421	0.0006	…	-0.0800	-0.1814	0.2592	-4.3509
α_{10}	0.6264	…	0.6343	0.6649	…	-0.8966	…	…
α_{11}	…	…	…	0.0114	0.1147	0.2392	…	73.1395
α_{02}	…	…	…	…	…	…	15.2093	-127.4035
α_{12}	…	…	…	…	…	…	-20.9339	136.3699
α_{20}	…	…	…	…	…	…	0.9499	-2.1679
α_{21}	…	…	…	…	…	…	…	-64.8359
Se	0.0293	0.0388	0.0308	0.0304	0.0242	0.0218	0.0236	0.0173
R_a^2	0.8309	0.7021	0.8122	0.8175	0.8848	0.9062	0.8902	0.9408
LPE(%)	8.9	16.2	9.0	9.1	6.3	6.2	6.5	3.3
AAPE(%)	4.0	5.5	4.0	3.9	3.3	2.7	2.5	1.8
SPE(%)	3.0	5.6	3.0	2.9	1.8	1.2	1.5	0.5
Dry season Variation								
α_{00}	0.4288	0.6943	0.2916	0.2920	0.5553	1.9812	-0.0054	…
α_{01}	…	-0.0161	0.0101	…	-0.0668	-0.3552	5.7503	…
α_{10}	0.2736	…	0.4051	0.3765	…	-1.8924	…	…
α_{11}	…	…	…	0.0211	0.1184	0.5064	…	…
α_{02}	…	…	…	…	…	…	-10.3384	…
α_{12}	…	…	…	…	…	…	0.7862	…
α_{20}	…	…	…	…	…	…	-0.3086	…
Se	0.0234	0.0266	0.0265	0.0258	0.0221	0.0135	0.0169	…
R_a^2	0.3596	0.1757	0.1812	0.2273	0.4310	0.7874	0.6687	…
LPE(%)	3.8	5.3	4.1	4.2	3.3	2.2	1.9	…
AAPE(%)	3.0	3.0	2.9	2.8	2.4	1.0	0.7	…
SPE(%)	0.6	0.7	0.5	0.5	0.4	0.1	0.1	…
Wet season variation								
α_{00}	0.1072	0.8522	0.1403	0.1209	0.6299	-16.2800	-4.8300	…
α_{01}	…	-0.0530	-0.0029	…	-0.0748	2.4099	167.7577	…
α_{10}	0.7065	…	0.6809	0.7084	…	23.5314	…	…
α_{11}	…	…	…	-0.0041	0.0991	-3.3308	…	…
α_{02}	…	…	…	…	…	…	-1184.6265	…
α_{12}	…	…	…	…	…	…	1065.8059	…
α_{20}	…	…	…	…	…	…	-20.9369	…
Se	0.0211	0.0423	0.0243	0.0243	0.0245	0.0272	0.0155	…
R_a^2	0.8777	0.5102	0.8381	0.8381	0.8364	0.7976	0.9344	…
LPE(%)	6.2	13.2	6.2	6.2	6.3	4.9	2.4	…
AAPE(%)	2.7	6.3	2.6	2.6	2.6	2.6	0.9	…
SPE(%)	0.8	3.0	0.8	0.8	0.8	0.6	0.1	…

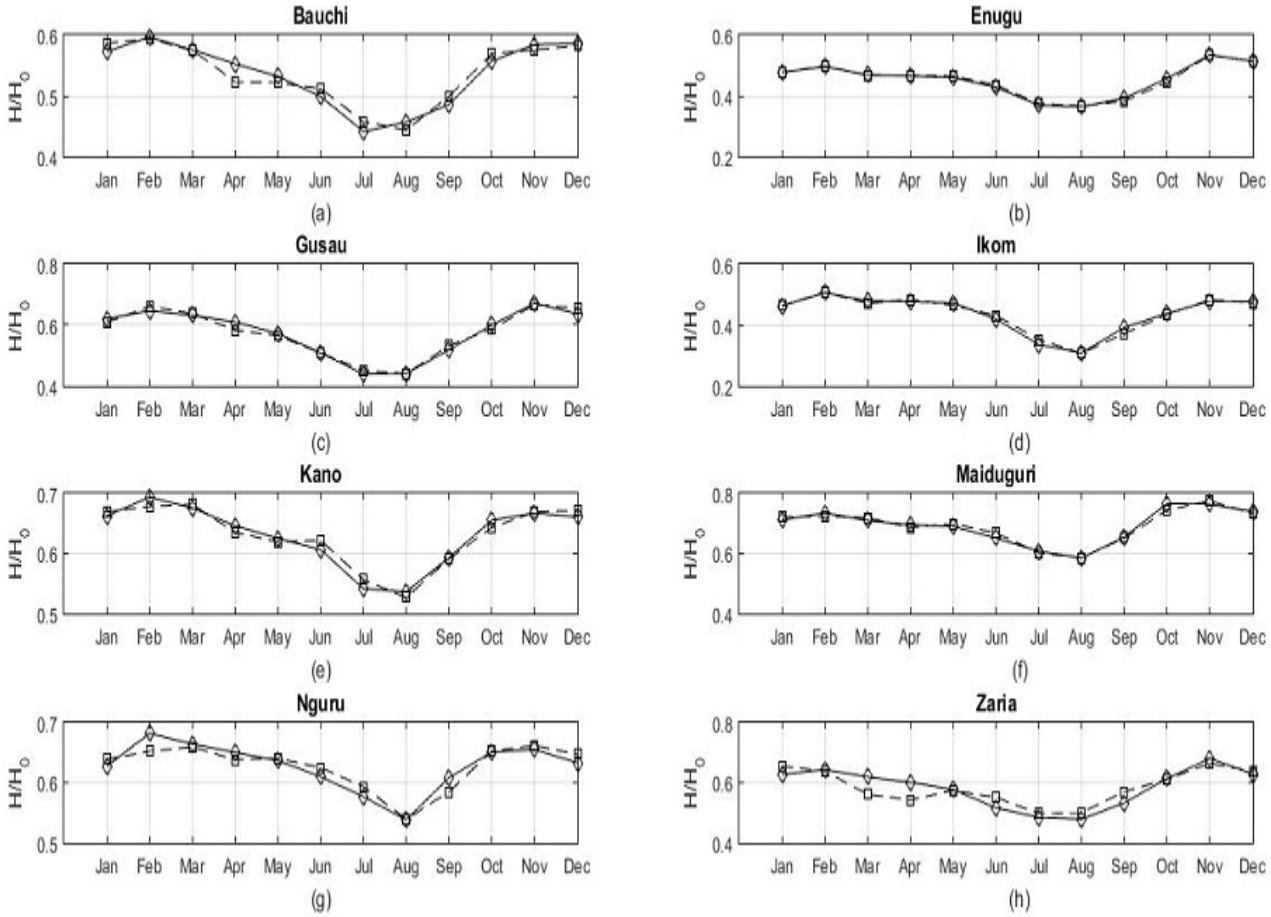
Table 13. Regression parameters for fits using cloud cover and relative sunshine duration (Yola)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly Variation								
α_{00}	0.1234	1.0566	0.1001	0.0809	0.5896	4.4959	-3.1098	-33.6901
α_{01}	…	-0.0798	0.0023	…	-0.0753	-0.6538	27.1376	580.1132
α_{10}	0.6860	…	0.7004	0.6533	…	-5.2004	…	…
α_{11}	…	…	…	0.0162	0.1122	0.8800	…	-395.9585
α_{02}	…	…	…	…	…	…	12.5182	-2449.4752
α_{12}	…	…	…	…	…	…	-119.4345	2980.7608
α_{20}	…	…	…	…	…	…	2.4562	47.7826
α_{21}	…	…	…	…	…	…	…	-360.9161
Se	0.0398	0.0531	0.0419	0.0417	0.0391	0.0295	0.0340	0.0167
R_a^2	0.7142	0.4910	0.6825	0.6864	0.7236	0.8428	0.7909	0.9499
LPE(%)	12.7	20.2	12.7	12.8	12.0	6.4	9.6	4.0
AAPE(%)	5.3	7.9	5.3	5.2	4.9	3.7	4.0	1.7
SPE(%)	5.7	10.4	5.7	5.6	4.9	2.2	3.1	0.6
Dry season Variation								
α_{00}	0.5001	0.6754	0.2337	0.3853	0.4819	1.3776	3.7483	…
α_{01}	…	-0.0094	0.0254	…	-0.0159	-0.1619	-55.7023	…
α_{10}	0.1747	…	0.3492	0.1324	…	-1.2395	…	…
α_{11}	…	…	…	0.0367	0.0585	0.2619	…	…
α_{02}	…	…	…	…	…	…	269.2077	…
α_{12}	…	…	…	…	…	…	-166.2372	…
α_{20}	…	…	…	…	…	…	3.9456	…
Se	0.0183	0.0230	0.0174	0.0171	0.0169	0.0198	0.0274	…
R_a^2	0.2713	-0.1455	0.3471	0.3697	0.3818	0.1525	-0.6304	…
LPE(%)	3.9	4.1	2.6	2.4	2.4	2.9	2.7	…
AAPE(%)	1.9	2.6	1.9	1.9	1.9	1.7	1.7	…
SPE(%)	0.3	0.5	0.2	0.2	0.2	0.2	0.2	…
Wet season variation								
α_{00}	0.0557	2.5005	-2.0630	-0.1883	-0.8815	-5.0360	6.3940	…
α_{01}	…	-0.2992	0.2633	…	0.0966	0.6843	-40.3158	…
α_{10}	0.7660	…	1.3834	-0.7428	…	4.9329	…	…
α_{11}	…	…	…	0.2893	0.1902	-0.4914	…	…
α_{02}	…	…	…	…	…	…	-106.8333	…
α_{12}	…	…	…	…	…	…	319.7313	…
α_{20}	…	…	…	…	…	…	-4.8260	…
Se	0.0139	0.0260	0.0092	0.0100	0.0097	0.0106	0.0130	…
R_a^2	0.9433	0.7998	0.9749	0.9702	0.9722	0.9669	0.9500	…
LPE(%)	4.5	7.8	2.5	2.7	2.6	2.4	2.1	…
AAPE(%)	2.0	3.8	1.1	1.3	1.3	1.1	0.8	…
SPE(%)	0.4	1.3	0.1	0.2	0.1	0.1	0.1	…

Table 14. Regression parameters for fits using cloud cover and relative sunshine duration (Zaria)

	Eqn(2)	Eqn(3)	Eqn(4)	Eqn(5)	Eqn(6)	Eqn(7)	Eqn(8)	Eqn(9)
Yearly Variation								
α_{00}	0.1879	1.9453	0.6699	0.2468	1.0138	5.9120	-25.1892	129.2375
α_{01}	…	-0.2002	-0.0585	…	-0.1089	-0.8140	352.6384	-2682.4963
α_{10}	0.6373	…	0.5016	0.9671	…	-6.7616	…	…
α_{11}	…	…	…	-0.0627	0.0737	1.0471	…	2633.0448
α_{02}	…	…	…	…	…	…	-1253.9576	12430.5129
α_{12}	…	…	…	…	…	…	139.7851	-18322.8995
α_{20}	…	…	…	…	…	…	-2.1147	-281.6579
α_{21}	…	…	…	…	…	…	…	1962.0920
Se	0.0403	0.0471	0.0415	0.0419	0.0412	0.0410	0.0398	0.0400
R_a^2	0.6224	0.4856	0.5996	0.5921	0.6067	0.6089	0.6321	0.6278
LPE(%)	12.7	14.0	12.0	12.3	11.9	10.2	9.7	10.6
AAPE(%)	5.2	6.9	5.2	5.2	5.1	4.9	4.1	3.1
SPE(%)	5.2	7.3	5.0	5.1	4.9	4.2	3.5	2.5
Dry season Variation								
α_{00}	0.4555	1.1176	-0.0359	0.3689	0.2778	-1.2127	4.1521	…
α_{01}	…	-0.0728	0.0572	…	0.0114	0.2334	-85.1282	…
α_{10}	0.2715	…	0.4405	-0.0534	…	2.2209	…	…
α_{11}	…	…	…	0.0690	0.0645	-0.2675	…	…
α_{02}	…	…	…	…	…	…	531.5038	…
α_{12}	…	…	…	…	…	…	-387.7922	…
α_{20}	…	…	…	…	…	…	7.0021	…
Se	0.0164	0.0211	0.0176	0.0180	0.0180	0.0207	0.0143	…
R_a^2	0.6308	0.3840	0.5746	0.5521	0.5561	0.4125	0.7174	…
LPE(%)	3.0	4.4	2.9	2.8	2.9	2.8	1.6	…
AAPE(%)	2.0	2.2	1.9	1.9	1.9	1.8	0.6	…
SPE(%)	0.3	0.4	0.2	0.2	0.2	0.2	0.1	…
Wet season variation								
α_{00}	0.1344	6.0477	2.1826	0.2130	2.5346	-6.2203	-144.2297	…
α_{01}	…	-0.7934	-0.2828	…	-0.3333	0.9221	1974.5586	…
α_{10}	0.6810	…	0.5404	3.7217	…	13.6161	…	…
α_{11}	…	…	…	-0.4570	0.0774	-1.8754	…	…
α_{02}	…	…	…	…	…	…	-6678.8654	…
α_{12}	…	…	…	…	…	…	-206.4465	…
α_{20}	…	…	…	…	…	…	4.1381	…
Se	0.0170	0.0348	0.0134	0.0127	0.0136	0.0143	0.0039	…
R_a^2	0.8967	0.5689	0.9359	0.9425	0.9345	0.9275	0.9946	…
LPE(%)	5.4	8.9	2.8	2.7	2.8	2.7	0.6	…
AAPE(%)	1.8	4.6	1.6	1.4	1.6	1.2	0.2	…
SPE(%)	0.3	1.7	0.1	0.1	0.2	0.1	0.0	…

Appendix B



Plots of observed and fitted yearly clearness index versus months of the year

Fig. 1. Plots of observed (solid line) and fitted (dash line) yearly clearness index versus months of the year