INTERNATIONAL ATOMIC ENERGY AGENCY
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SMR/147-10

COLLOQUIUM

COLLEGE ON SOIL PHYSICS
15 April - 3 May 1985

COLLOQUIUM ON ENERGY FLUX AT THE SOIL ATMOSPHERE INTERFACE
6 - 10 May 1985

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ABSTRACT

Thirty three infiltration tests were carried out on each of two soils (alfisols) each having an area of 0.014ha with a view to determine the spatial variability of the parameter and also the effects of the humus layer, its pore-size distribution and bulk density on infiltration. Results showed that removal of top soil significantly decreased infiltration rates. A semivariogram analysis revealed no spatial pattern between adjacent readings at 2 m spacing in either the North - West or East - West direction. Final intake rates were normally distributed. Scaling infiltration with the parameter A of the Phillip's two term infiltration equation showed that the scale factor α_A and $\alpha_{opt.}$ proved effective in giving representative means for field prediction of water movement. A functional relationship was established between infiltration rate and the bulk density and pore size distribution, which was adequately represented by a linear multiple regression model.

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A good knowledge of infiltration is one of the most efficient means of water management. Unfortunately the infiltration rate is influenced by many factors especially the conditions of the surface soil which make it vary widely in the field (Nielsen et al 1973; Sharma et al 1981, Sisson and Wierenga, 1981). How to cope with this variability in a given field is a problem which many soil physicists are concerned with. Some workers, for example, Grin (1971 and 1972), in an attempt to predict infiltration in the field have attempted to relate the process to the status and properties of the surface soil.

Based on the similar media concept first introduced in soil physics by Miller and Miller (1955) and recently developed by Simmons et al (1979) scaling of field soil water properties was made in variability studies with emphasis on the hydraulic conductivity. There are few reports in the literature pertaining to scaling of infiltration (Sharma et al, 1980, Vieira et al 1981),

The present work was carried out to

(i) study the characteristics and variability of infiltration

(ii) determine the effect of the humus layer by simulating a severely eroded soil and

(iii) determine the relationships between infiltration and the plysical properties of the surface soils.

MATERIALS AND METHOD

Two alfisols (Soils I and II) about 500m apart were selected at the University of Ibadan Farm for the study. On each site, a rectangular area of $144m^2$ was demarcated and grided on a 2 - by 2m grid to give 36 plots. On 21 of the plots, infiltration runs were carried out without disturbing the top soil and 12 additional runs were carried out after a removal of the top humus layer in order to observe the effect of simulated erosion or alteration of the top soil.

Double ring infiltrometers were used for the infiltration measurement. Equilibrium rates were attained after about 2-3 hours. Pore size distributions were determined using a Tension Table. Bulk density, particle size analysis and organic matter contents were determined using standard methods.

The infiltration capacities measured on each soil were analysed by the semivariogram procedure in order to detect any spatial arrangement of the readings. Semivariances γ_h, between points separated by a given distance h (the Lag) were calculated for the North - South and East-West directions using the following formula (Burgess and Webster, 1980):

$$\gamma_{(h)} = \tfrac{1}{2} \sum_{i=1}^{n} \left[Z_{(k)} - Z_{(k+h)} \right]^2 \quad \ldots\ldots\ldots\ldots \quad (1)$$

where n is the number of pairs of points and $Z_{(k)}$ is infiltration rate at the location k.

Based on the similar media concept, infiltration was scaled using Philip's infiltration model (Philip, 1957). The parameters S and A can be scaled as follows (Sharma et al, 1979):

$$S_j/\lambda_j^{\frac{1}{2}} = S_r/\lambda_r^{\frac{1}{2}} \quad \ldots\ldots\ldots \quad (2)$$

$$A_j/\lambda_j^{2} = A_r/\lambda_r^{2} \quad \ldots\ldots\ldots \quad (3)$$

where S_j and A_j are the values of S and A at the j^{th} location, S_r and A_r are the values of S and A for the reference soil and λ_j and λ_r are the microscopic lengths of the j^{th} and reference soils respectively. If similar media conditions hold, then the λ_j's would be equal.

Dimensionless scaling factors, α, can be defined as

$$\alpha = \lambda_j/\lambda_r = \lambda_j/\bar{\lambda} \quad \ldots\ldots\ldots\ldots \quad (4)$$

where $\bar{\lambda}$ is the characteristic length of a soil with average soil water properties and for such average soil the scaling factor would be equal to unity.

On the basis of a set of infiltration tests which yield n sets of S and A parameters the dimensionless scaling factors, α_S and α_A can be calculated as follows:

$$\alpha_{s_j} = (S_j/\bar{S})^2 \text{ and } \alpha_{A_j} = (A_j/\bar{A})^{\frac{1}{2}} \quad \ldots\ldots\ldots \quad (5 \& 6)$$

$$\text{where } \bar{S} = \frac{1}{n} \sum_{j=1}^{n} S_j \text{ and } \bar{A} = \frac{1}{n} \sum_{j=1}^{n} A_j \quad \ldots\ldots\ldots \quad (6) \& (7)$$

The measured infiltration I(t) can be scaled using either α_S or α_A according to the relationship:

$$\hat{I} = \alpha I \text{ and } \hat{t} = \alpha^3 t \quad \ldots\ldots\ldots\ldots \quad (8)$$

where $\hat{I}$ and $\hat{t}$ are the scaled cumulative infiltration and scaled time, respectively.

If the Phillip's equation constitutes a physical model for measured infiltration and if scaling holds, then the infiltration on a location and all locations in the scaled form will be:

$$\hat{I} = \bar{S} t^{\frac{1}{2}} + \bar{A} t \quad \ldots\ldots\ldots\ldots \quad (9)$$

In this study, infiltration was scaled using α_{A_j} and $\alpha_{opt.}$ as has been used by Sharma <u>et al</u> (1979). The latter factor was calculated by minimising the sum of squares of difference (Ss) between the scaled infiltration $\hat{I}$ and the average infiltration $\bar{I}$ (based on $\bar{S}$ and $\bar{A}$) under the constraint that

$$\sum_{j=1}^{n} \alpha_r = 1 \quad \ldots\ldots\ldots\ldots \quad (10)$$

$$\text{where } SS = \sum_{\hat{t}j} (\hat{I}\hat{t}_j - \bar{I}_{t_j})^2 \quad \ldots\ldots\ldots\ldots \quad (11)$$

where the sum θ is taken over all values of t_j for the entire infiltration period of the run.

The values of the parameters S and A of the Phillip's two-term equation used for scaling were determined at the 15th and 160th minute respectively at each location. S was calculated as follows:

$$S = I/t^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

where I is the value of the cumulative infiltration at time t = 15 minutes. A was the value of the infiltration rate at 160 minutes at the same location.

In order to study the relationship between infiltration capacity and the physieal properties of the top soil, the volume of pores drained at 20cm suction (pores larger than 150μm in diameter) and between 20cm and 50cm (pores ranging between 150μm and 60μm in diameter) and at suction higher than 50cm (pores smaller than 60μm) denoted as macroporosity I (MAP I), macroporosity 2 (MAP 2) and Microporosity (MIC) respectively were joined to bulk density (BD) as independent variables in a regression analysis.

RESULTS AND DISCUSSION

Equilibrium infiltration rates before and after the removal of the top soil ranged from 1.8 to 13.8cm/hr and 1.8 to 7.8 cm/hr respectively for soil I and from 3.6 to 15 cm/hr and 5.4 to 13.8 cm/hr respectively for soil II. Infiltration rates were significantly higher at the 5% level when the humus layer was remained intact as compared with its removal. Reductions in mean infiltration capacities when the humus layer was removed were 81% and 9.6% in soils I and II respectively. Statistical tests carried out on the values of α (indicator of the structural stability determined by using the Kostiakov's equation) and those of the total volume of large pores showed that (i) the structural stability decreased significantly when the humus layer was removed and (ii) a significant reduction in the total macroporosity was associated with the removal of the top soil.

Semivariograms showed that there was no spatial pattern of infiltration capacities in either North-South or East West direction on each field suggesting that the infiltration capacities can be described by frequency distribution properties.

Equilibrium infiltration rates were found to be normally distributed. The coefficients of variation (CV) were 41.1% and 41.0% for soils I and II respectively.

Graphs are presented to show the unscaled values of time change of cumulative infiltration I as well as scaled values using scale factors, α_A and $\alpha_{opt.}$ Scaling with α_A reduced the SS by 26.84% and 40.8% whereas scaling with $\alpha_{opt.}$ brought about 50.6% and 50.1% reduction in the SS for soils I and II respectively. Scaling shifted the data points towards a narrow band around the mean curve..

Correlation matrix table is presented to show the relationship between infiltration capacity as a function of pore-size distribution and bulk density of the surface soil. Pores larger than 150μm in diameter were best related to intake rates (r = + 0.57), followed by pores ranging between 150μm and 60 μm (r = + 0.51), bulk density (r = - 0.47) and microporosity (r = - 0.34). The multiple linear regression equation considering all the variables was:

$$INFR = 7.98 - 6.76\ BD + 0.33\ MAP1 + 0.34\ MAP2 + 0.009\ MIC \quad \ldots\ldots\ldots \quad (13)$$

where INFR represents the equilibrium infiltration rate. The computed F value, 11.74, was significant at the 5% level indicating that the hypothesis of linear regression was valid. The low coefficient of determination (R^2= 0.43) for the full model in equation 13 shows that less than 50% of the variability of infiltration was attributed to bulk density and pore size distribution of the surface soil.

SUMMARY AND CONCLUSIONS

Infiltration runs were carried out on two alfisols to study the field variability of the process and its relationship to some properties of the surface soil.

Medium to high infiltration capacities were observed on the two soils whether the top soil was removed or not. The values were significantly reduced when the surface humus layer was removed. Results show that the humus layer affect infiltration capacity by presenting a more stable and porous structure for water entry.

Equilibrium infiltration rates showed no spatial pattern at 2m spacing and exhibited coefficients of variation of 41.7 and 41.0% on soils and II respectively.

It was shown that scaling could be appropriate in giving more representative means for field prediction of the infiltration process and that scaling factors obtained by minimising the sum of squares about the mean infiltration curve was found be more satisfactory.

It was also shown that a functional relationship existed between final infiltration rates on the one hand and density and pore-size distribution of the surface soil on the other, and that this relationship could be correctly approximated by a multiple linear regression model.

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