SAMPLING STRATEGY FOR SOME PHYSICAL PROPERTIES

M.Ilyas, M.Hussain and A. Saleem
University College of Agriculture, Rawalakot, Azad Kashmir.

Interpretation of soil physical parameters based on few measurements is sometimes difficult because of the spatial variability of the soil. Spatial variability in a saline-sodic soil was evaluated by measuring field-saturated hydraulic conductivity (kfs) and infiltration rate (IR) in the field. The high coefficient of variation of 69 and 46 for Kfs and IR, respectively indicated the inherent soil variability of the study soil. The cumulative probability plots for Kfs and IR revealed near normal distribution of the data. Method to asses the number of field measurements needed for the evaluation of a particular soil physical parameter at a certain probability level is described. Depending upon the variability, it is suggested to take at least 10 field measurements for reasonable evaluation of soil's permeability to water.

INTRODUCTION

The most difficult process to evaluate in the soil is its permeability to water. Installation of many systems including agricultural, hydrological, environmental, and industrial depend critically on the permeability of the surrounding soil. Thus a wrong assessment and interpretation of permeability can lead to failure of an installed system. Water permeability is spatially variable and a dynamic property of soil being altered continuously by the physical, chemical and biological processes.

The complex soil matrix, which is mainly responsible for the variation in water permeability, involves a series of interrelated parameters in saturated-unsaturated flow. These parameters include the geometry and size of the pores, the characteristics of the unsaturated soil, the depth of the water table and the heterogeneity and anisorropy.of the soil. In addition, methods and equations used to measure and evaluate permeability contribute to the variation (Lee *et al., 1985:* Julie et al. 1988).

Considerable efforts have been made and techniques developed to measure infiltration rate (IR) and saturated hydraulic conductivity (K_{fs}) accurately in the field (Reynolds et al., 1984; Bouwer, 1986; Amoozegar, 1989; Ilyas et al, 1991: Reynolds and Elrick, 1991). Each method had its own application and practical limitations. Repacked soil columns and soil cores do not represent the field conditions because microprobes are destroyed, normal aggregation is broken and lateral flow eliminated (Anderson and Bouma, 1973; Bouma, 1984; Wagenct, 1984; Julie et al. 1988).

Taking all the sources of variability into account, the magnitude of the variation in K_{fsd} values may be from a few percent to more than a hundred percent. Sometimes, the results obtained are misleading. Bouma (1984) presented an interesting example in which the estimated K_{fs} of a silt-loam soil was 20 cm d^{-1}. Yet, a sprinkling rate of 120 cm d^{-1} (six times the estimated rate) did not produce surface ponding of water on that soil. Thus, interpretations on water permeability data are made with varying claims of confidence.

Difficulty in the interpretation of spatially variable K_{fs} and IR, and the approaches, such as geostatistics, have been well documented (MeBrathney, 1984: Wagenet, 1984; Warrick; *et al.* 1986). Application of geostatistics is mostly to soil survey studies. In field experiments, however, the effect of soil and other uncontrolled environmental variability is minimized through statistical designs by blocking, randomizing, and replications. Size of the replications in a field experimental design is especially important for spatially-variable parameters.

Objectives of this study were (I) to measure water permeability variation in a saline-sodic soil and, (2) to assess the, measurements required for a spatially variable parameter for a reasonable interpretation.

MA TERIAL AND METHODS

The field site was at Sandhoke Agricultural Research Station, between Gujranwala and Lahore. Preliminary classification lists the soil as fine-loamy, mixed, thermic, Typic Natrustalf. The soil physical characteristics of the site are given in Table I. Basically, a saline-sodic field ESP = 68, EC = 5.6 ds m-I was chosen to measure the effect of some reclamation treatments on water permeability. Prior to the application of the treatments, however, it was considered necessary to assess variability of the experimental soil for water permeability and the replications needed for the field experiment. For this purpose, thirty two measurements, for each K_{ts} and IR, were taken at approximately 1.5 m intervals in a square grid pattern over 50 m^2 area.

The K_{ts} measurements were made by using constant-head, PVC, well parameter (CHPWP) method (Ilyas *et a/.* 199J, 1992). K_{fs} was calculated by the three dimensional flow equation given in Reynolds *et al.* (1985) which considers all pressure, gravity, and capillarity effects. The IR measurements were made using doubling infiltrometers (Bouwer, 1986).

Table 1: **Some profile physical properties of the study soil.**

Depth	Clay	Silt	Sand	[mean ± SD = (n = 8)]		
				Kf e ±t	IRt	pb9[
cm	---------	%	------	IQ7m S·]	5-1	g cm'
0-20	21.6	38.0	40.8	1.2 ± 0.7	1.0 ± 0.2	1.56 ± 0.02
20-40	22.6	39.0	38.4	0.8 ± 0.5	-	1.61 ± 0.02
40-60	25.6	40.0	34.4	1.4±0.7	-	-
60-80	29.6	44.0	26.4	1.5 ± 0.8	-	-
80-100	35.2	32.4	32.4	2.2 ± 0.9	-	-
100-120	29.6	34.0	36.6	3.2 ± 1.8	-	-

t Kt - = Field-saturated hydraulic conductivity.
t IR = Infiltration rate.
lj[p, = Bulk density

RESULTS AND DISCUSSION

There was a considerable variability problem in water permeability of the study soil. It was difficult to decide whether to make statistical analysis and interpretation on the original *Kcs* and IR data or the transformed data. Variation in soil physical properties are often described by either the normal or long-normal distribution. Statistical distribution of a soil's permeability is generally found to be log-normal (Lee *et al.,* 1985: Talsma. 1987: Julie *et al.,* 1988: Starr, 1990).

However, cumulative probability plots for the K_{fs} and JR of the experimental soil indicted the data were not very different than the normal distribution (Fig. I) Therefore, the correlation of determination (r^2) were computed to compare the goodness of fit of cumulative and cumulative log-normal distributions for the K_{fs} and JR data (Table 2). Non-significant r^2 values were calculated among cumulative normal and cumulative log-normal values for K_{fs} and JR data. These values suggest that any significant variability detected by statistical analysis on normally distributed data will be due to the treatments applied rather than due to the large random scatter of the data.

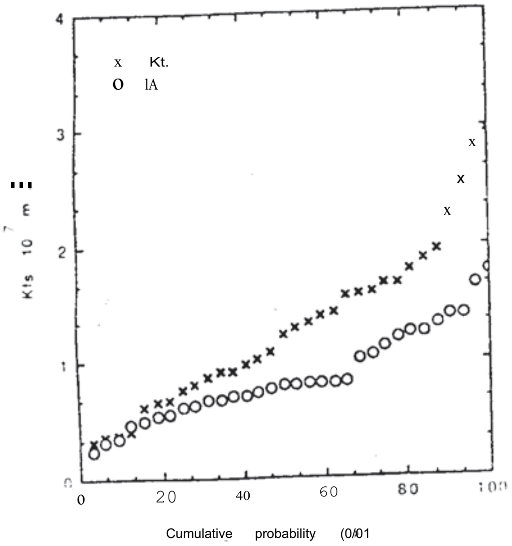

Fig. 1 Cumulative probability Vs. field saturated hydraulic conductivity (Kt's) and infiltration rate (IR) data of the study soil.

The high coefficients of variation (CV) of 69 and 46 for K_{fs} and JR, respectively indicate the inherent soil variability of the experimental soil (Table 2). The K_{fs} measurements showed higher CVs than did the JR values. Saturated flow in the soil is mainly governed by the macropores (> 1 mm). Any local variation of soil temperature (Jaynes, 1990), macropores, presence of wide cracks, root channels, and earthworm channels can cause significant variations in K_{fs} and JR. Theoretically, this source of variation should be the same for K_f, and JR. Tedious field measurement procedures and empirical models used for its computations make the K_f, more variable than JR. Results are in agreement with those of Starr (1990) who observed higher CVs for K_{fs} than for JR.

It is well established that the permeability exhibits extreme variability even within one soil type (Topp *et al.,* 1980; Julie *et al., 1988;* Starr, 1990). The soil in this study is saline-sodic and fine in texture (Table 1). Fine-textured soils are usually more variable in water permeability than are coarse-textured soils. Lee *et al.* (1985) reported CVs for K_f, on the order of 65% for sand soil, 130% for loam soil, and up to 600% for clay soil. Data in Reynolds and Elrick (1985), Starr (1990) yield CV values for K_f in the range of 40 to 120%. Consequently, many replications are required

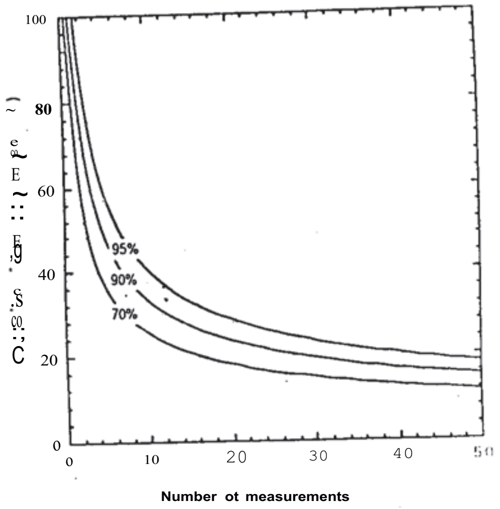

Fig. 2 : The relation between the number of measurements and the deviation from the mean (%) for field saturated hydraulic conductivity (Kt's) data of experimental soil at the 95%, 90% and 70% confidence limits.

above the water table J. Drain. & Reel, 3(2): 1-8.

Jaynes, D.B. 1990. Temperature variation effect on field-measured infiltration. Soil Sei. Soc. Am. J. 54: 305-3 I2.

Julic, *G.,* R.J. Lauren, 1. Wagenet, J. Bouma, and J.H. Wosten, 1988. Variability of saturated hydraulic conductivity in a Glossaquic Hapludalf with macroporcs. Soil Sci. 145: 20-28.

Lee. D.M., W.D. Reynolds, W.D. Elrick, and B.E. Clothier. 1985. A comparison of three field methods for measuring saturated hydraulic conductivity. Can. J. Soil Sci. 65 : 563-573.

McBrathney, A.B. 1984. The role of geostatistics in the design and analysis of field experiments with reference to the effect of soil properties on crop yield. p. 3-8. In D.R. Nielsen and J. Bouma (cd.) Proc. Workshop ISSS and SSSA on Soil Spatial Variability, Nov. 30-Dec. I. Las Vegas. NV.

Reynolds, W.D., and D.E.Elrick, 1985. In-situ measurement of field-saturated hydraulic conductivity, sorptivity, and the a-parameter using the Guelph Parameter. Soil Sci. 140: 292-302.

Reynolds, W.D., D.E. Elrick, and B.E. Clothier, 1985. The constant head well urarneters. Effect on unsaturated flow. Soil Sci., 139: 172-180.

Reynolds, W.D., D.E. Elrick. N. Baumgartner, and B.E. Clothier, 1984. The Guelph Permeameter for measuring the field-saturated soil hydraulic conductivity above the water table: 2. The apparatus Proc. Can. Hydrol. Symp. June 11-12. Quebec City. Quebec p, 657-665.

Starr, J.L. 1990. Spatial and temporal variation of ponded infiltration. Soil Sci. Soc. Am. 1. 54: 629-636.

Talsma, T. 1987. Re-evaluation of the well permeameter as field method for measuring hydraulic conductivity, Aust. J. Soil Res. 25: 361-368.

Topp, O.C., W.D. Zebchuck, and J. Dumanski, 1980. The variation of *in-situ* measured soil water properties within soil map units. Can. J. Soil Sci. 60: 497-509.

Wagenet. R.J. 1984. Measurements and interpretation of spatially variable leaching processes. p. Workshop ISSS and SSSA on Soil Spatial Variability. Nov. 30- Dec. Las Vcgas, NV.

Wanick, A.W., D.E. Meyers, and D.R. Nielsen, 1986. Geostatistical methods applied to Soil Science. In A. Klute (ed.) Methods of Soil Analysis, Part I. 2nd ed. Agron. Monogr. 9. ASA and SSSA. Madison, WI. p. 53-81.