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SOIL HYDRAULIC CONDUCTIVITY MEASUREMENT ON A SLOPING FIELD[1]

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ABSTRACT

A field methodology is presented for the measurement of the soil hydraulic conductivity in a sloping field, minimizing the leveling soil movement before water pounding and redistribution. The assurance of vertical flow only is performed through soil water potential isolines. The hydraulic conductivity was determined by the instantaneous profile method. Results for the nine neutron probe access tubes indicate that one single K(θ) relation is sufficient to represent the experimental site.

Key words: hydraulic conductivity, slope, neutron probe

DETERMINAÇÃO DA CONDUTIVIDADE HIDRÁULICA EM ÁREA COM DECLIVE

RESUMO

É apresentada, aqui, uma metodologia de campo para a determinação da condutividade hidráulica de um solo em declive, minimizando o corte de terra para posterior inundação e redistribuição da água. A garantia da ocorrência de fluxo de água apenas na vertical, é feita através de isolinhas de potencial da água. A condutividade hidráulica foi determinada pelo método do perfil instantâneo e os resultados para os nove tubos de acesso de sonda de nêutrons indicaram que uma única relação K(θ) é suficiente para representar a parcela.

Palavras-chave: condutividade hidráulica, declive, sonda de nêutrons

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INTRODUCTION

Among the methodologies used for soil hydraulic conductivity determination in the field, those employed with most success are based in internal drainage experiments. Some of the earliest contributions are those of Youngs (1964), La Rue et al. (1968) and Davidson et al. (1969). At a later stage, these methods were presented more formally (Hillel et al., 1972) or in a simplified form (Libardi et al., 1980) and Sisson et al. (1980), and in the last two decades used extensively to evaluate field soil hydraulic conductivity functions. One experimental shortcoming of these methodologies is the necessity of leveling the area in order to allow a homogeneous ponding with a water depth of 0.02 to 0.05 m, until steady-state infiltration is reached. Depending on the slope of the field and on the size of the flooded area, a significant soil cut has to be performed to level the area, removing topsoil from the upper part and adding soil to the lower part. Soil surface layer, which in many cases controls the process, is severely disturbed. This experiment is a trial that intends to minimize the problems listed above, and presents a hydraulic conductivity determination in a sloping area, leveling the soil in steps, with concomitant pounding. It is shown that no lateral water flow was present during water infiltration.

MATERIAL AND METHODS

A field of "Terra Roxa Estruturada" (Rhodic Kandiudox) of 7.4% slope, located in Piracicaba, SP, Brazil, was levelled in three steps (Figure 1A and B) in order to flood a 4.2 x 4.2 m plot. Nine access tubes for neutron probe soil water content θ ($m^3 m^{-3}$) measurements (depths 0.2; 0.4; 0.6; 0.8 and 1.0 m) were numbered as follows: 1.1; 1.2; 1.3 (step 1); 2.1; 2.2; 2.3 (step 2) and 3.1; 3.2; 3.3 (step 3) and six tensiometer sets for soil water matric potential h (m H_2O) (depths 0.3; 0.45; 0.60; 0.75; 0.9; 1.0 and 1.1 m) labelled as: 1a; 1b (step1); 2a; 2b (step 2); and 3a; 3b (step 3). Total soil water potential H = h + z values, where z stands for the gravimetric soil water potential (m H_2O), were calculated in relation to step 1, for which z (m) was assumed to be zero. At steady-state infiltration, saturated soil hydraulic conductivity K_o (mm day^{-1}) was measured using plastic cylinders of 0.3 m diameter. After this, flooding was terminated, plots were covered with a plastic sheet to avoid soil water evaporation and rainfall. Redistribution of water was monitored for two weeks, making measurements of θ (z,t) and h (z,t). This data was analyzed in order to establish soil hydraulic conductivity $K(\theta)$ functions using the simplified methodology of Libardi et al. (1980).

RESULTS AND DISCUSSION

Since the main difference between this experiment and all others based on soil pounding followed by internal drainage is the slope of the land, which was levelled in three steps, an analysis of the H(z) profiles was made in order to verify if there was lateral water flow. Figure 1C shows H(z) isolines at the end of the infiltration process, which indicate that the water flow occurred mainly in the vertical direction and that the Libardi et al. (1980) procedure could be applied without restriction.

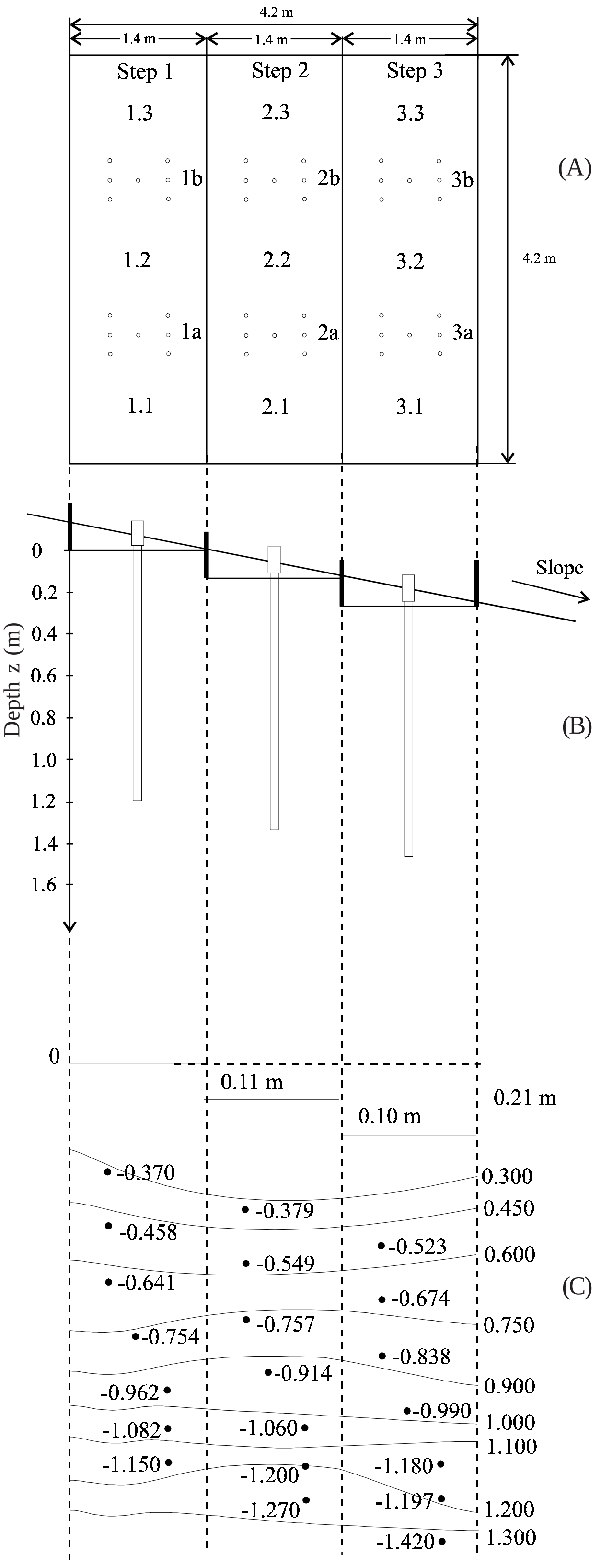

Figure 1. Schematic view of the field plot, showing the positions of neutron access tubes and of tensiometers. A. Top view; B. Central soil profile; and C. Central soil profile showing total water potential (H) isolines

Hydraulic conductivity $K(\theta)$ data are presented in Table 1, referring to the parameters K_o, γ and θ_o of the exponential model used by Libardi et al. (1980):

Table 1. Values of saturated hydraulic conductivity (K_o), dimensionless coefficient (γ) and saturated soil water content (θ_o)

Access Tube	K_o (mm day^{-1})		γ	θ_o
	Field*	Intercept**		
1.1	2274	0.0038	151.52	0.479
1.2	1152	0.0208	106.38	0.480
1.3	2769	0.0161	153.85	0.473
2.1	480	0.000273	222.22	0.456
2.2	2072	0.00179	208.33	0.473
2.3	2190	0.0211	114.94	0.459
3.1	2285	0.0192	107.53	0.456
3.2	1332	0.0360	116.28	0.458
3.3	2969	0.0149	131.58	0.459
Mean	1947	0.0149	145.9	0.466
SD	804.5	0.011	43.1	0.010
CV (%)	41.3	76.9	29.6	2.2
1.1; 1.2; 1.3 (step 1)	2065	0.0117	133.33	0.477
2.1; 2.2; 2.3 (step 2)	1581	0.00349	166.67	0.463
3.1; 3.2; 3.3 (step 3)	2195	0.0218	117.65	0.458
All	1947	0.0128	133.33	0.466

* Data from ring infiltrometers

** Data from the intercept of the θ versus ln t plots (Libardi et al., 1980)

$$K(\theta) = K_o \exp[\gamma(\theta - \theta_o)] \quad (1)$$

where:

θ - is the soil water content (m^3 m^{-3})

θ_o - its saturated value

K_o - the saturated soil hydraulic conductivity (mm day^{-1})

γ - a regression parameter.

Data of Table 1 are first presented individually for each of the nine neutron probe access tubes, followed by a mean, standard deviation (SD) and coefficient of variation (CV). K_o data of ring infiltrometers are 10^6 times larger than those calculated from the intercept of the θ versus ln t plots. This fact is well discussed by Reichardt et al. (1998), which show that K_o and θ_o can be seen as fitting parameters, and therefore, an infinite set of K_o/θ_o pairs can be used to describe the same $K(\theta)$ relation. Since infiltrometer K_o data represent direct measurements, they should be used in $K(\theta)$ equations of type (1). The saturated soil water content θ_o values shown in the last column of Table 1 are the neutron probe measurements performed at the end of the infiltration process.

Coefficients of variation of K_o values are the highest, suggesting that it is prohibitive to use average values. For γ values they are smaller but still very high. Values of θ_o present a very low CV, indicating an apparent soil homogeneity. It must be recognized that θ_o is part of the exponent of Eq. (1) and that very small changes in θ_o will imply in very large changes of K.

Table 1 also presents average data for each levelled step. These values were compared statistically using ANOVA and no significant difference was found for the mean values of K_o, γ and θ_o for steps 1, 2 and 3. This suggests that the high CV values found for the nine locations discussed above are acceptable. Since no difference was found, an overall average was calculated, yielding the last line of Table 1. Therefore, the mean hydraulic conductivity of the field, can be written as:

$$K(\theta) = 1947 \exp[133.33(\theta - 0.466)] \quad (2)$$

CONCLUSION

This study shows that the water flow during the redistribution occurred mainly in the vertical direction and that the Libardi et al. (1980) procedure, in this case, could be applied without restrictions.

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