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Inadequacy of Piezometer Method in Determining the Saturated Moisture Status of Layered Soil

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ABSTRACT. A study was conducted in a small catchment of 5.4 ha. at Giradurukotte Regional Research Station in Mahaweli System C to study the suitability of piezometer method in determining the saturated soil moisture condition of the soil with that of neutron probe technique. Piezometers, one above the less permeable sandy clay layer and the second below the sandy clay layer, were installed at 90 locations within the study site to monitor the daily ground water head fluctuations. Soil moisture measurements were made in 10 access tubes installed along the mid line of the catchment using a Wallingford soil moisture neutron probe. Count readings were taken at 0.1 meter intervals down to 1.2 m depth almost daily. The results indicated that the water table measurements from the piezometers alone does not represent the saturated conditions of the root zone and is less reliable compared to readings from the neutron probe.

INTRODUCTION

The aim of agricultural drainage is to provide favourable moisture, oxygen and salt balance needed for the crops to grow in the root zone. Most crops require that the soil zone remains unsaturated. Identifying the suitable conditions is often complicated since it intern is affected by a number of factors (stage of growth, soil fertility level, temperature, *etc.*). However crop yield was identified to be directly dependent on the oxygen and carbondioxide diffusion rates in the root zone (Grable, 1960). These diffusion rates depend on the soil water content in the root zone. Thus the soil water content can be used as a measure of various other properties in the root zone – aeration, temperature, *etc.* Many laboratory and field experiments have been conducted in many parts of the world to study the effect of soil water in crop yields (Harris *et al.*, 1962; Sutton, 1963; Sieben, 1964; Hoogerkamp and Wouldering, 1967; Stephens, 1969). In all these studies soil water content in the root zone was expressed by the depth of water table below ground level, assuming that the water table depths adequately express the prevailing soil moisture conditions. It has been reported that if water table rises and remains in the root zone longer than 48 hours agricultural production of most of the crops will be seriously affected. The main reason for taking the water table depths to express soil moisture is that they can be measured easily for an extensive area within a short period of time.

Soil water measurements

There are basically two ways to learn about the water in the soil;

i) observation of ground water tables in an open ended pipe, and

ii) measurement of soil moisture content in a particular volume of soil.

Ground water levels can be observed in existing wells, open bore holes or piezometers. The existing wells, although they offer ready made sites for ground water level observations, usually have large diameter and thus a large storage capacity. Therefore it may take a long time for the water level to adjust to changes in the water table or to recover when water has been taken from the wells specially if the wells are hand dug. If the existing wells have been bored or drilled it might go to greater depths penetrating several aquifers separated by clay layers. The water levels in these wells thus will not represent the water table depths.

The problem with open bore holes is that they can be destroyed by vandalism. They may collapse if they penetrate fine sand. For these reasons piezometers are usually used for ground water measurements in experiments.

Piezometers are open ended pipes driven into the ground up to the depth at which the water table lies. To ensure proper function of the piezometers the lower few centimeters of the pipe is usually perforated (ILRI, 1980).

It has been reported from previous drainage studies that the moisture content in the root zone and the water table in a piezometer do not always match and the relationship is not unique to any soil, location or time. However the actual relationship has not yet been studied or explained.

This paper presents some field results of ground water table measurements in piezometers and soil moisture measurements using a neutron probe which was obtained during a drainage study conducted in Mahaweli system C and to discuss the relationship between these two methods in considerable detail and to estimate their reliability to express soil moisture in the root zone.

MATERIALS AND METHODS

A small catchment of about 5.4 ha. in the Giradurukotte regional research station farm in zone 2 of Mahaweli system C was selected for the study which was conducted for a period of one year from September 1987. The topography of the catchment was rolling with slopes of more than 2%. The soils of the area were well drained Reddish Brown Earths (RBEs), imperfectly drained RBEs and Low Humic Gleys (LHGs) (Atputhanathan, 1988).

The clay content in the A, B and C horizons were 13, 24.6 and 6 percent respectively and the texture of the soils were sandy loam over sandy clay loam to sandy clay. The B horizon had a much higher water holding capacity than the A and the C horizons. Different layers in the soil were identified in relation to vertical movement of water (permeable A1, less permeable A2 and B and the permeable C) from hydraulic conductivity studies conducted in the catchment. Water stands above the restrictive layer during rainfall causing a temporary perched water table which usually flow horizontally downslope causing waterlogging in the low lying areas. Figure 1 shows the form of the geomorphological cross section of the study site landscape.

Ground water and soil moisture measurements in the study site

Piezometers were installed at 90 locations within the study site; at each location there was usually one piezometer above the less permeable sandy clay layer and a second piezometer tapping below the sandy clay layer. The ground water head fluctuations were monitored daily in these

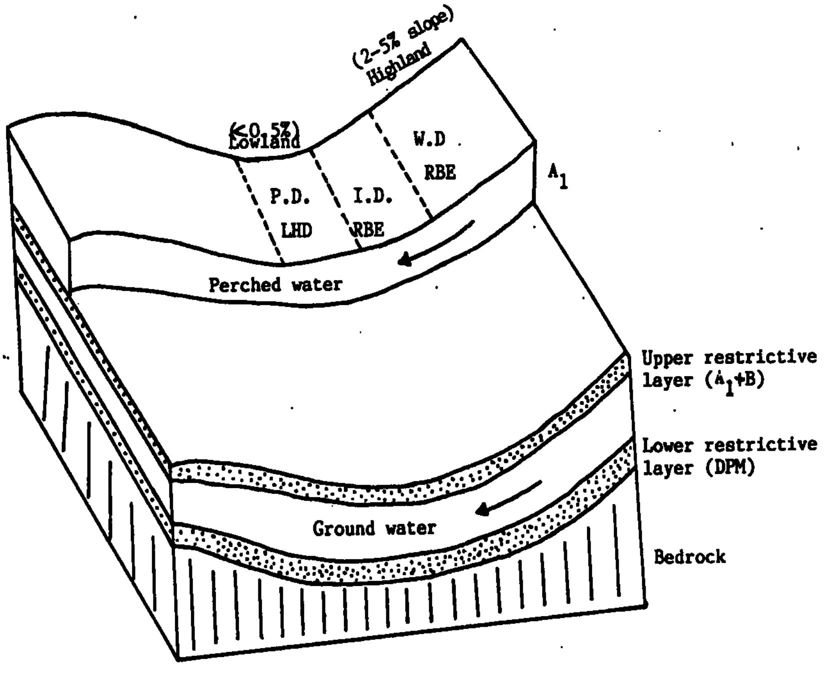


Fig. 1. Geomorphological cross section of the study site landscape.

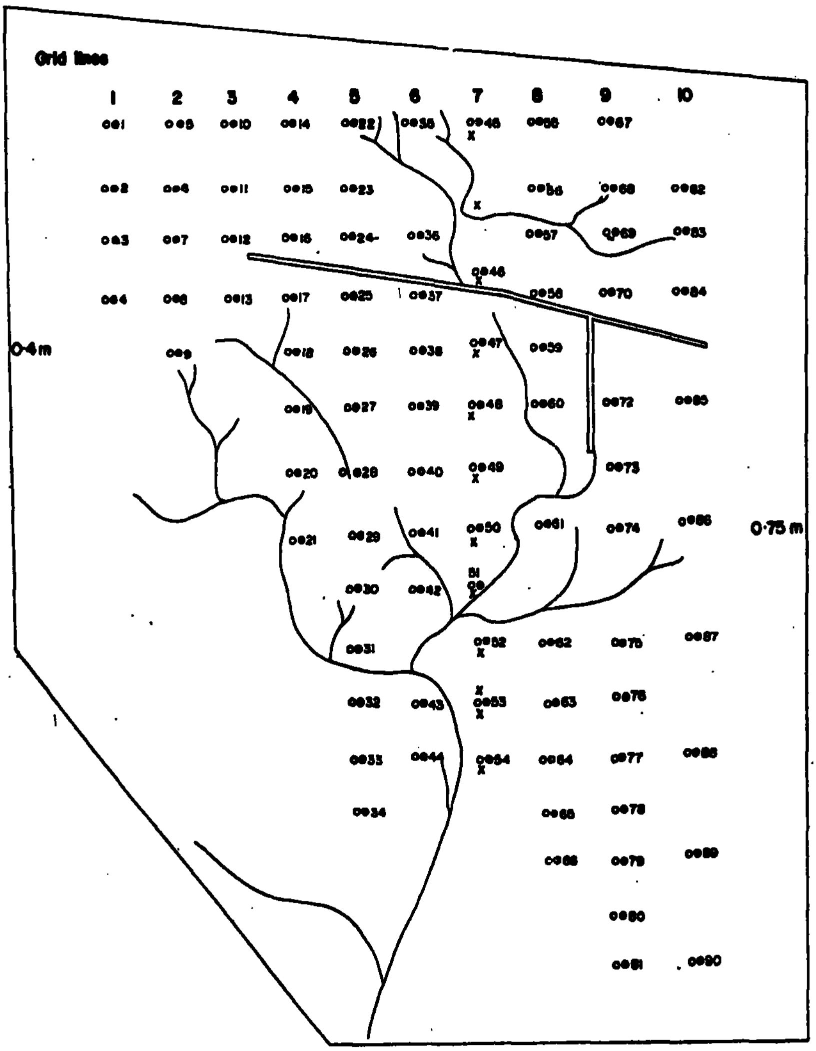
piezometers. Depths were measured in the piezometers from ground level using an electronic sounder connected to a measuring tape.

Soil moisture measurements were made in 10 Al access tubes installed along the mid line of the catchment using a Wallingford soil moisture neutron probe (IHII No. – 90). Count readings were taken at 0.1 meter intervals down to 1.2 m depth almost daily. The count readings were converted to volumetric moisture using the calibration equations developed for different layers in the study site during the study. The locations of piezometers and access tubes in the catchment is shown in Figure 2.

RESULTS AND DISCUSSION

The soil moisture measurements observed in some locations prone to waterlogging is shown in Figure 3. Piezometers were often dry to more than 1 meter even when the soil moisture in the 30 cm soil profile was close to field capacity (the field capacity moisture content value is 21%). The shallow piezometer readings were found closely correlated with rainfall. The water level rise to the ground surface rapidly after a rainfall and dry out in a few days times as the rain ceases, but the variations in soil moisture content were far slower at these locations. In contrast, at some locations the ground water levels rose even though the soil moisture declined during the dry spells (Figure 4). At station 50 the water levels in the deeper piezometer were at 30 cm level throughout the study period even when the total soil moisture in the 100 cm soil horizon was below permanent wilting point (the permanent wilting point moisture content was 14%) (Figure 4b). At station 49 the water levels in both the shallow and the deeper piezometers did not respond to the drastic changes in the soil moisture due to rainfall (Figure 5b).

In addition, the readings from the shallow and the deeper piezometers were contradictory at some locations. When the moisture contents and the depths in shallow piezometers have fallen to greater depths (up to 1 m) the deeper piezometers, however, show water levels close to the surface (around 30 cm below ground surface) which does not represent a water table at this depth. The response of deeper piezometers to rainfall events were usually less than that of the shallow piezometers at most of the locations. However, at some locations the



- ✕ Access tube
- ○ Observation piezometer BC
- ● Observation piezometer AC
- Natural drainage way
- Artificial interceptor drain

Fig.2. Locations of observation piezometer and access tubes within the study site.

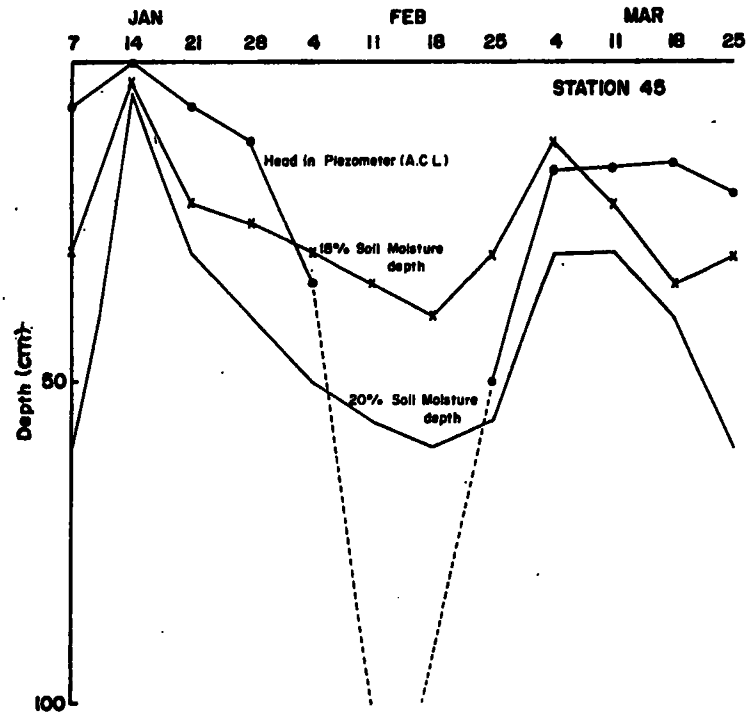


Fig.3. Head in the shallow piezometer and the depths at which soil moisture content is 18 and 20 %.

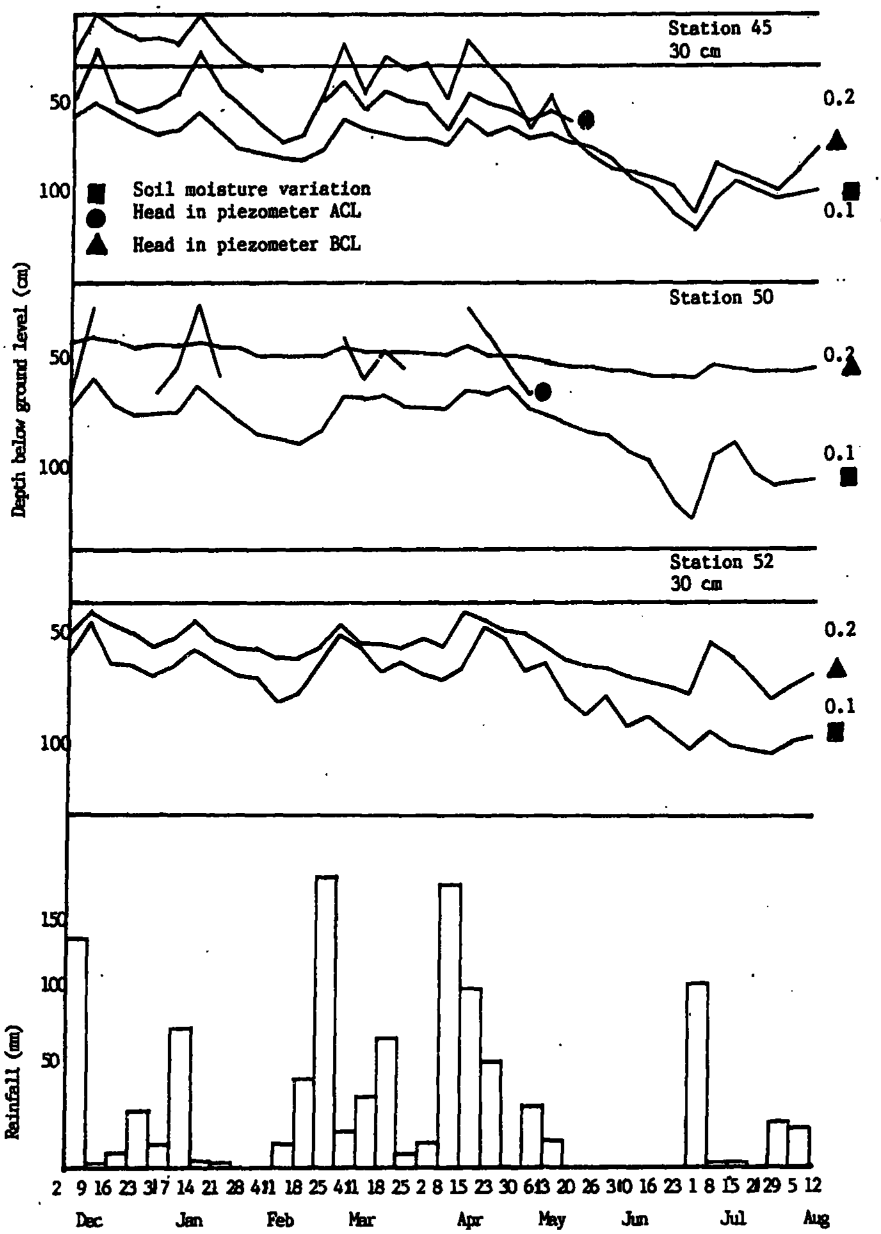


Fig.4. Heads in piezometers and soil moisture variations in the 100 cm soil profile at Stations 45, 50 and 52.

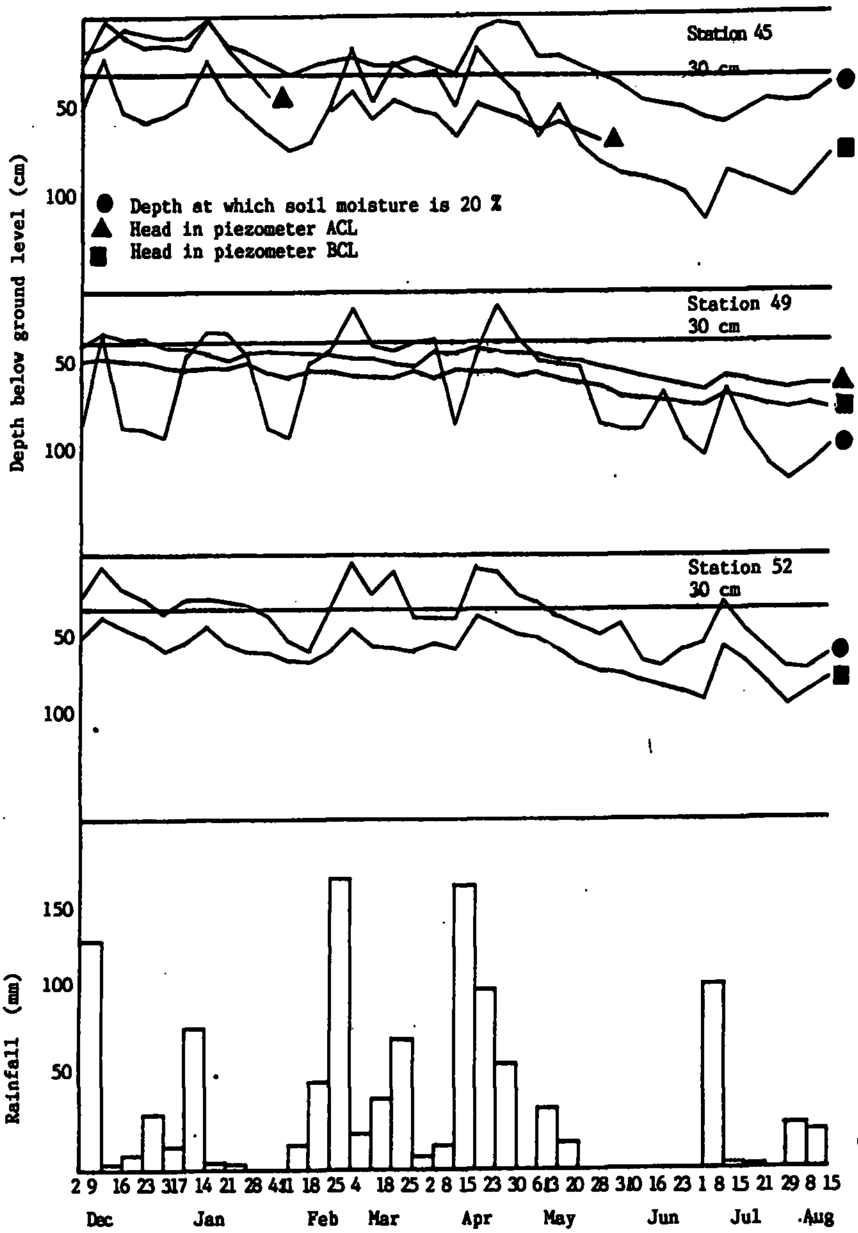


Fig. 5. Heads in piezometers and the depths at which soil moisture is 20% at Stations 45, 49, and 52.

response was prominent and the depth in deeper piezometers rose to depths even greater than that in shallow piezometers (Figure 4a and 5a).

Thus many of the observations in the water table heads in this drainage study apparently indicated that the cessation of high water table problems may be unreliable and the prevailing high soil moisture may continue much longer in the study site and vise versa. The possible reasons for such a behaviour are discussed below.

There is good hydraulic connection between the soil surface and the water table. If the soil zone is saturated then the flow is proportional to hydraulic conductivity of the soil. Even if the soil is layered the flow is a function of the ratio between the hydraulic conductivity of the layers and the system is easy to analyze. As the soil zone becomes unsaturated then the flow becomes a function of hydraulic conductivity, matric suction and the water content – the relationship of which is complicated and varies from one soil to another. Thus it is often difficult to generalize solutions for flow in unsaturated soils.

As long as the absolute value of the suction head at the soil surface is greater than the depth of water table, water will move upward in the soil. With shallow water table depths (<40cm) evaporation is limited by height above the water table and the capillary rise is a function of evapotranspiration. When depth of water table becomes higher (during dry spells) evaporation is not a function of capillary rise (Richards, 1931) and evaporation can take place without causing any rise in the water table.

Piezometers cannot always reflect this complex behaviour of water movement in the soil because;

i) Piezometers are slotted at the bottom, and the water in the piezometer is dependent on the pressure in the slotted portion which may not be the actual water table.

ii) If the piezometer is in contact with a higher conductivity layer water can drain quickly from the piezometer by passing the retarding effect of any low conductivity layers.

iii) It has been reported that the water level in a piezometer which penetrate into a semi permeable layer is a function of its depth of penetration (ILRI, 1980) since the water pressure in these layers are high and the flow direction in this layer is mainly vertical. Therefore, it is recommended that the piezometers should not penetrate to greater depths in the semi permeable layers (ILRI, 1980). If the shallow piezometers penetrate into the sandy clay semipermeable layer then the water level in the piezometer will rise or fall irrespective of the moisture changes in the upper permeable layers. However, it is difficult to determine the depth to which the piezometer should be installed since the water table usually fluctuates to great distances.

iv) Wind (1955) reported that small capillary rises can cause greater pressure changes in the soil zone which can allow the water levels in the piezometers to move to greater depths.

v) On the other hand water may enter or leave the soil moisture storage with only a negligible effect on the pressure of water at greater depths. If the soil happens to be dry at the surface when a rain occurs, the rainfall may be entirely absorbed within the root zone without any effect on the water table. Likewise the water from the root zone can be removed by evapotranspiration for a prolonged period without any noticeable effect on the water table elevation if the root zone is underlain by a restrictive layer or a relatively dry soil.

vi) The discrepancies observed in the readings of the shallow and the deep piezometers may be because that they represent the pressure at two different depths which is separated by a less conductive sandy clay layer. Water levels in the deeper piezometers rise after a rainfall mainly due to the pressure of the water collected above the restrictive layer. This response is prominent at locations where the thickness of the sandy clay layer is small (station 45).

CONCLUSIONS

As indicated by the results the water table measurements from the piezometers alone does not represent the saturated conditions of the root zone and hence is less reliable in determining the severity of water logging. Therefore, the indices which are based on the depth of water table and its duration, such as SEW index, should be used with caution. Readings from the neutron probes are more reliable since the access tubes are totally sealed and the neutron counts directly represent the actual soil moisture content in the root zone.

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