Indian J. Met. Hydrol. Geophys. (1975), **26**, 4, 525-530

551.579.5 : 551.573 (547.1)

Measurement of soil moisture in Poona black cotton soil using an infra-red moisture balance

R. R. KELKAR and V. R. CHIVATE

Meteorological Office, Poona

(*Received 14 August 1974*)

ABSTRACT. Measurements of soil moisture were made at 0, 15, 30 and 45 cm depths in black cotton soil at Poona in June-October 1973 using an infra-red moisture balance. The results are presented and discussed in relation to rainfall and evaporation.

Throughout the active monsoon period, the soil moisture in the 30-45 cm layer remained more or less constant (25 per cent by weight). Due to evaporation and infiltration into lower levels there was generally less moisture at 15 cm depth than at 30 or 45cm. The moisture content of the surface layer was most variable (8 to 32 per cent) and highly sensitive to rainfall and evaporation.

An inverse relationship has been observed between soil moisture and soil temperature at any depth.

1. Introduction

In recent years, there has been a growing emphasis on the importance of soil moisture in the soil-water-plant relationship. A knowledge of optimum soil moisture levels at various stages of crop growth is essential for the efficient scheduling of irrigation and timing of agricultural operations. This has direct economic significance, particularly in those regions where dry land farming is being developed. Soil moisture measurements also form part of hydrological investigations on run-off and drainage losses and are used in water and soil conservation studies.

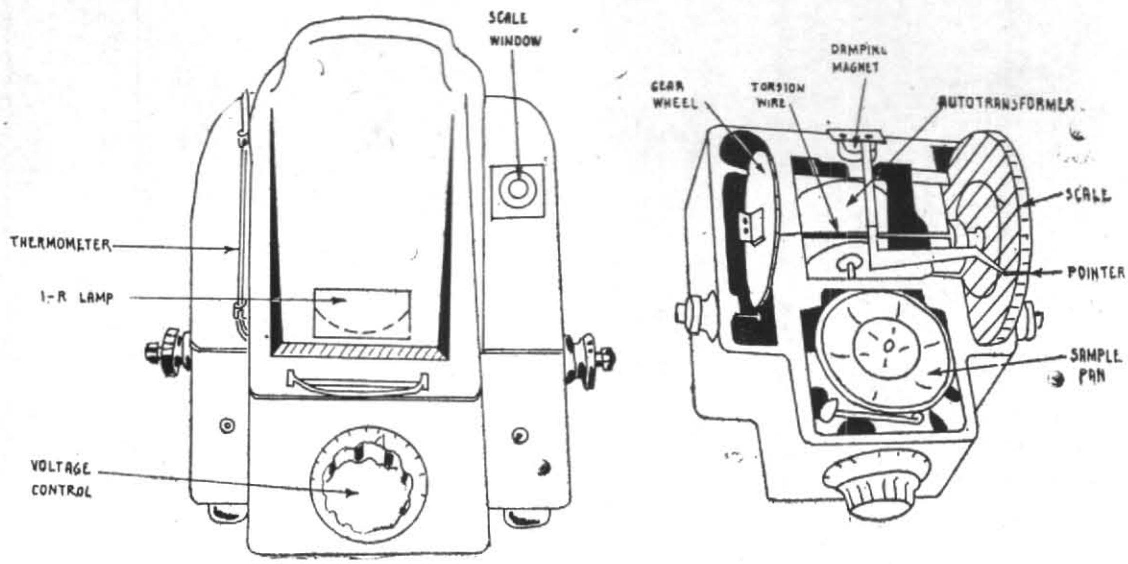
Although a wide range of methods are available for measuring soil moisture, the gravimetric method is the most widely accepted. It is also the only method which has been generally recommended for routine application in agricultural practices (Stanhill 1968). The gravimetric method is simple and does not need specially skilled personnel. Difficulties in sample extraction, prolonged heating process and non-repeatability of measurement at the same point in the soil are its major drawbacks. However, even in sophisticated techniques which overcome these problems, such as those based on neutron moderation or gamma-ray absorption, the basic calibration has still to be made with reference to gravimetric measurements (Beskin 1966).

In the gravimetric method, the soil sample is initially weighed on a chemical balance, dried in a steam oven, then cooled and weighed again, the soil moisture being computed from the loss in weight. The infra-red moisture balance employs the gravimetric principle, but comprises of an infra-red lamp and a torsion balance in a single compact unit. Drying and weighing of the sample can thus proceed simultaneously and at the end of the drying process, the soil moisture is directly readable on a scale. Using this instrument, measurements of soil moisture were made in black cotton soil at Poona during the period June to October 1973. The results are presented in this paper and discussed in relation to rainfall, evaporation and soil temperature. A comparative analysis of simultaneous measurements made with the infra-red moisture balance and the conventional steam oven method is also presented.

2. Design and operation of the infra-red moisture balance

The infra-red moisture balance (Toshniwal Model EI-06) measures the moisture content of materials which do not change their chemical structure while losing water under exposure to infra-red radiation. It can be conveniently used for determining the amount of moisture in agricultural soils. The labelled diagram of the instrument is shown in Fig. 1. The overall dimensions are 35 cm × 30 cm × 35 cm.

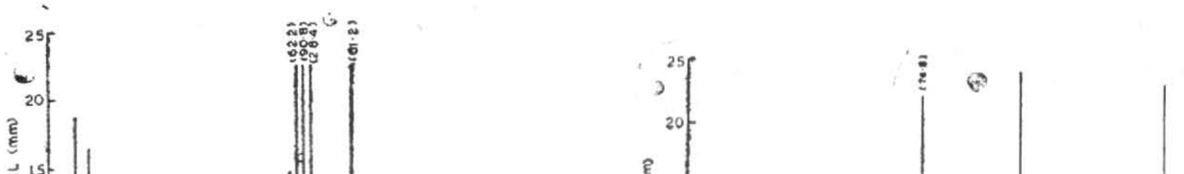
Unlike the oven method, drying and weighing are done here simultaneously. The heat source consists of an infra-red lamp of 250 watts power. The penetration of heat is, therefore, deeper and more uniform than in the oven method. The



(a) Front view

(b) Top view, with upper housing removed to reveal the mechanism

Fig. 1. Moisture balance



(a) 1 June to 15 August 1973

(b) 15 August to 31 October 1973

Fig. 2. Variation of soil moisture in relation to 24-hr rainfall and evaporation for the periods (a) and (b)

power supply to the lamp can be varied by means of a built-in dimmerstat which enables the temperature of the soil sample to be controlled. A thermometer is provided to read the chamber temperature. There is little likelihood of the soil specimen re-absorbing moisture from air during the measurement.

Weighing is done by means of a torsion wire to ensure a high degree of accuracy. The weight scale is directly calibrated in terms of moisture percentage, and is graduated in steps of 0·2 per cent. At the commencement of the measurement, the wire tension is adjusted so that the scale reads 100 per cent. A fixed quantity, 25 gm, of the soil sample is then placed on the pan, and the scale is readjusted to read zero. After the infra-red lamp is put on, the moisture evaporates and the reading on the scale changes gradually, becoming steady when the sample is completely dry. The final reading gives the percentage by weight of the moisture present in the soil sample. In practice, this procedure takes less than 20 minutes for a relatively dry sample (moisture content less than 10 per cent). In the case of a moist sample (moisture content more than 30 per cent), a maximum time of 1 hour is required for the soil moisture determination.

3. Results and discussion

3.1. *Variation of soil moisture in relation to rainfall and evaporation*

Soil moisture measurements in black cotton soil with the infra-red moisture balance were made at the Central Agricultural Meteorological Observatory in Poona during the period 1 June 1973 to 31 October 1973. This period was selected in order to analyse the variation in soil moisture with respect to rainfall, considering run-off to be negligible. The interval between two successive observations was, on the average, three days and the time of observation was 0830 IST. Soil samples were extracted by means of an auger from 15, 30 and 45 cm depths below the surface, the root density of most crops being maximum in the upper 45 cm of the soil. Samples were also collected directly from the soil surface.

Isopleths of soil moisture showing its variation with time and depth are presented in Fig. 2. Amounts of 24-hour rainfall and evaporation recorded at 0830 IST are also plotted in the figure. The evaporation was measured with a standard Class A Pan Evaporimeter. At the commencement of the experiment, the soil was quite dry, the moisture content being less than 10 per cent at the surface and increasing gradually upto 15 per cent at 45 cm depth. Pre-monsoon thundershowers in the first week of June therefore had an immediate effect of increasing the moisture to 24 per cent at the surface and 20 per cent at 45 cm depth.

After the advance of the monsoon into Madhya Maharashtra on 10 June there was a lull in the monsoon activity right upto the end of June. The total rainfall during the period 10-30 June at Poona was only 18·8 mm. The effect of the pre-monsoon showers was thereby lost and the moisture content again decreased to 10-15 per cent at all depths during the latter half of June.

The monsoon strengthened in the first half of July when there were two spells of heavy precipitation. Rainfall during 24 hours ending at 0830 IST of 6 and 7 July was 62·2 and 90·8 mm respectively. Again, rainfall during 24 hours ending at 0830 IST of 14 July was 61·2 mm. After each spell, the soil moisture approached or exceeded the value of 30 per cent at all depths. Thereafter right upto the end of the monsoon season, the moisture content at and below 15 cm depth stabilised around 25 per cent. The moisture content of the 30-45 cm layer was less than 20 per cent on 7 August following a dry period. But its decrease to 10 per cent on 16 August cannot be very easily explained. Weather conditions on and preceding this date were mainly overcast skies with light rain. Since the middle layers had a moisture content of 20 per cent, evaporation could not have been responsible for the lower layer drying to the very low value reported. If the run-off is assumed to be negligible, the cause has to be found elsewhere.

As may be expected, the moisture content of the surface samples was seen to be highly sensitive to rainfall, evaporation and solar radiation received at the earth's surface. On rainless days with high evaporation and strong radiation flux (*e.g.*, 18 to 26 June, 16 October etc), the moisture content dropped below 10 per cent. On the other hand, on days with little evaporation and decreased solar radiation (*e.g.*, 28 August, 18 September etc), even moderate showers increased the moisture at the surface to 25 per cent or more.

After the withdrawal of the monsoon from Madhya Maharashtra on 10 October, the soil moisture showed a clear trend towards depletion at all depths. This trend was, however, reversed again as a result of the post monsoon showers in the last week of October.

3.2. *Field capacity*

No direct determination of the field capacity

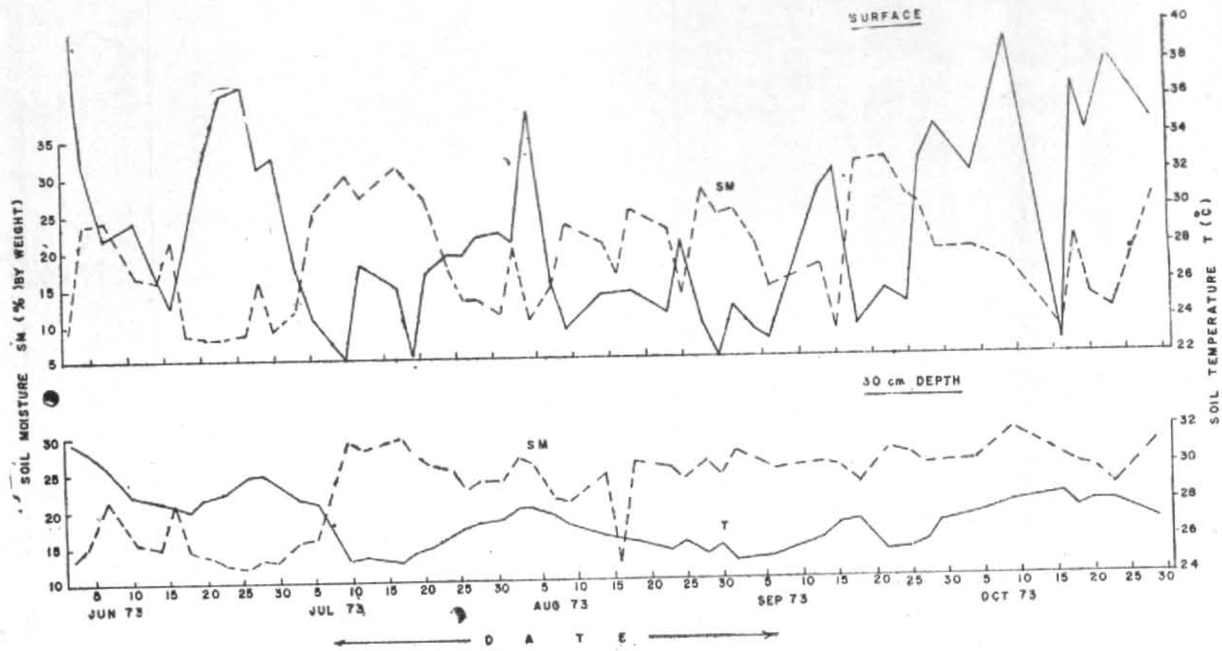


Fig. 3. Temporal variation of soil moisture and soil temperature

TABLE 1

Period (At 0830 IST)	Rain-fall amt. (mm)	Date of sampl-ing	Soil moisture (% by weight)			
			0 cm	15 cm	30 cm	45 cm
5-5 Jul	181·4	10 Jul	30·0	24·4	29·0	29·6
13-14 Jul	61·2	17 Jul	31·2	28·3	29·3	30·2
19-20 Sep	74·8	22 Sep	31·7	27·8	27·2	28·0

of the Poona black cotton soil was made using the infra-red moisture balance. However, during the course of the present investigations, the soil plot earmarked for sampling had become waterlogged on three occasions as a result of heavy rain. Soil samples taken two to three days later after allowing the water to percolate, yielded moisture percentages as shown in Table 1.

The highest observed moisture content of 31·7 per cent is reasonably close to the average field capacity of 35 per cent for clay soils (Robertson *et al.* 1959). In earlier studies on the Poona black cotton soil, Katti (1935) had found the field capacity to be 38·7 per cent while Mallik *et al.* (1959) had reported soil moisture to be 38 and 36 per cent at 15 and 30 cm depths respectively in a sugarcane field.

3·3. *Relationship between soil moisture and soil temperature*

As the soil moisture measurements in the present study were made quite frequently, *viz.*, two or three times a week, it became possible to examine the correlation between soil moisture and soil temperature. Fig. 3 shows the temporal variation of soil moisture and temperature at the surface and 30 cm depth during the period June to October 1973. Since the soil temperatures in the 0-30 cm soil layer exhibit a strong diurnal oscillation, averages of observations made at 0730 and 1430 IST have been plotted.

Fig. 3 suggests that a wetting of the soil is strongly associated with decreasing soil temperatures. Likewise, a decrease in the moisture content of soil is associated with a rise in the soil temperatures. This relationship appears to be more prominent at 30 cm depth than at the surface. The correlation coefficients between soil temperature and soil moisture are $-0 \cdot 51$ and $-0 \cdot 94$ at the surface and 30 cm depth respectively, both being significant at the 5 per cent probability level. However, an attempt to estimate moisture content of soils from temperature observation will have to be based upon considerations of the complex processes of heat exchange and moisture redistribution in the soil.

3·4. *Comparison with measurements by the steam oven method*

Measurements of soil moisture are made at the Central Agricultural Meteorological Observatory, Poona every Thursday as part of the routine observational schedule. The soil auger is used for sampling, and the samples are dried in a steam oven for a 48-hr period which in actual practice is spread out over a week at the rate of 8 hours a day. The samples are cooled and dried ina desiccator after removal from the oven. Weighing of the samples before and after the drying process is done with a simple chemical balance.

During the period June to October 1973, two sets of soil samples were extracted simultaneously on Thursdays, one of which was analysed in the routine manner described above and the other placed in the infra-red moisture balance. Fig. 4 shows a week-to-week comparison of the soil moisture at four depths (0, 15, 30 and 45 cm) obtained by these two methods. In a majority of cases, the moisture values differed only by 3 per cent. In those cases where the infra-red balance yielded a higher moisture percentage, it is probable that the heating process of the oven method was not entirely adequate. Besides, the temperature of the infra-red balance chamber was controlled to avoid spuriously high readings due to decomposition of extraneous matter in the soil sample.

4. Concluding remarks

(*i*) The study has shown that the infra-red moisture balance can be most conveniently used in intensive investigations requiring frequent and accurate measurement of soil moisture. The chief advantage of the infra-red balance over the oven method is the great reduction in the measurement time to about 20-40 minutes only. The infra-red balance is also far more elegant and at the same time, easy to operate.

(*ii*) The investigation presented in this paper has brought out the manner in which the soil moisture at different depths responds to rainfall and varies in relation to evaporation and soil temperature. It is proposed to carry out a similar study in the period March to May when the moisture content of the soil is depleted to very low values and there is a chance of pre-monsoon thundershowers.

(*iii*) The errors involved in sampling by means of a manually operated auger are well-known. The accuracy of the measurements could be further enhanced by employing a power core sampler which gives samples of known volumes with minimum disturbance to the soil profile. This would also enable measurements of bulk density and computation of soil moisture on volumetric basis.

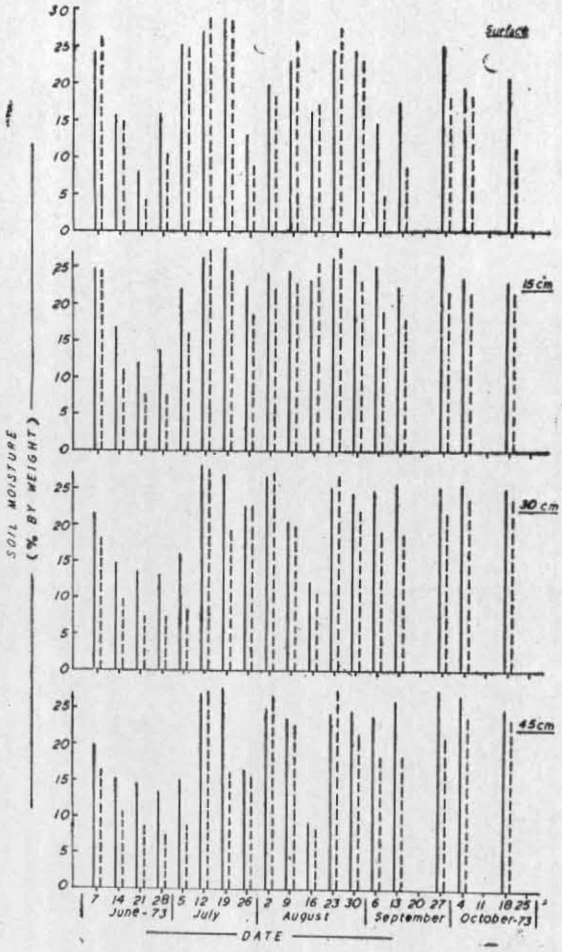


Fig. 4. Comparison of weekly soil moisture measurements with the *i-r* moisture balance (solid lines) and by the oven method (broken lines)

(*iv*) Gravimetric measurements inevitably show some horizontal variability of soil moisture. In order to obtain representative data, it is necessary to analyse samples taken from a large number of points. Hills *et al.* (1969) have recommended 4-19 samples for soil plots smaller than 950 sq. m and 44-80 replications for larger drainage areas and catchment areas.

Acknowledgement

The authors are grateful to Shri C.R.V. Raman for his interest in the work and to Dr. R.P. Sarker for going through the manuscript critically. They also wish to thank Shri B. Srinivasa Murthy and Shri B. C. Biswas for their helpful comments. Thanks are due to Shri Y.G.H. Khan who typed the manuscript and to colleagues in the Drawing Section who prepared the diagrams.

REFERENCES

Beskin, L. I.	1966	*Instruments and methods for meteorological observations*, Israel Program for Sc. Translation, pp. 95-101.
Hills, R. C. and Reynolds, S. G.	1969	*J. Hydrology*, **8**, pp. 27-47.
Katti, M. S.	1935	*Curr. Sci.*, **4**, p. 419.
Mallik, A. K. and Venkataraman, S.	1957	*Indian J. Sugarcane Res. Dev.*, **2**, pp. 15-18.
Robertson, G. W. and Holmes, R. M.	1959	*Pub. No. 1054* Res. Br., Canada, Dep. Agric; 12 pp.
Stanhill, G. (Ed.)	1968	*WMO Tech. Note No. 97*, 69 pp.