USE OF NEUTRON SCATTERING TECHNIQUE FOR ESTIMATING SOIL WATER CONTENT IN THE LATERITIC SOIL OF CENTRAL KERALA

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ABSTRACT

The technique of neutron scattering for estimating soil water content was studied with reference to calibration and field use. The method of field calibration of the equipment had been explained in detail and the calibration relationship obtained is explained. A few examples on the use of the equipment in studying soil water content are also given.

INTRODUCTION

THE measurement of soil water content with neutron scattering method has been well established as a successful technique[1–4]. It has now been developed as a research instrument for studies of soil water in the field. In developed countries, this method has been used in irrigation, recharge, lysimeter and watershed-management studies on the consumptive use of water by plants. As a result of this increased activity, a lot of additional experience with the method has been accumulated[5]. Recently, this method has been adopted in India for water management studies. This paper reports about the feasibility on the use of neutron scattering method for the *in situ* measurement of soil water content in a lateritic soil of Central Kerala based on a study conducted with the equipment.

THEORIES AND ASSUMPTIONS

The principle involved in the neutron scattering method of measuring soil water content is given here. When a source of fast neutrons is inserted into a material capable of moderating, i.e. slowing down, the fast neutrons, it will become surrounded by a cloud of slow neutrons. The density of these slow neutrons in the immediate vicinity of the source is proportional to the concentration of the moderating media.

When a fast neutron source is placed in a moist soil, the emitted neutrons interact with the surrounding medium. The emitted neutrons collide with the nuclei of the soil in a billiard-ball fashion, their direction is changed and they lose energy. As a result, its speed diminishes until it approaches one that is characteristic for particles at the surrounding temperature. These neutrons are called thermal neutrons or slow neutrons. Finally, the slow neutrons is absorbed by the nuclei present in the soil and its existence is terminated.

The moderating ability of all soil nuclei is small compared to that of hydrogen. Upon collision with a hydrogen nucleus, which has almost the same mass as that of a neutron, the fast neutron is slowed down very appreciably; the extent depending on the angle of collision. Therefore, if the soil contains a considerable amount of hydrogen, the neutrons are slowed down before they get very far away from the source. The slow neutrons thus produced tend to be concentrated around the source. If the medium surrounding the source is low in water content, and therefore has less hydrogen, the cloud of slow neutrons is less dense and extends farther from the source than if the medium is high in hydrogen content or water content. Thus it is possible to measure the moisture content of the soil by observing the density of the slow neutron cloud that develop around the fast neutron source when it is inserted into the soil.

It has been assumed that the hydrogen in the soil is solely the result of the presence of water. In reality, this may be far from true. Hydrogen may be present in appreciable quantities as an integral part of clay crystal lattices or of amorphous colloidal material. Also organic matter in the soil contains hydrogen. However, the differences in calibration due to the presence of non-water hydrogen have been difficult to demonstrate experimentally[5]. The true cause of this anomally has never been entirely established. It is possible that the energy reduction that the neutron sustain, when they collide with hydrogen, particularly at low speeds, is dependent upon the chemical binding of the hydrogen in such a way that hydrogen which is a part of the large molecules or of extended clay lattice structures behaves as if it had a higher atomic number. Consequently, the colliding neutron may lose little of its energy[5]. It is also worth mentioning here that some soil elements such as cadmium, boron and chlorine have an unusually high absorption capacity for slow neutrons. Hence their presence tends to decrease the density of slow neutrons.

The interaction between fast neutrons and soil water is independent of such environmental factors as temperature and pressure. It is affected very little by chemical composition of the soil or the degree of binding of the water by soil particles[6]. This implies that the neutron method will have wide general adaptability and that corrections in its use are generally not necessary. This method gives a direct measure of the moisture content by volume, since the presence and the weight of the other soil elements are generally not significant. To the first approximation, the relationship between slow neutron density and moisture content by volume is linear. In actuality, calibration curves generally deviate from a perfect straight line[5].

INSTRUMENTAL

The diagrammatic representation of the parts and assembly of the neutron moisture meter used for the study is presented in figure 1. The major components of the equipment include (1) probe, (2) electronic automatic rate scaler, (3) plastic shield body, (4) cable connecting probe and rate scaler, (5) depth indicator, and (6) rechargeable battery. The probe is nothing but the source-counter assembly which is inserted into the access tube after releasing from the plastic shield body shown in figure 1(a) during measurement. The Am-Be mixture of 50 millicurie activity was the fast neutron source which is located on the mid-plane of the active length of the BF_3 counter tube. In addition to the source and counter, the probe also contained inside a preamplifier in the upper portion to magnify the impulses of the counter tube. The electronic automatic rate scaler has a three-digit display which showed the counts/sec and one selector switch to select 16/64 sec counting duration. The display appears at the end of the counting time and disappears after a few seconds. The 12 volt rechargeable battery can easily be connected to the rate scaler with the help of a central screw. The battery is charged with the help of a separate charging equipment. The rate scaler and probe is connected by means of a high voltage cable of sufficient length which can be disconnected when the equipment is not in operation. The cable passes through a depth indicator and lock-release assembly mechanism. The depth indicator shows the depth in centimetres. The whole body of the meter is built with plastic material. The lower end of the probe, where the source is situated, is protected with a thick plastic shield which helps to eliminate radiation hazard. In short, the equipment is very handy and easy to operate by a single individual.

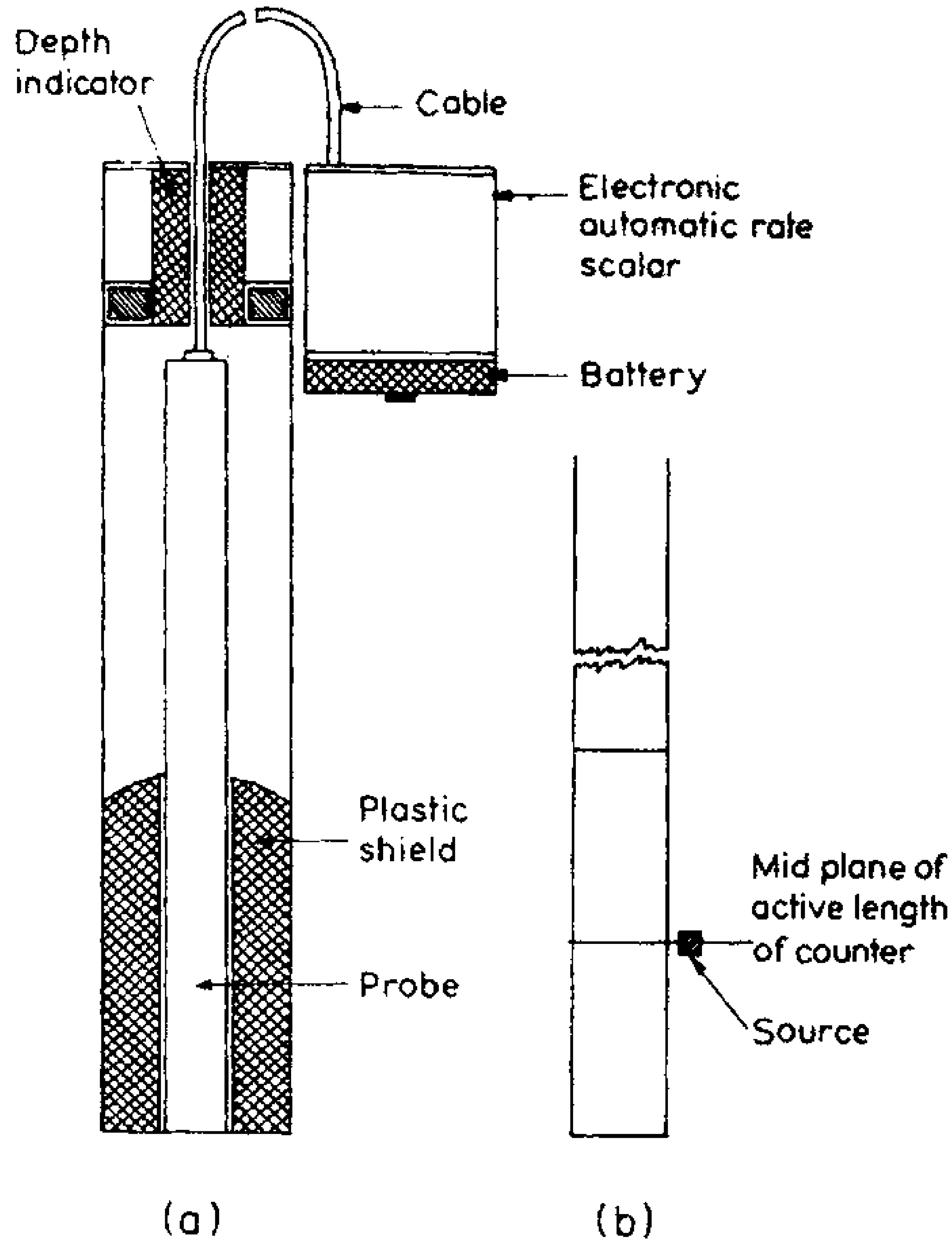

Figure 1. Modern neutron moisture meter **a.** Probe-rate scaler-shield assembly, **b.** Source-counter geometry.

CALIBRATION

Field calibration process was selected as the method to calibrate the instrument for field use. It involved selecting sites representing a range of soil moisture conditions and installing access tubes. In the present study, 38 mm GI pipe was installed as the access tube. The soil selected for the study was lateritic in origin. A traverse of meter readings was made in each tube to determine the central point of a layer of uniform moisture-content soil. This was done by making meter readings of 15 cm depth increments until a layer of uniform moisture of at least 60 cm in thickness was encountered. Then the effective centre of the probe was positioned in the vertical centre of the layer of uniform moisture content. Five readings, each of 64 sec duration were taken and their averages worked out. When these measurements were made, care was taken to ensure that the effective centre of the probe was at least 30 cm below the surface of high moisture content soils and at least 45 to 60 cm below the surface of low moisture content soils. Readings in a water drum (60 cm in diameter and 80 cm in depth) were also made each time when the calibration measurements in the soil were taken with the probe. This was immediately followed by the collection of soil samples for moisture and volume determinations by gravimetric method. The soil samples for gravimetric determinations of moisture content and volume were collected from a soil layer of 5 cm thickness at a radius of about 15 cm from the access tube located at the same depth as the neutron calibration readings. A 50 c.c. core sampler was used for this. Eight such core samples were taken for each reading, with the sampling holes spaced equally around the access tube. These soil samples were weighed and dried in an oven at 105°C to find out the moisture content and expressed as volume fraction. Ninety-eight pairs of such moisture contents and calibration readings were made within a moisture range of 0.088–0.506 volume fractions. The calibration relationship between moisture content and count rate is plotted in figure 2. This relationship was used to translate the entire count rate into moisture content and the error of prediction was determined as discussed below.

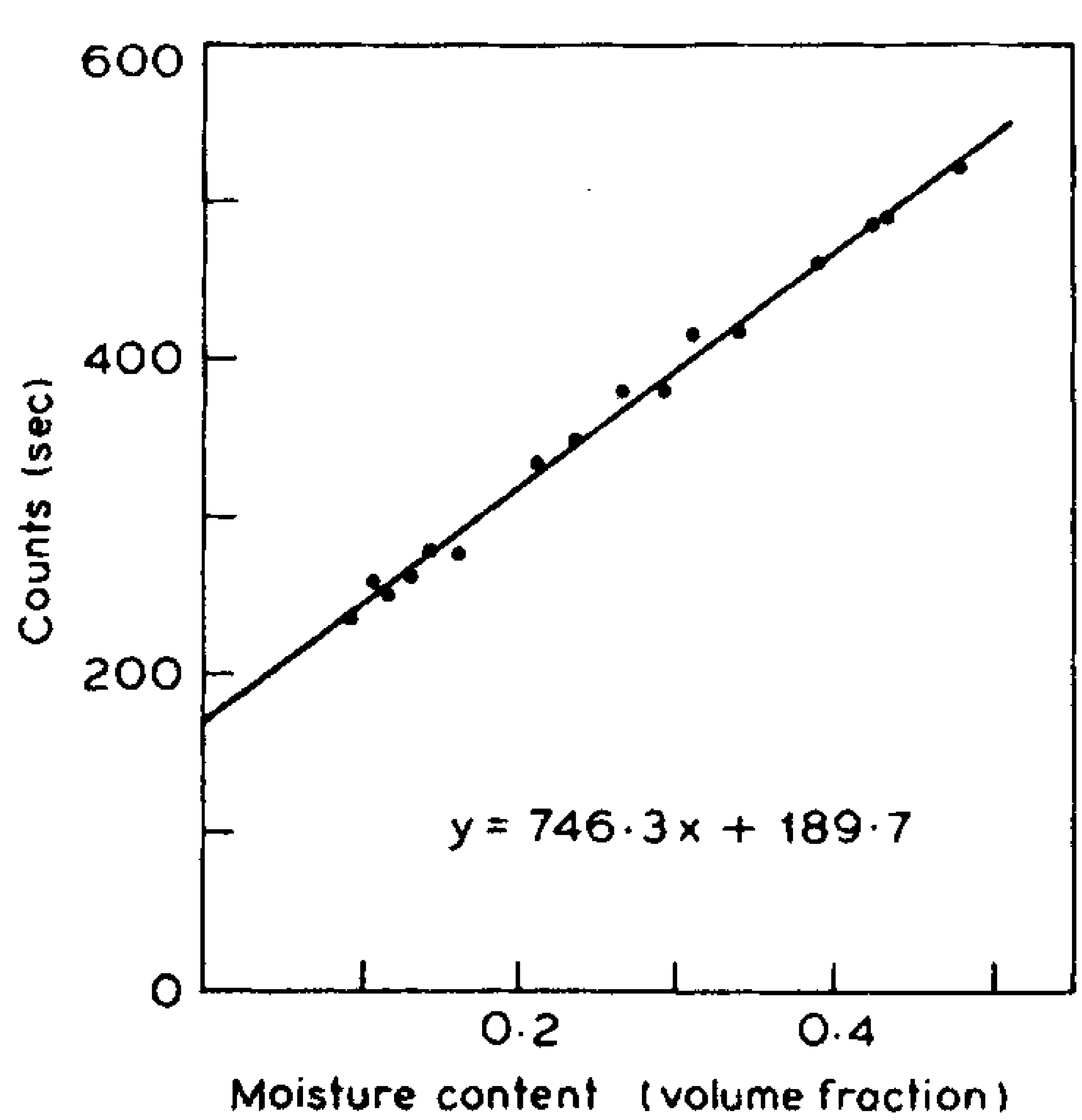

Figure 2. Calibration curve with a few actual points.

DISCUSSION

As there were certain errors in determining the moisture content of the standard samples and also in determining the count rate, there resulted an error called the "error of prediction". Analyses of the available data in the present study indicated that the error of prediction was as low as 0.87% of the moisture by volume. It is important to realize that this error cannot be diminished by additional measurements, longer counting times or anything pertaining to the improvement of measuring count rate. The only method by which this error can be reduced is by procuring more calibration points and by increasing the precision with which the moisture content in the calibration procedure is established.

The calculations mentioned above had been carried out for the case where the absolute counting rate is related to moisture content. It is better to work with the ratio of the counting rate in the soil to the counting rate in the standard and to express the data and the calibration relationship accordingly. This makes no difference in the calibration values, but has the advantage that any error by way of shift in the instrument in the course of time which affects the accuracy of the counting time, or by way of shift in certain parts of the instrument with repairs, adjustments etc of the system which affect the sensitivity of the instrument, will all be eliminated. It also has the advantage that more than one instrument can be used at the same time with the same calibration equation. But the standard counting rates for each time and each instrument must be determined with a considerably greater precision than the counting rate in the unknown. In other words, the standard must be counted for a period of time sufficiently long to eliminate the counting error of standard as a factor. For this, at least ten standard counts of 64 sec duration at each time when the count rate is determined in an unknown, is recommended to obtain the correct ratio. (In the present study, the mean counting rate in the water standard was 741.5 counts/sec.) Hence it is inferred that the neutron method enables measurement and monitoring of the soil moisture content of the soil profiles, even of appreciable depths with greater ease and accuracy. The method is recommended for estimating the moisture charge in the soil profile of the required depth. However, it may be noted that normal measurements with the neutron probe should be made in soil of depth more than 30 cm. Separate calibration curves will be required for depths less than this. It is also dangerous to use the equipment in less than 30 cm depth. Examples of measurements and monitoring of the soil water content with the neutron moisture meter are given in figures 3, 4 and 5. It can be seen that change in water content can be estimated with greater stability and precision with the neutron method than with any other methods of measurements.

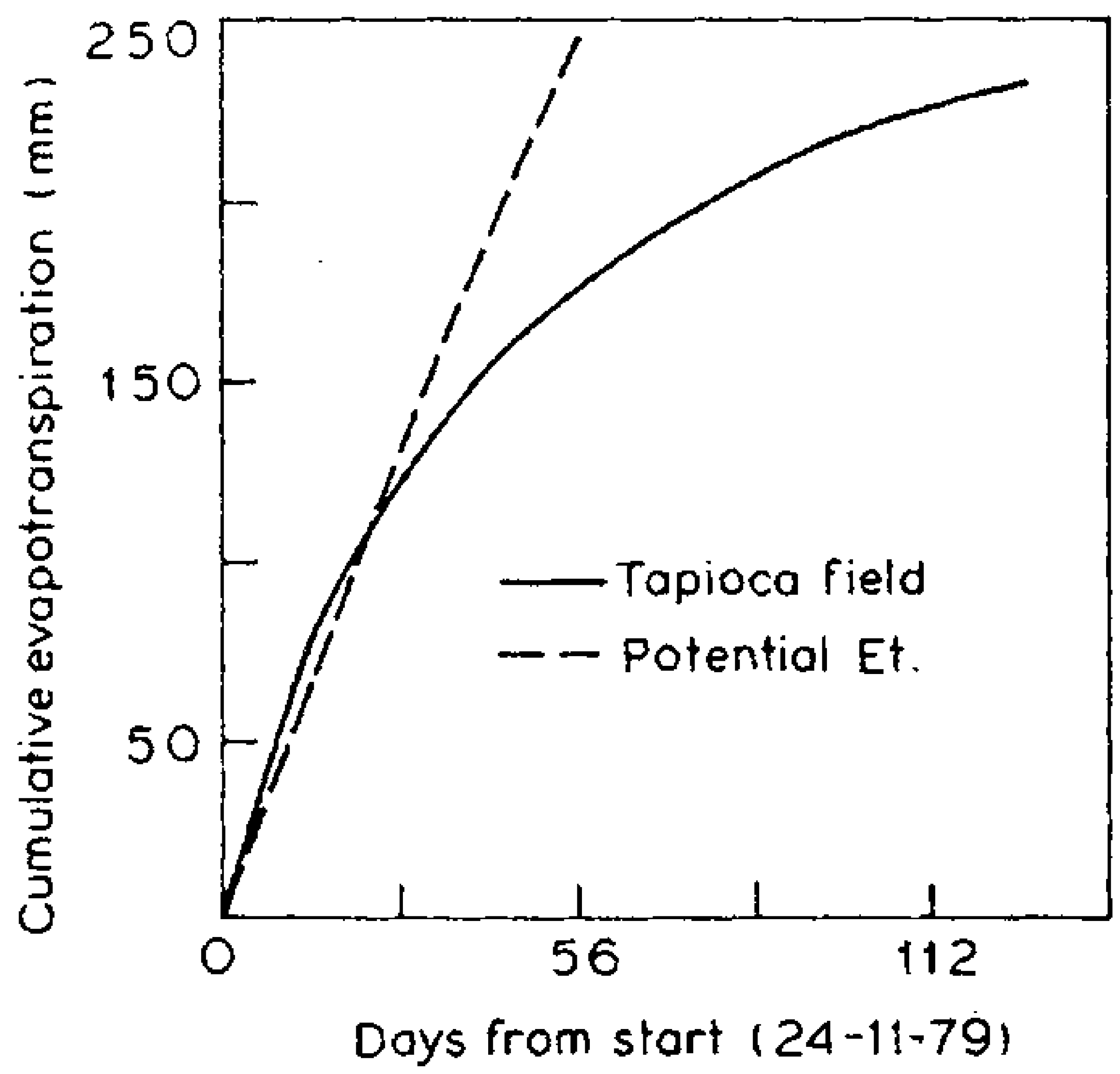

Figure 3. Estimation of evapotranspiration by changes in soil water content.

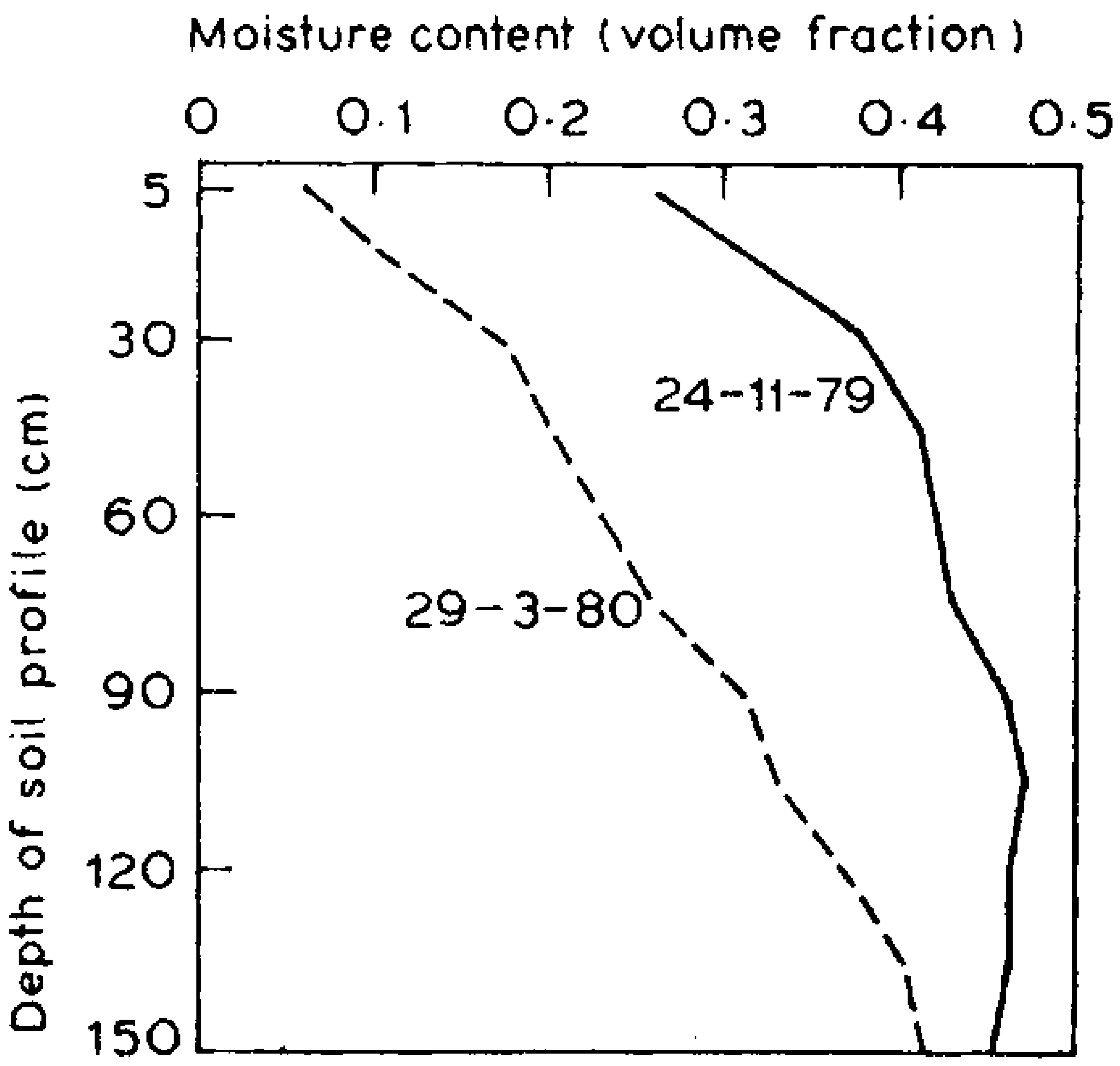

Figure 4. Soil moisture depletion in Cassava after cessation of rainfall.

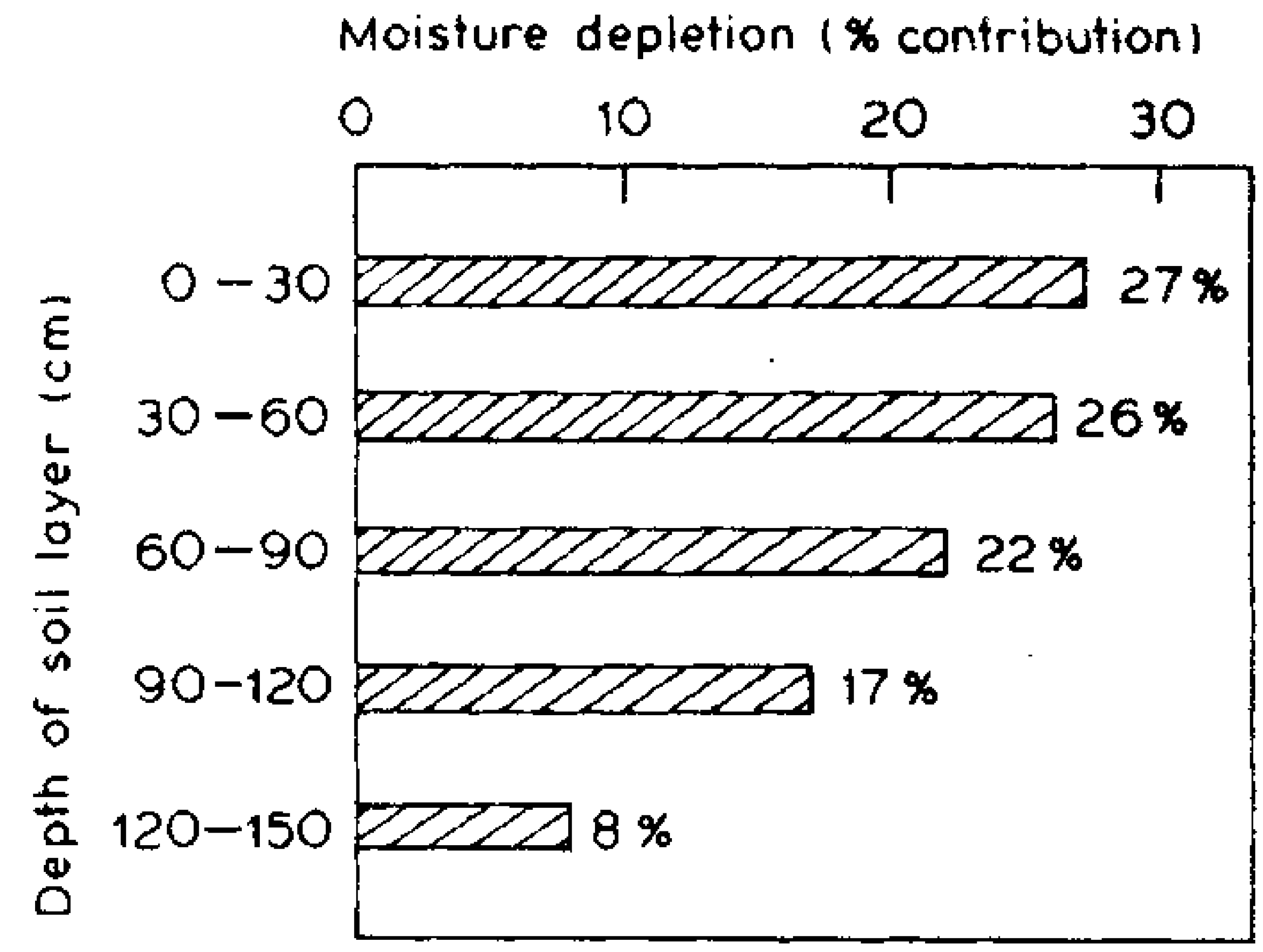

Figure 5. Soil moisture depletion in Cassava: Percentage contribution of different soil layers.

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1. Belcher, D. J., Cuykendall, T. R. and Sack, H. S., *Tech. Dev. Rep. U.S. Civ. Aero. Auth.*, 1950, No. 127.
2. Spinks, J. W. T., Lane, D. A. and Torchinsky, B. B., *Can. J. Tech.*, 1951, **29**, 371.
3. Hignett, C. T., *Div. Soils Tech. Rep. CSIRO*, 1980, No. 42, p. 31.
4. Hansen, V. E., Israelsen, O. W. and Stringham, G. E., *Irrigation principles and practices*, John Wiley, New York, 1979, p. 417, 4th edn.
5. van Bavel, C. H. M., Nixon, P. R., Hauser, V. L., *U.S. Dept. Agr.*, 1963, ARS 41-70, p. 39.
6. Holmes, J. W. and Jenkinson, A. F., *J. Agric. Engin. Res.*, 1959, **4**, 100.