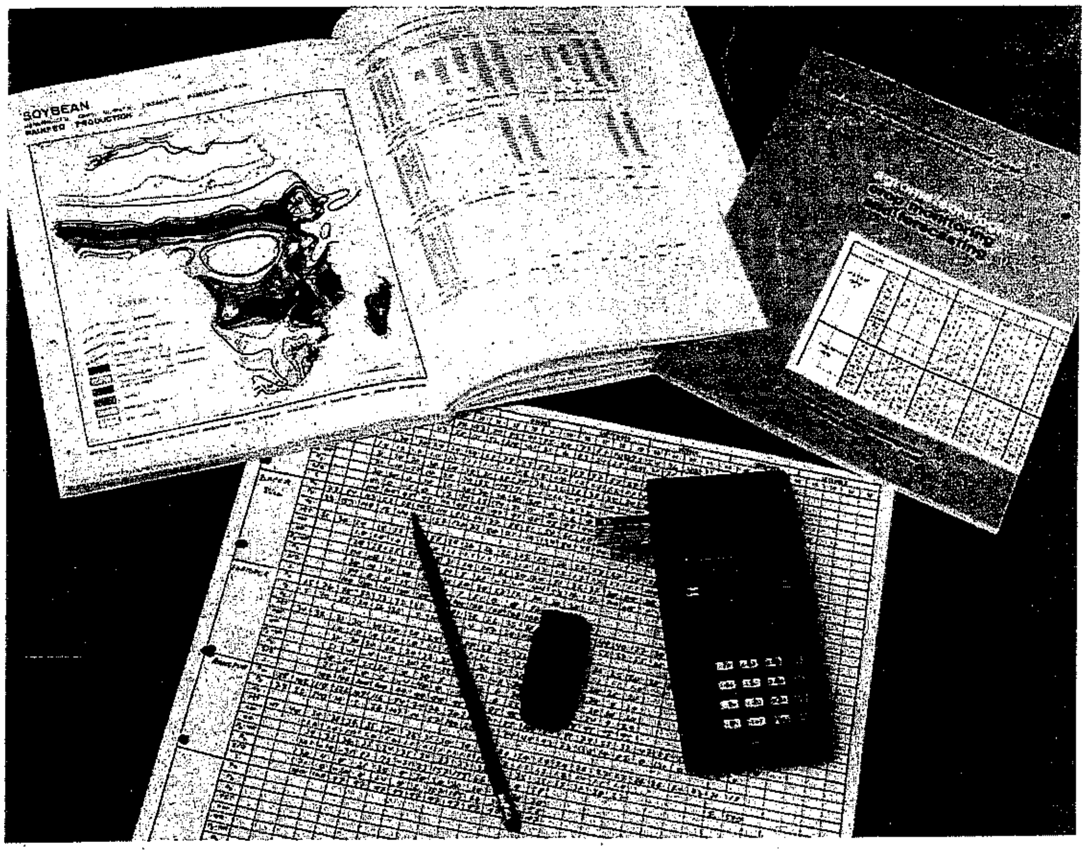
FAO PLANT PRODUCTION AND PROTECTION PAPER 45

pocket computers in agrometeorology



FOOD AND AGRICULTURE ORGANIZATION
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FAO PLANT PRODUCTION AND PROTECTION PAPER 45

pocket computers in agrometeorology

by
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Chapter 5

Interpolation of some weather element normals

Averaged over long periods, the weather elements typically assume the shape of smooth curves when plotted against time. The year to year variability is cancelled out, particularly when the time units are months or even decades. For shorter periods, very long records are required and the concept of climatological normal does not apply any more.

For practical reasons, the published normals refer to monthly periods. However, in most instances the time unit used in operational agrometeorology is the pentade, week or decade. Hence the necessity to interpolate the normals for shorter periods. This approach could be quite easy in the case of decades but difficulties arise when the time periods are, for instance, weeks or periods of any length. The present chapter provides a method to solve these problems.

Particularly for the rains, the normals are often misleading, since they do not represent the expected or most likely value. Quintiles or deciles that provide an approximation of the statistical distribution can be interpolated as well for shorter periods.

5.1 Method

From a theoretical point of view, the methods must be different if the parameter is a sum (integral, like total rain, total hours of sunshine, etc.) or an arithmetic mean (like temperatures, windspeed, etc.).

In practice, however, the same alogrithm can be used for for both types of variables, as exemplified under 5.1.2 below.

It should be stressed here that the limits used to define a span of time are not identical with day numbers:

```
   1     2     3     4     5     6        day number
+-----+-----+-----+-----+-----+-----+
0     1     2     3     4     5     6     time limits
```

Thus, for example, days 2 and 3 are comprised within the limits 1 and 3.

In addition, a method will be given that allows mean day-time and night-time to be calculated from temperature extremes (chapter I.6).

5.1.1 Rains, PET, total hours of sunshine

In the discussion below the weather element will be assumed to be rainfall. The methods can be used without any modification for other accumulated parameters.

Let C_1, C_2 and C_3 be the normal rainfall accumulation over 3 succeeding months with n_1, n_2 and n_3 days respectively. A function Y is to be found, such as:

$$\int_0^{X_1} Y dx = C_1; \qquad \int_0^{X_2} Y dx = C_1 + C_2; \qquad \int_0^{X_3} Y dx = C_1 + C_2 + C_3$$

where $X_1 = n_1, X_2 = n_2 + n_1$ and $X_3 = n_1 + n_2 + n_3$.

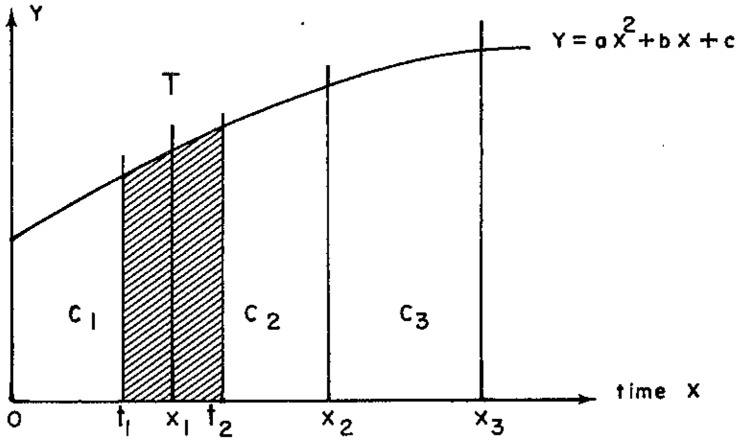

Figure 5: The normal rainfall amounts C_1, C_2 and C_3 fallen during n_1, n_2 and n_3 days respectively define the curve Y. This can be used to interpolate the rainfall for shorter periods (amount T from t1 to t2).

With a second degree parabola for Y the following equations will yield the constants a, b and c:

$$\begin{cases} \frac{a}{3} x_1^3 + \frac{b}{2} x_1^2 + cx_1 = C_1 \\ \frac{a}{3} x_2^3 + \frac{b}{2} x_2^2 + cx_2 = C_1 + C_2 \\ \frac{a}{3} x_3^3 + \frac{b}{2} x_3^2 + cx_3 = C_1 + C_2 + C_3 \end{cases}$$

the determinant of which is:

$$d = \begin{vmatrix} x_1^3 & x_1^2 & x_1 \\ x_2^3 & x_2^2 & x_2 \\ x_3^3 & x_3^2 & x_3 \end{vmatrix}$$

It may be calculated as: $d = x_1 x_2 x_3 (x_1 - x_2)(x_1 - x_3)(x_2 - x_3)$

Applying Cramer's method it is found that:

$$\frac{a}{3} = \frac{C_1}{d} (x_1 - x_2) (x_1 - x_3) (x_2 - x_3)$$

$$+ \quad \frac{C_2}{d} x_1 (x_2 - x_3) (x_1 - x_2 - x_3)$$

$$+ \quad \frac{C_3}{d} x_1 x_2 (x_1 - x_2)$$

With $K_1 = C_1 - \frac{a}{3} x \frac{3}{1} = \frac{b}{2} x \frac{2}{1} + cx_1$

$K_2 = C_1 + C_2 - \frac{a}{3} x \frac{3}{2} = \frac{b}{2} x \frac{2}{2} + cx_2$

c and b may be calculated as:

$$c = \frac{K_2 x_1^2 - K_1 x_2^2}{x_1^2 x_2 - x_2^2 x_1} = \frac{K_1 x_2^2 - K_2 x_1^2}{n1 \ n2 \ x2}$$

and $\frac{b}{2} = (C_1 - cx_1 - \frac{a}{3} x_1^3) / x_1^2$

For any time interval (t_1, t_2) the normal rain or PET will be given by:

$$P = \int_{t_1}^{t_2} Ydx$$

or: $P = \frac{a}{3} (t_2^3 - t_1^3) + \frac{b}{2} (t_2^2 - t_1^2) + c (t_2 - t_1)$

For any period from day i to day j of the intermediate month t_1 and t_2 are given by:

$$t_1 = n_1 + i - 1$$

and $t_2 = n_1 + j$

It usually acceptable to take some constant and standard value for the lengths of the months, for example $n_1 = n_2 = n_3 = m = 30$. The coefficients of the parabola are then more easily calculated with:

$$\frac{a}{3} = \frac{C_1 - 2C_2 + C_3}{6m^3}$$

$$\frac{b}{2} = \frac{-6C_1 + 9C_2 - 3C_3}{6m^2}$$

$$c = \frac{11C_1 - 7C_2 + 2C_3}{6m}$$

the determinant being $d = -12m^6$.

In the case of decades a further simplication is obtained since the normals P_1, P_2 and P_3 of decades 1 to 3 are calculated as:

$$P_1 = \frac{5C_1 + 26C_2 - 4C_3}{81}$$

$$P_2 = \frac{-C_1 + 29C_2 - C_3}{81}$$

$$P_3 = \frac{-4C_1 + 26C_2 + 5C_3}{81}$$

In these calculations m is supposed to be m = 30 and the assumed length of each decade is 10 days. It is easily seen that:

$$P_1 + P_2 + P_3 = C_2$$

5.1.2 Temperature, windspeed, etc.

If we define y_1, y_2 and y_3 as the normals of three consecutive months, these values are first turned into sums to obtain C_1, C_2 and C_3:

$$C_1 = y_1 \, n_1$$

$$C_2 = y_2 \, n_2$$

$$C_3 = y_3 \, n_3$$

The coefficients a, b and c, as well as t_1 and t_2 are then computed as under 5.1.1. The next step consists in dividing the value of P (a sum) by $t_2 - t_1$ to yield the average.

For decade normals and under the assumption that m = 30, the values are obtained from:

$$P_1 = \frac{5\,y_1 + 26\,y_2 - 4\,y_3}{27}$$

$$P_2 = \frac{-y_1 + 29\,y_2 - y_3}{27}$$

$$P_3 = \frac{-4\,y_1 + 26\,y_2 + 5\,y_3}{27}$$

5.2 A TI-58/59 programme (m = 30)

5.2.1 Memory allocation

C_1, C_2 and C_3 are successively stored into MØ:

$t_1 \rightarrow$ M1

$t_2 \rightarrow$ M2

$a/3 \rightarrow$ M3

$b/2 \rightarrow$ M4

$c \rightarrow$ M5

$180 \rightarrow$ M6

5.2.2 Programme listing

Programme	Comments
2nd Lbl A STO Ø STO3 RCL Ø x 6 +/- = STO4 RCLØ x 11 = STO5 R/S	put in C_1 $C_1 \rightarrow M3$ $-6C_1 \rightarrow M4$ $11\ C_1 \rightarrow M5$
2nd Lbl B STOØ x 2 +/- = SUM3 RCLØ x 9 = SUM4 RCLØ x 7 +/- = SUM5 R/S	put in C_2 $M3 - 2C_2 \rightarrow M3$ $M4 + 9C_2 \rightarrow M4$ $M5 - 7C_2 \rightarrow M5$
2nd Lbl C STOØ SUM 3 x 3+/- = SUM4 RCLØ x 2 = SUM5	put in C_3 $M3 + C_3 \rightarrow M3$ $M4 - 3C_3 \rightarrow M4$ $M5 + 2C_3 \rightarrow M5$
 RCL6 INV 2nd Prd 5 x 30 = INV 2nd Prd 4 x 30 = INV 2nd Prd 3 R/S	compute a/3, b/2 and c $M5/180 \rightarrow M5$ $M4/180/30 \rightarrow M4$ $M3/180/30/30 \rightarrow M3$
2nd Lbl D STO 1 R/S	put in t_1
2nd Lbl E STO 2	put in t_2
$y^x 3$ - RCL1 $y^x 3$ = x RCL3 + (RCL2 x^2 - RCL1x^2) x RCL4 + (RCL2 - RCL1) x RCL5 =	$a/3\ (t_2^3 - t_1^2)$ $+ b/2\ (t_2^2 - t_1^2)$ $+ c\ (t_2 - t_1)$
R/S	display the normal

5.3 Programme Operation

Input	Key	Display
C_1 or y_1 n_1	A	$11C_1$
C_2 or y_2 n_2	B	$-7C_2$
C_3 or y_3 n_3	C	162000
t_1	D	t_1
t_2	E	P
if average	$/(t_2 - t_1)$	normal

5.4 Examples

5.4.1 Manual calculations

a) Example with rainfall data

The precipitation normals (mm) at Oran/Essenia (Algeria) are:

67 70 54

for December, January and February. Compute rainfall normal for the two-weekly period from 5 January to 18 January as well as the 3 decade normals of January.

With the input data:

$n_1 = 31$ $C_1 = 67$

$n_2 = 31$ $C_2 = 70$

$n_3 = 28$ $C_3 = 54$

d is found to be:

$$d = (31 - 62)\ (31 - 90)\ (62-90)\ .\ 31\ .\ 62\ .\ 90$$

$$d = -\ 8858651760$$

$$\frac{a}{3} = \frac{67}{d}\ (31 - 62)(31 - 90)\ (62 - 90)$$

$$+ \frac{70}{d}\ .31\ (62 - 90)\ (31 - 62 - 90)$$

$$+ \frac{54}{d}\ .31.62\ (31 - 62)$$

$$\frac{a}{3} = -.0000793945$$

$$K_1 = 67 + .0000793945 \times 31^3 = 69.3652$$

$$K_2 = 67 + 70 + .0000793945 \times 62^3 = 155.9219$$

and $$c = \frac{K_1\ .62^2 - K_2.31^2}{31.31.62} = \frac{116798.88}{59582} = 1.9603$$

and $\frac{b}{2} = \frac{67 - 1.9603 \times 31 + .0000793945 \times 31^3}{31^2}$

$\frac{b}{2} = \frac{8.5959}{961} = .008945$

The values of t_1 and t_2 are computed from:

$t_1 = 31 + 5 - 1 = 35$

$t_2 = 31 + 18 = 49$

Then the corresponding normal is given by:

$P = -.0000793945\ (49^3 - 35^3) + .008945\ (49^2 - 35^2) + 1.9603\ (49 - 35)$

$P = -5.94 \quad + 10.52 \quad + 27.44$

$P \approx 32$ mm

The decade normals will be taken as:

$P_1 = \frac{5 \times 67 + 26 \times 70 - 4 \times 54}{81} = 24.0$ mm

$P_2 = \frac{-67 + 29 \times 70 - 54}{81} = 23.6$ mm

$P_3 = \frac{-4 \times 67 + 26 \times 70 + 5 \times 54}{81} = 22.5$ mm

b) Examples with temperatures

The temperature normals for a hypothetical station are, in January, February and March (°C):

17 25 19

Compute the normals for the weeks ending 5, 12, 19 and 26 February as well as the decade normals, assuming a standard month of $m = 30$ days.

First compute $C_1 = 17 \times 30 = 510$

$C_2 = 25 \times 30 = 750$

$C_3 = 19 \times 30 = 570$

and the values of t_1 and t_2. They are:

28 and 35	for the week ending on	5 February
35 and 42		12
42 and 49		19
49 and 56		26

The parabola coefficients are found to be:

$\frac{a}{3} = -.002593$

$\frac{b}{2} = .3667$

$c = 8.333$

and the four weekly normals are (^{o}C)

165.79/7 = 23.7

175.04/7 = 25.0

178.97/7 = 25.6

177.55/7 = 25.4 respectively.

The decade normals turn out to be:

24.4, 25.5 and 25.1 ^{o}C

5.4.2 <u>Example of calculations using the programme</u>

The rainfall normals at Iringa Nduli Airport meteorological station (7^{o} 40S, 35^{o} 45E, 1246 m; Tanzania) are in mm 118, 135, 75, 7 during February through May. Compute the weekly rainfall normals for March and April from the week starting on 6 March. The table below lists i, j, t_1 and t_2.

Month	i	j	t_1	t_2
March	6	12	35	42
	13	19	42	49
	20	26	49	56
	27	"33"	56	63
April	"-4"	2	25	32
	3	9	32	39
	10	16	39	46
	17	23	46	53
	24	30	53	60

The normal for the week from 27 March to 2 April will be computed twice: as a "March-week" and as an "April-week". The average weighted by the number of days in March (5) and in April (2) will be taken as the weekly normal.

The programme is run in Fix 0 mode.

Input	Key	Output	Comments
118	A	1298	
135	B	-945	
75	C	162000	
35	D	35	
42	E	33	6 - 12 March
42	D	42	
49	E	32	13 - 19 March
49	D	49	
56	E	30	20 - 26 March
56	D	56	
63	E	28	27 - "33" March
135	A	1485	
75	B	-525	
7	C	162000	
25	D	25	
32	E	26	"-4" - 2 April
32	D	32	
39	E	22	3 - 9 April
39	D	39	
46	E	19	10 - 16 April
46	D	46	
53	E	15	17 - 23 April
53	D	53	
60	E	12	24 - 30 April

For the week from 27 March to 2 April, the normal would be "corrected" as:

$$(28 \times 5 + 26 \times 2) / 7 = 27.42 \simeq 27$$

In this case, the correction is insignificant.

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