

# NEUTRON PROBE MEASUREMENT OF SOIL WATER CONTENT CLOSE TO SOIL SURFACE

M.C. FALLEIROS<sup>1</sup>

*Universidade Estadual de Londrina, C.P. 6001, CEP: 86051-970 - Londrina, PR.*

A. RAVELO SANCHEZ<sup>2</sup>

*Istituto de Investigaciones Fundamentales en Agricultura Tropical, Havana-Cuba.*

M.DORNELAS de SOUZA

*EMBRAPA/Centro de Pesquisa Agro-Florestal, C.P. 133, CEP: 69301-970 - Boa Vista, RR.*

O.O.S. BACCHI<sup>3</sup>; J.E. PILOTTO; K. REICHARDT<sup>3</sup>

*Centro de Energia Nuclear na Agricultura/USP, C.P. 96, CEP: 13400-970 - Piracicaba, SP.*

**ABSTRACT:** The problem of neutron probe soil water content measurements close to soil surface is analysed from the spatial variability and also from the slow neutron "loss" to the atmosphere points of view. Results obtained on a dark red latosol of the county of Piracicaba, SP, indicate the possibility of precisely measuring the neutron "sphere of influence" when different media are used on soil surface.

**Key Words:** neutron probe, soil water content, spatial variability.

## MEDIDA DE UMIDADE DO SOLO COM SONDA DE NÊUTRONS NAS PROXIMIDADES DA SUPERFÍCIE

**RESUMO:** O problema da medida da umidade nas proximidades da superfície do solo é abordado do ponto de vista de sua variabilidade espacial e da "perda" de nêutrons lentos para a atmosfera. Dados, obtidos em terra roxa estruturada do município de Piracicaba, SP, mostram a possibilidade de se avaliar, com precisão, a "esfera de influência" da medida, quando se utilizam meios diferentes na superfície do solo.

**Descritores:** sonda de nêutrons, umidade do solo, variabilidade espacial.

### INTRODUCTION

The principle of soil water content measurement with neutron probes involves the establishment of a slow neutron "cloud" in the soil around the probe, which defines its "sphere of influence". For measurements close to soil surface, part of the sphere is in the atmosphere, causing a loss of slow neutrons and consequently incorrect measurements. It is therefore of great importance to know the radius of the sphere to define how close to soil surface measurements can be taken without neutron loss. Several authors, e.g. HAVERCAMP et al. (1984), MENDES et al. (1992) and TURATTI & REICHARDT (1991) avoid surface measurements and assume surface water content as being equal to the first

measurement made in depth. KIRDA & REICHARDT (1992) compare neutron probe measurements with other non-nuclear methodologies, but avoid discussing surface measurements with depth probes. GREACEN (1981) describes extensively the assessment of soil water content by the neutron method, and for the case of surface measurements, suggests the elaboration of special calibration curves or the use of specially designed surface equipment. This study contributes to the understanding of neutron probe measurements close to soil surface, suggesting a new approach to define how close to soil surface safe water content measurements can be made and also quantifying the spatial variability of these measurements, for a given soil type.

<sup>1</sup> Bolsista da CAPES

<sup>2</sup> Bolsista da AIEA

<sup>3</sup> Bolsista do CNPq.

**MATERIAL AND METHODS**

1. **SOIL:** a dark red latosol, known as "terra roxa estruturada", with 64.0; 7.5 and 28.5% of clay, silt and sand, respectively;

2. **NEUTRON PROBE:** manufactured by Nardeux, France, model SOLO 25, with Am-Be 1,48 GBq source.

3. **EXPERIMENTAL DESIGN:** two plots of 7 x 7 m, two meters apart, each with 9 aluminum access tubes, as shown in Figure 1. These access tubes were used to make neutron probe readings from above soil surface down to the 50 cm depth. Measurements were performed with the upper part of the access tube in air, in plastic (using a factory designed "deflector") and in water (using a pool avoiding water infiltration into the soil). Measurements were performed in two soil water content conditions:

- i) dry condition, in the dry season, when water content reaches minimum values in the field, and
- ii) wet condition, in the rainy season, when water content reaches maximum field values.

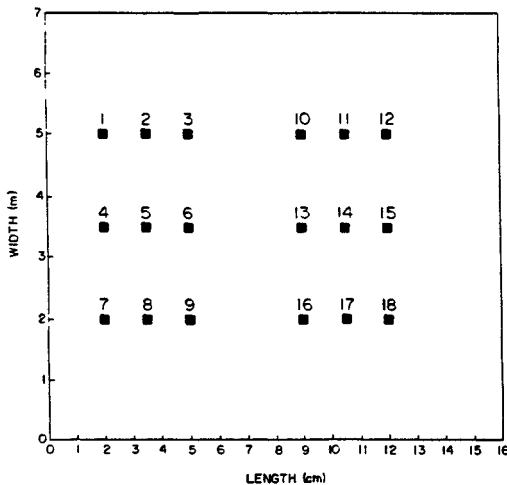


Figure 1 - Field distribution of aluminum access tubes.

**RESULTS AND DISCUSSION**

Figures 2 and 3 present soil water content data obtained from the access tubes having the upper part in air, as recommended. The figures give an idea of the variability of soil water content measurements which is quantified in TABLE 1. The tendency of an increase in C.V. from the 50 cm depth in direction to soil surface might be due to the erratic loss of neutrons to the atmosphere. It is difficult, however, to separate this effect from water content and bulk density effects, since these parameters are more variable close to soil surface.

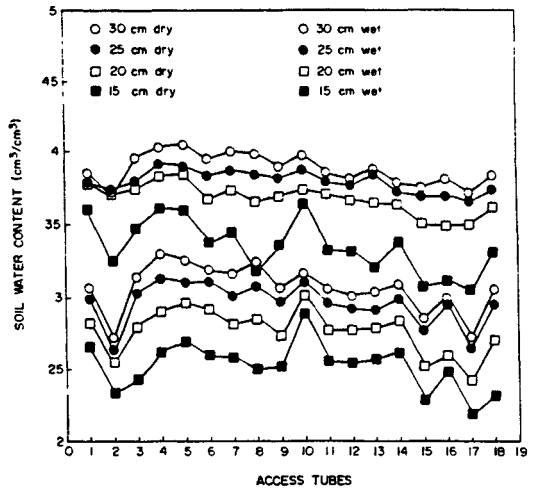


Figure 2 - Soil water distribution at depths 15, 20, 25 and 30 cm, for typical dry and wet soil conditions.

From the depths greater than 30 cm, for which one can be sure that the slow neutron cloud is completely inside the soil, coefficients of variation are of the order of 4.5% for the dry condition and of 3.0% for the wet condition. TABLE 1 also presents the number N of measurements necessary to obtain a new mean value within d% deviation of the estimated true mean. N was calculated according to WARRICK & NIELSEN (1980) using the equation:

$$N = x_{\alpha}^2 \cdot \alpha^2 / d^2$$

where  $x_{\alpha} = 1,96$  and  $\alpha^2$  is the variance. The N values shown in TABLE 1 are a guide for the most common question which is the recommendation of number of access tubes needed.

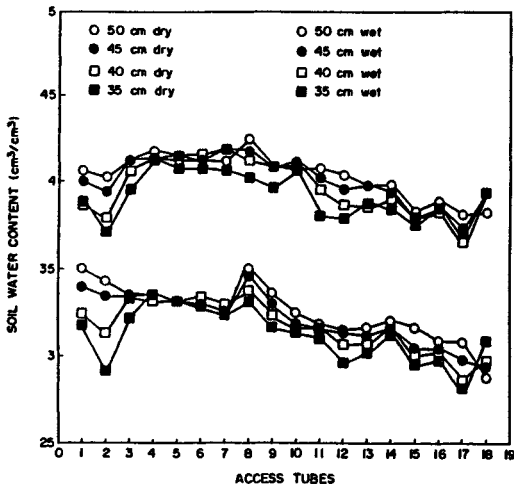


Figure 3 - Soil water content distribution at depths of 35, 40, 45 and 50 cm, for typical dry and wet soil conditions.

Data shown in Figure 4 are count-ratios (CR), obtained dividing slow neutron counts in soil, soil-air and air, by counts in water. As the probe moves from soil to air, slow neutrons are lost and CR values tend to zero. The problem lies in finding the depth below which one is sure that there is no neutron loss, thus defining the sphere of influence of the probe. If the soil is homogeneous and at constant water content in depth, CR values are constant in depth if the sphere of influence is completely inside the soil. Small deviations from this value indicate that part of the sphere reached the atmosphere, and its radius can be estimated graphically, as shown in BACCHI & REICHARDT (1990).

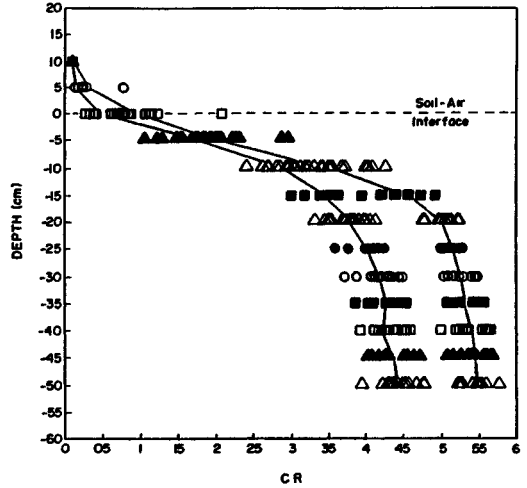


Figure 4 - Soil water content as a function of depth for typical dry and wet soil conditions.

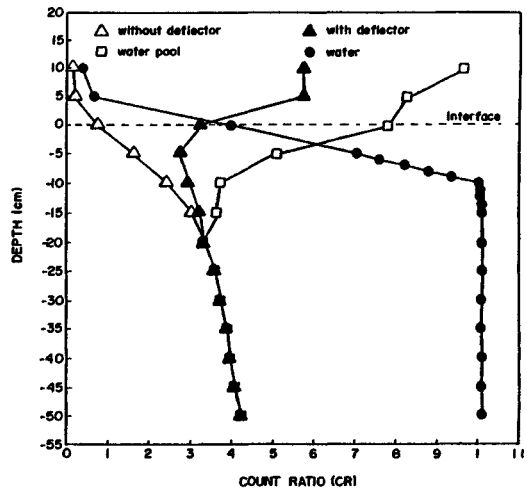


Figure 5 - Count-ratio as a function of depth with and without deflector and with a water pool around the access tube.

TABLE 1 - Average values, variances, coefficients of variation and number of samples N necessary for a given accuracy, for neutron probe measurements, in two water content conditions.

Depth (cm)	Water Content (cm <sup>3</sup> /cm <sup>3</sup> )	Var. x 10 <sup>-4</sup>	C.V. %	Samples number		
				M 5%	M 2%	M 1%
Dry condition						
50	0,3244	0,62	4,68	1	6	23
45	0,3208	0,38	3,79	1	4	15
40	0,3171	0,76	4,48	2	8	29
35	0,3124	1,46	4,67	3	15	58
30	0,3052	2,16	5,21	4	23	89
25	0,2945	1,81	4,85	4	20	80
20	0,2763	1,78	5,46	4	23	90
15	0,2523	2,10	6,26	5	27	127
Wet condition						
50	0,4023	0,58	2,83	1	4	14
45	0,4011	0,97	3,22	1	6	24
40	0,3974	1,73	3,75	2	11	42
35	0,3924	1,42	3,29	2	9	36
30	0,3869	0,87	2,71	1	6	23
25	0,3787	0,33	1,90	1	3	9
20	0,3679	0,36	2,77	1	3	11
15	0,3354	1,94	5,40	3	7	67

In most cases, however, soil is not homogeneous and mostly in terms of water content. It is therefore not possible, in situations like Figure 4, to define the radius of the sphere. On the other hand, if a medium of high neutron moderation characteristics is placed around the access tube, above soil surface, the definition of the influence sphere becomes very evident. Figure 5 is an example using a plastic factory made neutron "deflector" or a water pool around access tube at soil surface. When part of the slow neutron sphere reaches this different medium of high moderation property, count ratios at soil surface increase rapidly in relation to measurements taken in the air.

Although the effect becomes more evident for the water pool, this procedure is very unpractical to be performed under field conditions for a large number of access tubes. The factory made deflector or any plastic or paraffin block are very handy and can be used successfully to define the shallowest depth at which safe measurements can be made using neutron probes.

In the case of Figure 5 it can clearly be seen that the radius is of the order of 20.0 cm for the soil. Measurements were also taken with and access tube in water (Figure 5) showing that in this case the radius of the sphere of influence is of the order of 10.0 cm.

## REFERENCES

- BACCHI, O.O.S.; REICHARDT, K. A sonda de nêutrons e seu uso na pesquisa agrônômica. *Boletim Didático*. CENA/USP, Piracicaba, n.22, p.1-84, 1990.
- GREACEN, E.L. *Soil water content by the neutron method*. East Melbourne: CSIRO, 1981. 140p.
- HAVERCAMP, R.; VAUCLIN, M.; VACHAUD, G. Error analysis in estimating soil water content from neutron probe measurements: 1. Local standpoint. *Soil Science*, Baltimore, v.137, n.2, p.78-90, 1984.
- KIRDA, C.; REICHARDT, K. Comparison of neutron moisture gauges with non-nuclear methods to measure field soil water status. *Scientia Agricola*, Piracicaba, v.49, n.1, p.111-121, 1992.
- MENDES, M.E.G.; VILLAGRA, M.M.; SOUZA, M.D.; BACCHI, O.O.S.; REICHARDT, K. Relações hídricas em seringal no município de Piracicaba, SP. *Scientia Agricola*, Piracicaba, v.49, n.1, p.103-109, 1992.
- TURATTI, A.L.; REICHARDT, K. Soil water storage variability in Terra Roxa Estruturada. *Revista Brasileira de Ciência do Solo*, Campinas, v.15, n.3, p.253-257, 1991.
- WARRICK, A.W.; NIELSEN, D.R. Spatial variability of soil physical properties in the field. In: HILLEL, D., ed. *Applications of soil physics*. New York: Academic Press, 1980. cap. 13, p.319-44.

Received in April 7, 1993

Accepted in July 1, 1993

---

Enviado para publicação em 07.04.93

Aceito para publicação em 01.07.93