Pak. J. Agri. Sci. Vol. 32 (4), 1995

DETERMINATION OF SOIL HYDRAULIC PROPERTIES WITH THE PARAMETER OPTIMIZATION METHOD

M. Abid, A. Hassan[1], J.M.H. Hendrickx[2] and J. Beekma[3]
Department of Soil Science, Agriculture College, BZU, Multan
[1]Department of Soil Science, University of Agriculture, Faisalabad
[2]Department of Geoscience, New Mexico Institute of Mining and Technology, Scorro, USA,
[3]International Land Reclamation Institute, Wageningen, The Netherlands

A field experiment was conducted to determine unsaturated hydraulic conductivity K(θ) and water retention h(θ) curves of an important soil from Punjab, Pakistan. The matric potential (h) and volumetric soil water content (θ) were measured with tensiometer and neutron probe, respectively. Observed data were fitted to the van Genuchten-Maulem model through SFIT computer model to obtain moisture retention and hydraulic conductivity curves of the soil. Parameter optimization looks like a promising technique for relatively good description of the hydraulic behaviour of the soil.

Key words: parameter optimization, soil hydraulic properties

INTRODUCTION

Quantitative data on soil hydraulic properties, necessary for computer simulation and prediction of water and solute movement in the unsaturated zone of the soil, are very rare in Pakistan. These hydraulic properties are water retention h(θ) and unsaturated hydraulic conductivity K(θ), where θ is the volumetric soil water content ($L L^{-1}$), h is the soil water pressure head (L) and K is the hydraulic conductivity ($L T^{-1}$).

Numerous methods are available for measuring the water retention as well as hydraulic conductivity of the soil (Klute and Dirksen, 1986; Kool and Parker, 1987; Hendrickx *et al.,* 1990). These methods are laborious and time consuming. One rather convenient method is the parameter optimization method which can be successfully used in the field as well as in the laboratory. The parameter optimization method is attractive because parameter estimation can be obtained from transient flow events. Another advantage is that any initial and boundary conditions may be employed. The flow problem is solved by using the van Genuchten equation parameters (van Genuchten, 1980) which describes the shape of the water retention and hydraulic conductivity curves of different soils. The unknown parameters in these functions are estimated by minimizing deviations between observed and model predicted output. Therefore, it allows relatively simple experimental design with more flexibility than traditional methods. This research was conducted with the cooperation of the International Waterlogging and Salinity Research Institute (IWASRI)Netherlands Research Assistance Project (NRAP). The objective of this research was to evaluate the parameter optimization method to determine the hydraulic properties of Drainage IV Project soils.

MATERIALS AND METHODS

Theory: van Genuchten (1980) described both the h(θ) and K(θ) relations with four independent parameters (θ_r, θ_s, α and n) which have to be estimated from observed data. The volumetric water content (θ) is expressed as a function of pressure head (h) with the empirical equation:

$$\theta = \theta_r + \frac{\theta_s - \theta_r}{[1 + (\alpha h)^n]^m} \qquad (1)$$

Where,

θ_r = residual water content ($cm^3\ cm^{-3}$)

θ_s = volumetric water content at saturation ($cm^3\ cm^{-3}$), and

α, n and m = shape parameter of the curve.

van Genuchten *assumed* that

$$m = 1-(1/n) \qquad (2)$$

Maulem (1976) gave K (h) relation based on theoretical pore-size distribution as:

K(hJ = *K,S/* If,' I/Ih (Xli. dx/f,' 11th *(X)].* dx]? (3)

Where.

λ	=	shape parameter of the *curve*
$\times$	=	a help variable, and
S_e	=	relative saturation

Relative saturation can be defined as:

$$Se = \theta - \theta_r) / (\theta_s - \theta_r) \quad (4)$$

By using equations 1,2 and 3 one can derive:

$$K (S_e) = K_s S_e [1 - (1 - S^{1/m})^m]^2 \quad (5)$$

This equation is the Maulem (1976)-van Genuchten (1980) hydraulic conductivity model. Equation 5 in terms of pressure head is given as:

K (h) = K_s^{λ} 1([I + (eh)"]"' - *(a* h)".1])f / [I + *(a* h)Ilj(m<2) (6)

Site Description and Layout: The field experiment was conducted on. a loamy soil, the Hafizabad soil series (coarse loamy, mixed, hyperthermic, Typic Haplargid) with water table at approximately 6m deep (Abid, 1991). The description of the soil profile at experimental site is given in Table I. The soil is loam in texture and has a weak structure. A leveled plot (14 m long and 6 m wide) was separated from the surrounding area by earthen bounds. In this plot five PVC access tubes were installed at a depth of 2:5 m, on the central line, 2m apart from each other. Around the neutron probe access tube- four tensiometers were installed on each side of the tube. These were installed at a 30 cm distance interval, the ceramic cups placed at 0.25, 0.50, 0.75, 1.00, 1.25, 1.50 and 1.75m depth. The plot was ponded with water for a prolonged period to ensure that the soil is saturated. This was verified with zero matric potential.

Table I. Soil profile description at the experimental site

Depth(mJ	Profile C\escription
0.0-0.15	Loam, massive structure
0.15-0.95	Loam, weak structure
0.95-1.20	Loam, with fine medium nodules, weak structure
> 1,20	Sandy loam, massive structure, free drainage

The soil water content and water tension were measured at regular increasing intervals until change over time became negligible. The K was determined with instantaneous profile method based on Darcian flow analysis (Hillel *et al*., *1972).*

RESULTS AND DISCUSSION

In order to get the unique solution of the optimization procedure, the number of parameters to be optimized are reduced. Therefore, saturated soil moisture content, A. and El taken from Hendrickx (1990) were fixed at their initial values (did not allow them to optimize in the optimization procedure). Saturated hydraulic conductivity (KJ, *a* and n were optimized. Residual water content at 0.00 created problem in the uniqueness of the parameter optimization procedure but when it was fixed at 0.078 (taken from Carsel and Parris, 1988), it provided a reasonable uniqueness of the parameters. Table 2 shows the van Genuchten-Maulem equation parameters of Hafizabad soil series of neutron access tubes at different depths. As a measure of the best fit of the correlation coefficient R~ is also given in Table 2.

Table 2. Optimized van Genuchten-Maulem equation parameters of Hatizabad soil series of access tube T,

Depth(cm)	a(cm-:-')	n	Kjcm h-')	R'
25	0.016	1,668	0.474	0.995
50	0.014	1.419	0.715	0.998
75	0.115	1.301	0.997	0.998
100	0.009	2.338	0.552	0.998

Water Retention: Figure I shows the moisture retention curves of access tube at 25 cm depth. It is clear from this figure that moisture Content decreases with an increase in the matric potential. Results showed that moisture contents were 30 and 12%, respectively at field capacity (33 kPa) and permanent wilting point (1500 kPa). The available moisture content (difference between wilting point and field capacity) was 18% at this depth. This difference might be due to the sampling error/spacial variability. Moghal *et al.* (1992) showed that laboratory measured water retention values revealed a poor prediction of water retention than that of the field experiment.

Hydraulic Conductivity: Figure 2 divulged the comparison between unsaturated hydraulic conductivity measured with the instantaneous profile method and the model predicted K(El) relations. This comparison showed satisfactory agreement at all the soil depths because the difference expressed in the order of magnitude is less than one. This difference in order of magnitude increases as the soil becomes drier (Fluhler *et al.,* 1976). The results at 25 cm depth, however, deviated a little bit from this agreement which might be due to cultivation and high microbial activities. Furthermore, instantaneous profile method is not applicable where the lateral movement of soil water is appreciable (Hillel, 1972).

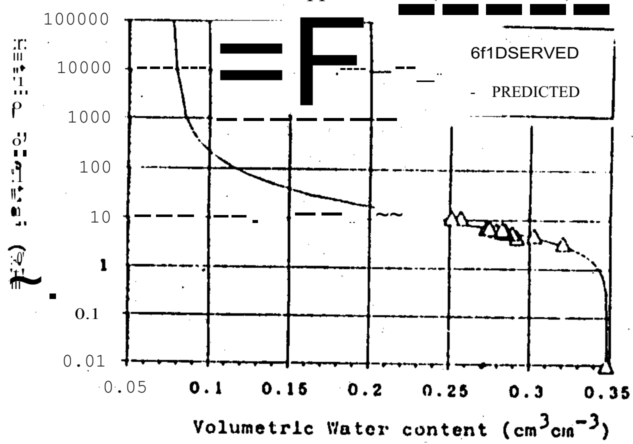

Fig. I. **Predicted and observed h(θ) relation of Hafizabad soil series for access tube T_1 at 25 cm depth.**

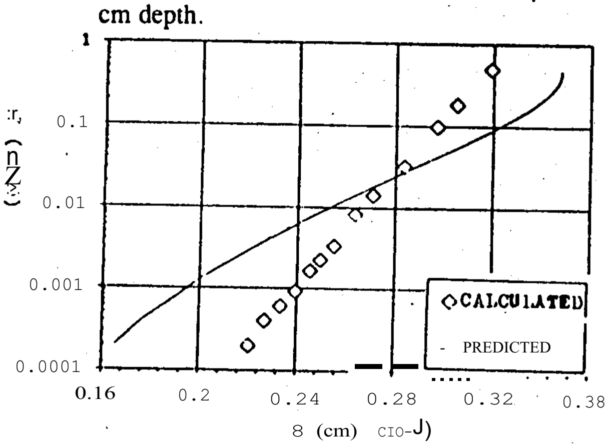

Fig. 2. Predicted and calculated K (6) relation of Hatizabad soil series for access tube T. at 25 cm depth.

Conclusions

* For an unique solution of the optimization procedure, the number of parameters should be reduced. This technique gave better results when easily measured parameters were fixed at their initial values.
* The K(e) relations measured with instantaneous profile method were not reliable at the surface of the soil.

REFERENCES

Abid, M. 1991. Determination of soil hydraulic properties with the parameter optimization method. M.Sc. (Hons.) Agri. Thesis, Univ. Agri., Faisalabad.

Carsel, D.K. and R.S. Parris. 1988. Developing joint probability distribution of soil water retention characteristics. Water Resour. Res. 24: 755-769.

Fluhler. H., M.S. Ardakani and L.H. Stolzy. 1976. Error propagation in determining hydraulic conductivities from successive water content and pressure head profiles. Soil Sci. Soc. Am. J. 40: 830-836.

Hendrickx, J.M.H., M.A. Chaudhry, J.W. Kijne, M. Sadiq aadZ.I. Raza. 1990. Soil physical measurements for drainage design in arid regions. In Symp. on Land Drainage for Salinity control in Arid and Semi-Arid Regions. Feb. 25-March 2, 1990. Cairo, Egypt. YoU: 124-134.

Hillel, D., V.D. Krentos and Y. Stylianous. 1972. Procedure and test of an internal drainage method for measuring soil hydraulic characteristics in situ. Soil ScL 114: 395-400.

Khan, G.S. and A. Tariq. 1990. Hydraulic characteristics of some important soil series of Pakistan. In Proc. Int. Symp. On Applied Soil Physics in Stress Environments. (Ed. M. Ahmad, M.E. Akhtar & M.I. Nizami), pp. 224-437. BARD (PARC), Islamabad, Pakistan.

Klute, A. and C. Dirksen. 1986. Hydraulic conductivity and diffusivity: Laboratory' methods. Agronomy. 9: 687-734. Am. Soc. Agron. Madison. WI, USA.

KooI, A. and J.C. Parker. 1987. Estimating soil hydraulic properties from transient flow experiments: SFIT user's guide. Report submitted to the Electric Power Research Institute, Palo Alto, California, USA.

Maulem, Y. 1976. A new model for predicting the hydraulic conductivity of porous media. Water Resour. Res. 12: 513-522.

Moghal, M.A., J.M.H. Hendrickx, J. Akhtar andR. Wahid. 1992. Field method for determination of water retention and unsaturated .hydraulic conductivity in the Drainage IV Project Area. Report No. 24,The Netherlands Research Assistance Project. Lahore, Pakistan.

van Genuchten, M.Th. 1980. Closed form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J. 44: 892-898.