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Estimation of sunshine hours by harmonic analysis

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ABSTRACT

Fourier series was utilized for the estimation of monthly sunshine hours based on the mean monthly measured sunshine hours. The mean monthly measured sunshine hours data of 34 years, from 1958 to 1994 at Anand has been used in the present study. Fourier series was developed by taking different harmonics i.e., 3rd to 6th harmonic. Estimates thus obtained revealed that the results obtained with the third harmonic are in good agreement with measured monthly sunshine hours. The differences between measured and estimated sunshine hours were found statistically non- significant.

Key words : Sunshine hours, Harmonic analysis, Fourier analysis

The phenological growth and yield of a crop are largely influenced by the thermal regime and sunshine. Observations conducted over a period of years indicated that the sunshine hour duration does not change appreciably from year to year and varies only with latitude and season. Hours of bright sunshine are measured at only selected locations. Hence, an attempt has been made to estimate the actual sunshine hours using fourier series.

MATERIALS AND METHODS

Data of 34 years from 1958 to 1994 at Anand (22° 35' N, 72° 55' E, 45 m AMSL) were collected to establish the series. Any periodic function can be represented by fourier series.

The general form representing the monthly mean sunshine hours can be written as :

$$S(t) = A_o + \sum_{1}^{6} A_n cosznt + B_n sinznt$$

where, $S(t)$ = sunshine hours

t = month (from Jan. to Dec.)

A_n and B_n = fourier coefficients

n = harmonic number

$z = 360°/12 = 30°$

RESULTS AND DISCUSSION

The results of the harmonic analysis, presented in Table 1 shows the absolute deviation by using third to sixth harmonics. The fourier equation developed from the available data upto the sixth harmonics is as under:

$$S(t) = A_o + \sum_{1}^{6} A_n cosntz + B_n sinntz$$

$$S(t) = A_o + A_1 costz + A_2 cos2tz + A_3 cos3tz + A_4 cos4tz + A_5 cos5tz + A_6 cos6tz + B_1 sintz + B_2 sin2tz + B_3 sin3tz + B_4 sin4tz + B_5 sin5tz + B_6 sin6tz \quad \text{.........(1)}$$

where,

$A_1 = 1.974$	$B_1 = 1.073$
$A_2 = -1.451$	$B_2 = -0.698$
$A_3 = -0.043$	$B_3 = 0.683$
$A_4 = 0.000$	$B_4 = -0.072$
$A_5 = -0.089$	$B_5 = -0.713$
$A_6 = -0.038$	$B_6 = 0.000$

The measured and expected sunshine hours are presented in Fig.1 using the respective harmonics. It is observed that differences in the observed and estimated values of sunshine hours are higher on application of higher order of harmonics.

Table 1: Absolute deviation for observed and estimated sunshine hours by different harmonics

Month	3 HAR	4 HAR	5HAR	6 HAR
Jan.	0.4370	0.4800	0.5690	0.6074
Feb.	0.0105	0.0728	0.0035	0.0418
Mar.	0.5298	0.5920	1.1650	1.1267
Apr.	0.0090	0.0090	0.7220	0.6837
May	0.5314	0.5937	0.7925	0.5308
June	0.0190	0.0815	1.0459	1.0076
July	0.4380	0.4406	0.5271	0.4888
Aug.	0.1726	0.1103	0.3892	0.4275
Sep.	0.7006	0.6363	1.2092	1.2475
Oct.	1.3250	1.3250	0.6120	0.5737
Nov.	0.6102	0.5479	0.1120	0.1503
Dec.	0.1102	0.0483	0.0410	0.4240

Absolute deviations between observed and estimated sunshine are presented in Table 1. Results reveal that the absolute deviation is minimum except for the month of October. Although we have developed the fourier series for higher harmonics yet the use of higher harmonics do not seem to improve the reliability of results but on the contrary it increases the deviation between measured and estimated sunshine hours. The equation representing three harmonics is as under :

$$S(t) = 8.18 + A_1\cos tz + A_2\cos 2tz + A_3\cos 3tz + B_1\sin tz + B_2\sin 2tz + B_3\sin 3tz \quad ....(2)$$

where the values of A's and B's are given above.

Table 2 : Per cent absolute deviation between observed and estimated sunshine hours for different harmonics

Month	3 HAR	4 HAR	5 HAR	6 HAR
Jan.	4.7800	5.2516	6.2264	6.6450
Feb.	0.1070	0.7536	0.0357	0.4269
Mar.	5.4400	6.0842	11.973	11.576
Apr.	0.0890	0.0890	7.1980	6.8165
May	5.3460	5.9928	4.9547	5.3400
June	0.2516	1.0768	13.852	13.345
July	10.045	10.105	12.089	11.211
Aug.	4.6026	2.9413	10.378	11.400
Sep.	9.9517	9.0383	17.176	17.720
Oct.	14.402	14.402	6.6521	6.2358
Nov.	6.7800	6.0877	1.2447	1.6700
Dec.	1.2720	0.5577	0.4734	4.8900

The percentage differences between observed and estimated sunshine hours and their Chi square analysis are presented in Table 2 and 3 respectively. The percentage differences are minimum in the third harmonic in all the months. These differences when further tested by Chi square were found non-significant.

Among the different months July to October showed larger differences when compared to other months in the year. This is

Fig. 1 Comparision of observed and estimated sunshine hours for different harmonics

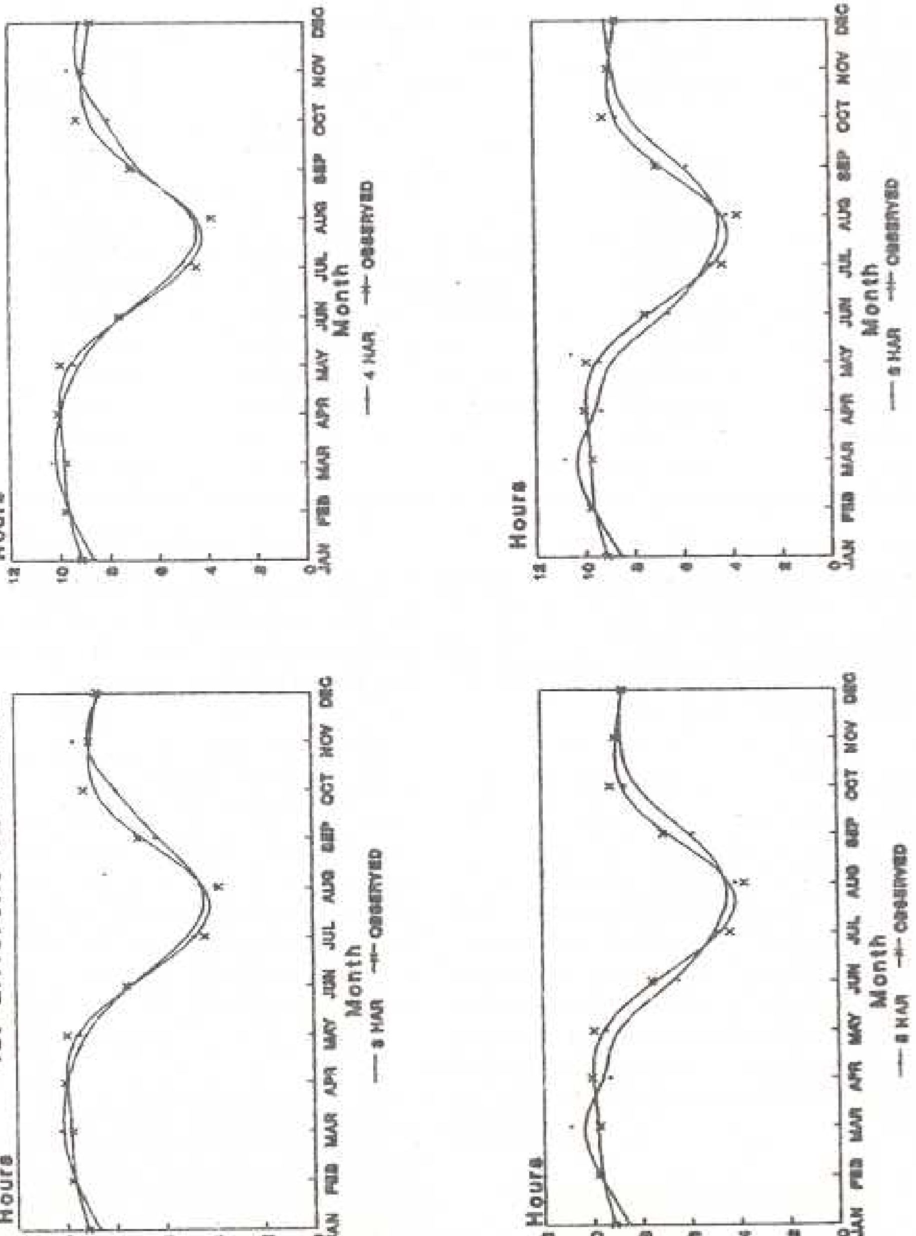

Table 3 : Chi square coefficients between observed and estimated sunshine hours for different harmonics

Month	3 HAR	4 HAR	5 HAR	6 HAR
Jan.	0.021940	0.026600	0.037700	0.04320
Feb.	0.001070	0.000540	0.000010	0.00017
Mar.	0.420580	0.033900	0.124570	0.11692
Apr.	0.000009	0.000080	0.056000	0.05001
May	0.030000	0.037710	0.256000	0.02994
June	0.000070	0.000860	0.168000	0.15518
July	0.030000	0.040400	0.056800	0.04927
Aug.	0.007590	0.003500	0.036590	0.04374
Sep.	0.077400	0.057500	0.250700	0.26866
Oct.	0.222930	0.222900	0.043600	0.03815
Nov.	0.038900	0.033300	0.001410	0.00255
Dec.	0.001420	0.000270	0.000193	0.19790

due to the fact that this period is a monsoon period with cloudiness. There is no uniformity in pattern intensity, depth and types of clouds over the years. This has greater role in absolute deviation between actual and estimated sunshine hours.

It is concluded from the analysis that fourier series could be used to estimate monthly average sunshine hours for Anand and nearby places. Similar equations can also be developed for other stations.