Mausam, (1979), 30, 4, 511-516

551.579.5

Estimation of soil moisture at deeper depth from surface layer data

B. C. BISWAS and S. K. DASGUPTA

Meteorological Office, Pune

(*Received 29 September 1978*)

ABSTRACT. *In situ* measurements of soil moisture at deeper layers is very difficult especially in heavy soils. Regression equations have, therefore, been developed to estimate in the clear season soil moisture variations at deeper layers from fluctuation of soil moisture in the surface layer. Estimated values are compared with observed ones. The estimates are seen to be reasonably accurate.

1. Introduction

A knowledge of the pattern of soil moisture distribution and its accumulation at various depths in different types of rainfall years is vital for designing effective agronomic practices. The assessment of the march of the productive soil moisture by physical measurement, specially in the deeper layers is very difficult without disturbing soil and plant roots. Moreover, taking samples from deeper layers are also labourious and time consuming. A large number of samples per unit area are required to be taken for obtaining a representative value of soil moisture. One of the ways to avoid these difficulties is to formulate some method of estimation of soil moisture at the deeper layers from parameters which can be measured easily.

Studies on some of the characteristics of soil moisture variations in the surface layer and the movement of moisture through the soil have been made by Ramdas and Mallik (1942), Ramdas (1951), Baier and Robertson (1966) and Baier (1969). Biswas (1978) studied the fluctuations of soil moisture at the different layers in relation to rainfall for a few stations.

Attempts have been made in this study to estimate soil moisture at deeper depths from soil moisture at or near the surface layer by fitting suitable regression equations using soil moisture data recorded at various stations of different climatic and soil zones.

2. Data

Three stations, Delhi, Surat and Dharwar, where reliable soil moisture data were available for a long period, were taken for the study. Observations were recorded fortnightly for the four depths, 15 cm, 30 cm, 45 cm and 60 cm. At Dharwar observations were available on bare soil only and for one additional depth 7.5 cm. At Surat observations were taken on bare soil and soil covered with two varieties of cotton crop, the varieties being 'Suyog' and '2087' henceforth referred to as cotton V_1 and cotton V_2 respectively. At Delhi observations were taken on soil covered with two varieties of wheat, namely, 'NP 4' and 'NP 710' henceforth referred to as wheat V_1 and wheat V_2 respectively. The observations over bare soil were round the year. The observations in crop were available at Delhi taken during November to April of next year and Surat from the end of September to March. The soil moisture values for a particular fortnight for all the years for which data were available were averaged out. This was done mainly to get rid of small observational errors and also to avoid situations where observations were taken just after the occurrence of heavy rainfall since under such condition the soil moisture profile will be considerably disturbed.

3. Method

When plotted as a graph the soil moisture values showed the following features :

(*i*) The variation of soil moisture at a particular depth was more or less linear with the soil moisture near the surface layer (Figs. 1 to 6).

(*ii*) The variation of soil moisture with depth was curvilinear, but approached linearity with decrease in soil moisture near the surface layer (Fig. 7) to quite low values.

Incorporating these two features the equation suggested to estimate soil moisture at deeper depth from that at or near the surface layer was of the form,

$$S=A(d-d_0)+S_0\ [1+B(d-d_0)^2]+S_e \qquad (1)$$

where S is the soil moisture at depth d and S_0 the soil moisture at or near the surface layer whose depth is d_0; A, B and S_e are constants in the equation. S_0, d and d_0 being known S was estimated from them.

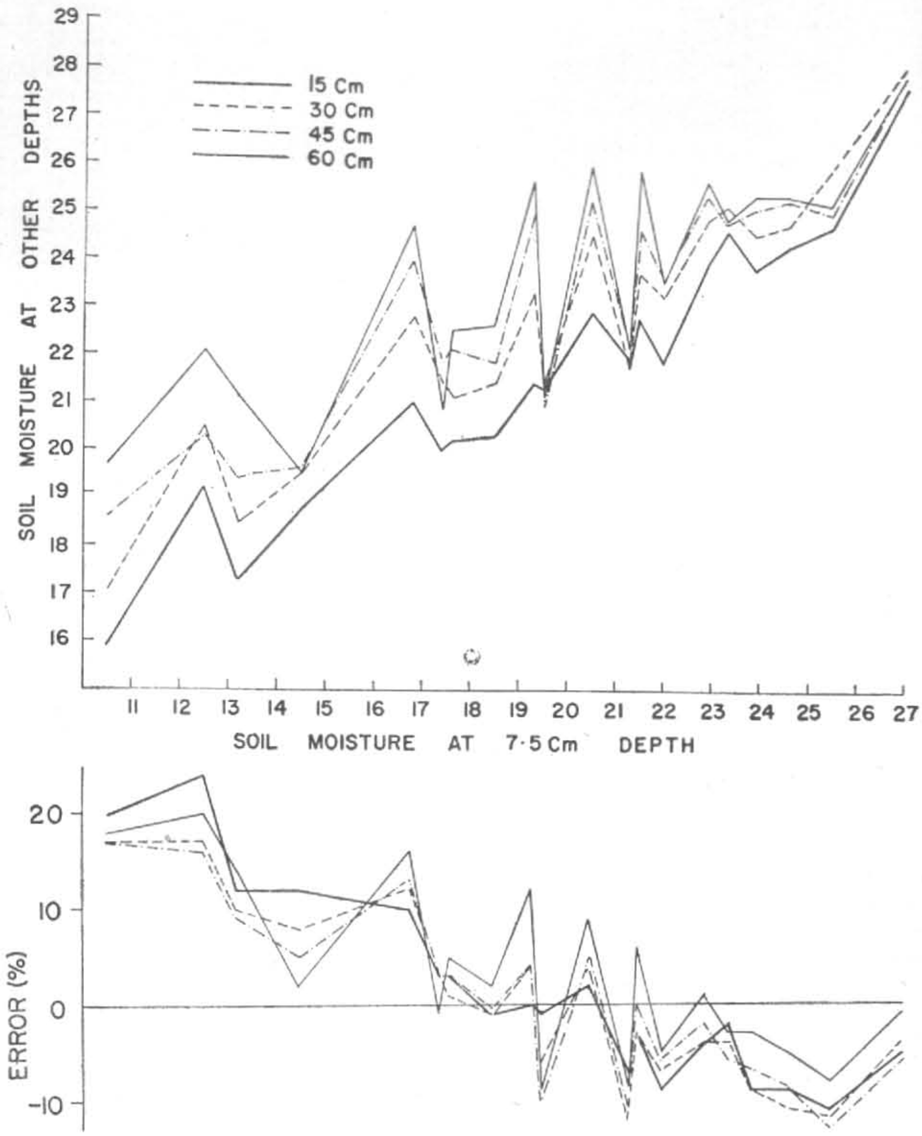

Fig. 1. Soil moisture (%) at Dharwar over bare plot along with the errors of estimation expressed as per cent of observed values

TABLE 1

Constants in regression Eqn. (1) coefficient of determination (C.D.) between soil moisture amounts

Station	Vegetation	A	B	S_e	C. D.			
					15 cm	30 cm	45 cm	60 cm
Dharwar	Bare soil	0.3356	— 0.000451	0.1187	0.90	0.85	0.77	0.62
Surat	Bare soil	0.6712	— 0.001298	0.5893	—	0.94	0.79	0.79
	Cotton V_1	0.4675	— 0.000810	— 0.1918	—	0.94	0.88	0.86
	Cotton V_2	0.3575	— 0.000520	— 0.3825	—	0.96	0.94	0.46
New Delhi	Wheat V_1	0.4087	— 0.000493	— 1.8453	—	0.94	0.92	0.96
	Wheat V_2	0.3230	— 0.000295	— 1.4090	—	0.92	0.94	0.88

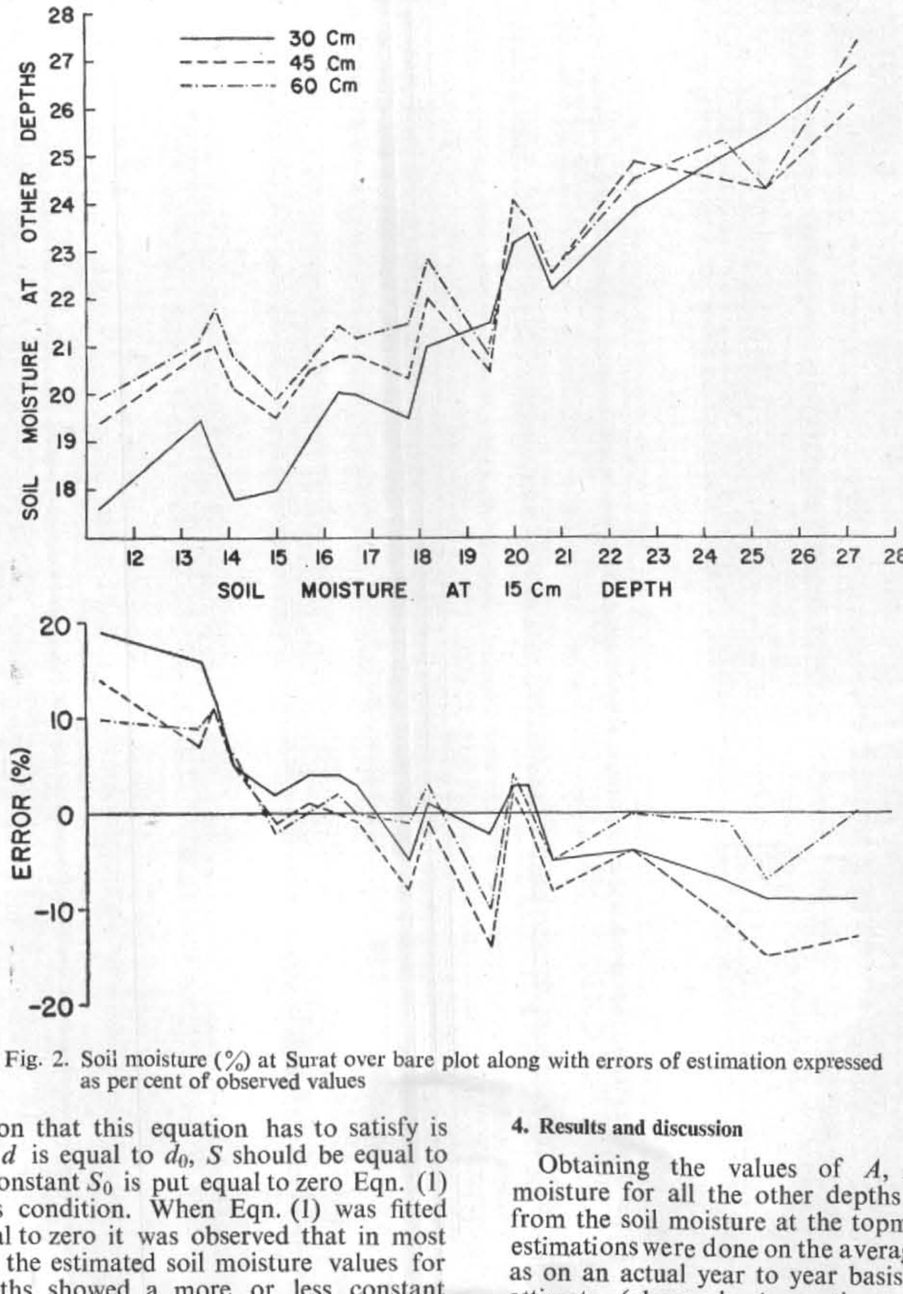

Fig. 2. Soil moisture (%) at Surat over bare plot along with errors of estimation expressed as per cent of observed values

A condition that this equation has to satisfy is that when d is equal to d_0, S should be equal to S_0. If the constant S_0 is put equal to zero Eqn. (1) satisfies this condition. When Eqn. (1) was fitted with S_c equal to zero it was observed that in most of the cases the estimated soil moisture values for all the depths showed a more or less constant deviation from the observed values. This constant deviation was considered to be a characteristic of the soil and vegetation and hence the constant S_c was introduced and it is equal to a constant value other than zero when d is different from d_0 and equal to zero when d is equal to d_0.

Putting $\Upsilon = S - S_0$, $X_1 = (d - d_0)$ and $X_2 = S_0\,(d - d_0)^2$ the Eqn. (1) can be rewritten as

$$\Upsilon = S_c + AX_1 + BX_2 \qquad (2)$$

This equation was fitted to the soil moisture data for different stations and for different crops by the method of multiple regression and the constant S_c, A and B were determined (Table 1).

4. Results and discussion

Obtaining the values of A, B and S_c soil moisture for all the other depths were estimated from the soil moisture at the topmost layer. The estimations were done on the averaged data as well as on an actual year to year basis. The errors of estimate (observed *minus* estimated soil moisture expressed as per cent of observed values) subsequently computed showed (Figs. 1 to 6) that the estimates were considerably good. Only in a few cases the errors were more than 20 per cent of the observed values. The high coefficients of determination (Tables 1 and 2) also reveal the same.

The constants S_c in Eqn. (1) showed some characteristic features. Values of S_c were positive over bare soil and negative over soil covered with vegetation. A possible explanation for this could be that the relative loss of moisture due to evaporation from the surface layer over bare soil is more than that at deeper layers. Similarly for soils

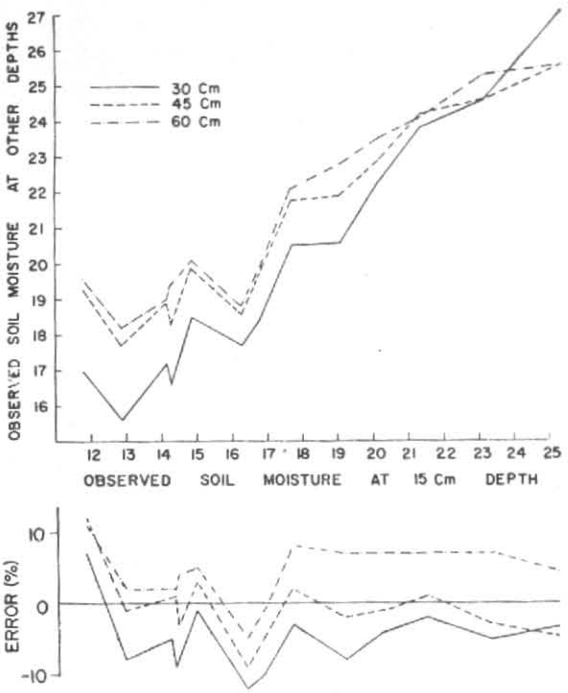

Fig. 3. For Cotton V_1

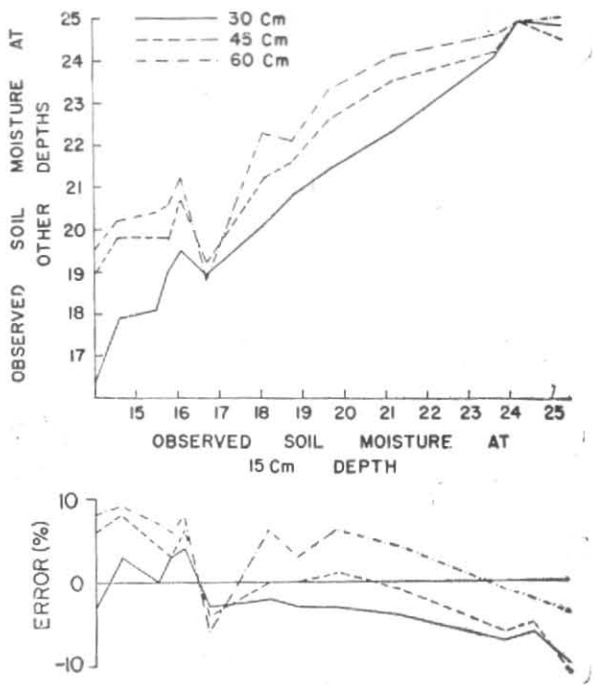

Fig. 4. For Cotton V_2

Figs. 3-4. Soil moisture (%) at Surat, along with errors of estimation expressed as per cent of observed values

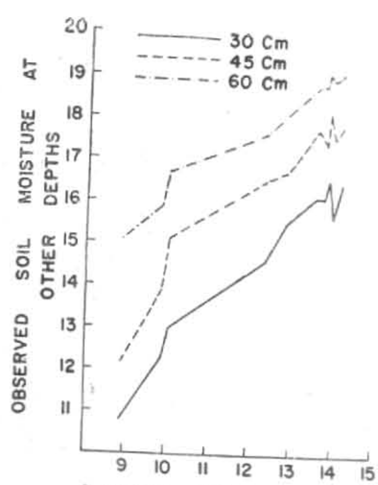

Fig. 5. For Wheat V_1

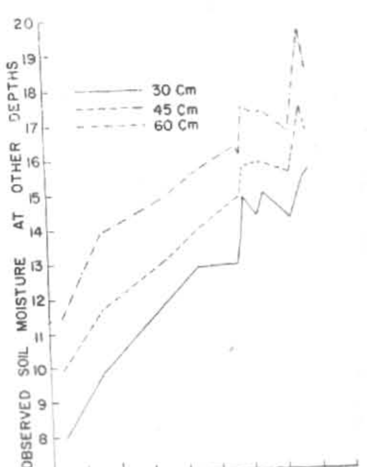

Fig. 6. For Wheat V_2

Figs. 5-6. Soil moisture (%) at New Delhi, along with errors of estimation expressed as per cent of observed values

TABLE 2

Coefficients of determination between the observed and estimated soil moisture amounts at Surat wheat V_2 for the different depths for the period 1953 1966

Year	Depth		
	30 cm	45 cm	66 cm
1953	0.81	0.75	0.46
1955	0.94	0.83	0.86
1956	0.84	0.78	0.79
1957	0.90	0.82	0.79
1958	0.85	0.80	0.76
1959	0.97	0.93	0.95
1960	0.71	0.72	0.55
1962	0.83	0.78	0.74
1963	0.91	0.84	0.87
1964	0.88	0.78	0.87

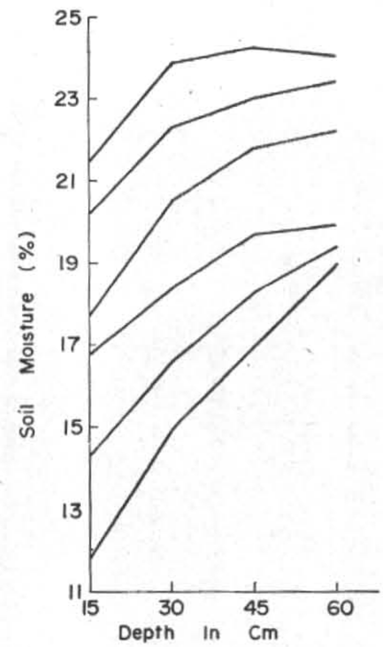

Fig. 7. Variation of soil moisture with depth at Surat

with vegetation cover the loss of moisture from surface layer due to evaporation is less whereas the loss of moisture from deeper layers due to transpiration is comparatively higher. Dharwar is having mixed red and black types of soil and annual rainfall is 813 mm. Moisture at 7.5 cm depth varies from 10.5 to 26.8 per cent and moisture at other layers vary from 15.6 to 28.1 per cent. Only on one occasion the error of estimation was more than 20 per cent and on all other occasions the errors were much less than 20 per cent. Coefficient of determination varies from 0.62 to 0.90.

The coefficients of determination (Table 2) between the observed and estimated values of soil moisture at Surat were between 0.71 and 0.97 at 30 cm depth, between 0.72 and 0.93 at 45 cm depth and in except one or two occasions were more than 0.77 at 60 cm depth. These indicate good fit of the equation.

The values of the constants A, B and S_a (Table 1) for crop showed that even though the soil type and climate were the same the constants differed slightly from vareity to variety of a certain crop.

The Eqn. (1) for the estimation of soil moisture was based on certain assumptions. These assumptions prohibit the use of the equations in situations immediately after rainfall or irrigation. The equation cannot be used during monsoon season or for kharif crops and also for irrigated crops. In many of the dry farming tract in India, the main crops are raised on stored soil moisture and Eqn.(1) would be useful in estimating the soil moisture status for such crops from surface layer, say at 15 cm or less deep measurements.

5. Conclusion

The CAgM of WMO has recommended four methods for measurement of soil moisture at different depths. If observations are recorded at the same place by these four methods and any one of them is taken as the standard, the values may vary by more than 15 per cent. Considering this situation the equation developed for above stations may be conveniently used to estimate the soil moisture of deeper layers from that of the surface layer during post monsoon season.

Acknowledgements

We wish thank to Dr. R. P. Sarker, Deputy Director General of Observatories (Climatology & Geophysics) and Shri S. Venkataraman, Director, Agricultural Meteorology Division, Pune for their interest and encouragement. Thanks are due to Shri M. Sethumadhavan for typing the paper,

References

Baier, W. and Robertson, G. W, 1966, A new versatile soil moisture budget, *Can. J. Plant Sci.*, **46**.

Baier, W., 1969, Concepts of soil moisture availability and their effects on soil moisture estimates from a meteorological budget, *Agric. Met.*, **6**, 3.

Biswas, B. C., 1978, Soil moisture variation under rainfed condition at Pune and Delhi in relation to rainfall, *Indian J. Met. Hydrol. Geophys.*, **29**, 3, pp. 555-560.

Biswas, B. C. and Mhaiskar, P. R., 1977, Estimation of soil moisture deficit from meteorological factors, *Indian J. Met. Hydrol. Geophys.*, **28**, 3, pp. 355-358.

Ramdas, L. A. and Mallik, A. K., 1942, Studies on soil, *Proc. Indian Acad. Sci.*, **16**.

Ramdas, L. A., 1951, The movement of moisture through the soil, Proc. of the symp. on Groundwater, Publ. No. 4 of Central Board of Geophysics.