ESTIMATION OF DIFFUSE SOLAR RADIATION AT BARRA DE SANTA ROSA (PB)

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ABSTRACT

Results of a study on the estimation of mean monthly values of diffuse solar radiation at Barra de Santa Rosa (PB) are reported in this paper. Radiation data at the station for nine years are used to obtain equations relating the diffuse fraction of global radiation to the clearness index and the sunshine ratio. Mean monthly values of the diffuse radiation fraction derived from the equations are compared with measured values. The applicability of previously reported expressions, for stations in this region is investigated.
KEY WORDS: Diffuse solar radiation, global radiation, clearness index

ESTIMATIVA DA RADIAÇÃO SOLAR DIFUCA EM BARRA DE SANTA ROSA (PB)

RESUMO

Resultados de um estudo de avaliação dos valores médios mensais da radiação solar difusa em Barra de Santa Rosa (PB) são apresentados neste trabalho. Foram usados nove anos de dados de radiação coletados nesta localidade para obter equações que relacionam a fração difusa de radiação global para o índice de clareza e a razão de brilho solar. Valores médios mensais da radiação difusa derivada das equações foram comparados com valores medidos. A aplicabilidade das expressões previamente apresentadas para localidades desta região foi investigado.
Palavras Chave: Radiação solar difusa, radiação global, índice de clareza.

INTRODUCTION: Availability of solar radiation data is a basic necessity for the design of energy conversion devices. In assessing the performance of systems utilizing solar energy an important input parameter is the diffuse solar radiation on a horizontal surface at the location of interest. Diffuse solar radiation is still measured at only a few locations. In developing countries this dearth is even more acute. A series of empirical correlations have been suggested for the estimation of the diffuse fraction of global radiation.

Results of a study on the estimation of diffuse solar radiation at Barra de Santa Rosa in Paraiba state are reported in this paper. Radiation data at the station for nine years is

used to derive equations for the estimation of the diffuse fraction of global radiation. The validity of previously reported equations, for stations in this region is verified.

METHODOLOGY: The extraterrestrial solar radiation is computed using the equation

$$R_T = \frac{24}{\pi} I_{SC} . E_0 \left[\sin\phi . \sin\delta \left(\frac{W_S \pi}{180} \right) + \cos\phi . \cos\delta . \sin W_s \right] \quad (1)$$

Where I_{sc} is the solar constant (4921 KJ $m^{-2}h^{-1}$). The eccentricity factor (E_0), solar declination (δ) and the sunset hour angle (W_s) are computed from the following expressions :

$$E_0 = 1 + 0.033 . \cos\left(\frac{360\, N_d}{365} \right) \quad (2)$$

$$\delta = 23.45 . \sin\left[\frac{360}{365} (284 + N_d) \right] \quad (3)$$

$$W_S = \cos^{-1}\left[- \tan\phi . \tan\delta \right] \quad (4)$$

N_d is the day number and Φ is the latitude.

The maximum possible sunshine (N) in hours is given by

$$N = \frac{2}{15} \cos^{-1}\left[- \tan\phi . \tan\delta \right] = \frac{2W_S}{15} \quad (5)$$

Daily values of global radiation (R), diffuse solar radiation (R_s) and sunshine (n) at Barra de Santa Rosa during nine years between 1975 and 1994 are used to derive equations relating the diffuse fraction of global radiation to the clearness index K_T (K_T = Rs/R) and the sunshine ratio (n/N).

RESULTS: Climatological mean monthly values of some radiation quantities and related ratios at B arra de Santa Rosa are presented in Table 1.
Using daily values of the radiation parameters during nine years the following relationship is derived between Rs/R and the clearness index K_T.

$$Rs/R = 1.06 - 1.386\ K_T \quad (6)$$

Values of Rs/R derived from the above equation are given in Table 2 together with the measured values.
Liu and Jordon (1960) developed a statistically based correlation from results obtained from a single station Blue Hill MA. Klein (1977) developed the following mathematical expression for the correlation

$$Rs/R = 1.390 – 4.027\ K_T + 5.531\ K_T^2 - 3.108\ K_T^3 \quad (7)$$

Page (1961) developed correlations between daily total and diffuse radiation for ten widely spread stations in the 40^o N – 40S latitude belt and obtained the following relationship

$$Rs/R = 1.00 – 1.13\ K_T \quad (8)$$

Gopinathan (1988) derived an expression for Rs/R as a function of both the clearness index and the sunshine ratio .The equation

$$Rs/R = 0.879 – 0.575\ K_T - 0.323\ (n/N) \quad (9$$

was found to provide good estimates of diffuse solar radiation for stations in South Africa.

Values of Rs/R based on Eqs 7, 8 and 9 are included in the table 2 Mean percentage error (MPE), mean bias error (MBE) and the root mean square error (RMSE) in Table 2 show that equation 6 estimates diffuse solar radiation at BR the station with more precision than the other equations.

While the work of Liu and Jordon (1960) is based on data from a single location it has been found to yield good results in different locations in the world .In the present case their equation provides better estimates of diffuse fraction of global radiation than that of Gopinathan (1988) .The Eq of Page cannot be used at this location though it has been extensively used (Iqbal 1979, Lewis 1983, Modi and Sukhatme 1979, Vignola and McdDaniels 1984).

An Angstrom type equation for the estimation of global radiation at Barra de Santa Rosa has been reported earlier (Kumar et al., 2006)

$$R/Rt = 0.33 + 0.27\ n/N \quad (10\ )$$

From Eqs 6 and 10 we obtain

$$Rs/R = 0.6 – 0.37\ n/N \quad (11\ )$$

Values of Rs/R based on Eq 11 given in Table 2 show that this equation provides nearly as good estimates as that of Liu and Jordon (1960). It may be mentioned here that Eq 6 needs only global radiation data while Eq 11 needs global radiation and sunshine.

M	R	Rs	R_T	R/R_T	n	N	n/N	Rs/R
Jan	18.0	7.4	37.8	0.477	7.32	11.65	0.63	0.41
Feb	18.8	7.6	38.3	0.490	7.09	11.78	0.60	0.40
Mar	18.2	7.1	37.9	0.481	6.75	11.96	0.56	0.39
Apr	16.7	6.6	36.0	0.464	6.43	12.14	0.53	0.39
May	15.8	6.2	33.5	0.470	6.33	12.30	0.51	0.40
Jun	14.0	6.3	32.0	0.437	5.73	12.38	0.46	0.45
Jul	14.4	6.6	32.6	0.441	5.78	12.35	0.47	0.46
Aug	16.9	6.5	35.2	0.480	6.98	12.20	0.57	0.38
Sep	18.1	6.9	37.3	0.484	7.61	12.03	0.63	0.38
Oct	20.3	6.7	38.3	0.531	8.44	11.84	0.71	0.33
Nov	19.3	7.2	38.0	0.507	7.99	11.68	0.68	0.37
Dec	18.5	7.1	37.5	0.494	7.51	11.61	0.65	0.38

Table 1. Radiation data at Barra de Santa Rosa - PB ($6^o 43' S$ $36^o 03 W$)

		$(R_S/R)_{Est.}$				
Month	$(R_S/R)_{Meas}$	Liu & Jordon Eq. 7	Gopinathan Eq. 9	Page Eq. 8	Eq 6	Eq. 11
Jan	0.41	0.39	0.40	0.46	0.40	0.37
Feb	0.40	0.38	0.40	0.45	0.38	0.38
Mar	0.39	0.39	0.42	0.46	0.39	0.39
Apr	0.39	0.40	0.44	0.48	0.41	0.40
May	0.40	0.40	0.44	0.47	0.40	0.41
Jun	0.45	0.43	0.48	0.51	0.45	0.43
Jul	0.46	0.42	0.47	0.50	0.45	0.43
Aug	0.38	0.39	0.42	0.46	0.39	0.39
Sep	0.38	0.38	0.40	0.45	0.39	0.37
Oct	0.33	0.35	0.34	0.40	0.32	0.34
Nov	0.37	0.36	0.37	0.43	0.36	0.35
Dec	0.38	0.38	0.39	0.44	0.38	0.37
MPE (%)		3.1	5.3	16.5	2.1	3.9
MBE		-0.006	0.019	0.064	-0.0017	-0.009
RMSE		0.017	0.026	0.066	0.01	0.019

Table 2. Measured and estimated values of diffuse fraction of global radiation

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