WATER RESOURCES RESEARCH, VOL. 32, NO. 6, PAGES 1895–1896, JUNE 1996

Comment on "In situ method for estimating subsurface unsaturated hydraulic conductivity" by Uri Shani and Dani Or

J.-Y. Parlange,[1] R. Haverkamp,[2] D. A. Barry,[3] W. L. Hogarth,[4]
T. S. Steenhuis,[1] P. J. Ross,[5] and K. R. J. Smettem[6]

Shani and Or [1995] propose estimating hydraulic conductivity K in terms of the soil-water pressure ψ by measuring the pressure P within and the discharge Q out of a spherical cavity under steady state conditions. The authors have already pointed out some of the difficulties inherent with the method, for example, the assumption of a soil which follows the model of *Gardner* [1958], defining an equivalent spherical cavity radius r_o and the eventual presence of cracks. Possible methods to alleviate some of those difficulties, as well as additional potential sources of errors, are discussed in the following.

First, equations (7), (8), and (9) of *Shani and Or* [1995] relating P and Q can be improved. Writing

$$P = \frac{Q}{4\pi K_s r_o} - A, \tag{1}$$

if $A = 0$, we have the standard point source result, with K_s being the saturated conductivity. They estimate A as

$$A = \alpha^{-1} + \alpha Q/8\pi K_s, \tag{2}$$

where α is *Gardner*'s [1958] coefficient such that

$$K = K_s \exp \alpha\Psi \tag{3}$$

Hence their result can be written as in their equation (11):

$$P = \frac{Q}{4\pi K_s r_o}\left(1 - \frac{\alpha r_o}{2}\right) - \frac{1}{\alpha}. \tag{4}$$

In particular, if $P = 0$, equation (4) gives

$$\frac{Q\alpha}{4\pi K_s r_o} = 1\Big/\left(1 - \frac{\alpha r_o}{2}\right), \tag{5}$$

which is correct for $\alpha r_o/2$ sufficiently small. However, it has been shown earlier [*Parlange*, 1972] that a much better approximation is to replace $(1 - \alpha r_o/2)^{-1}$ by $(1 + \alpha r_o/2)$, which can be significantly different; for example, for $\alpha r_o/2 = 1/2$ the former is equal to 2 and the latter to 1.5, a 30% error! Later, *Parlange and Hogarth* [1985a] obtained exact and approximate results. Using the approximate result, equation (4) of *Parlange and Hogarth* [1985a], we obtain

$$P = \frac{Q}{4\pi K_s r_o}\Big/\left\{1 + \left[\alpha r_o/2\Big/\left(1 + \frac{\alpha r_o/2}{3 + \alpha r_o}\right)\right]\right\} - \frac{1}{\alpha} \tag{6}$$

although in most cases it will be sufficient to use

$$P = \frac{Q}{4\pi K_s r_o}\Big/\left(1 + \frac{\alpha r_o}{2}\right) - \frac{1}{\alpha}. \tag{7}$$

A second correction is due to the measurement of P and its relation to r_o and the fact that pressure varies with position along the cavity wall due to gravity. It seems that their water pressure outlet is at the top of the cavity, which is a convenient location. Actually, the measured pressure P should be increased by the distance between the outlet and the center of the cavity. Again, if the outlet is at the top of a spherical cavity, it can be shown that P should be changed to $P + r_o$ in the left-hand side of (6) or (7). This point is rather intuitive but was discussed in detail by *Parlange* [1974] taking $P = 0$ at the top of the cavity, so that $P + r_o$ reduces to r_o. Equation (11) in that paper then gives, with present notations and neglecting terms of order $(\alpha r_o)^2$,

$$r_o = \frac{Q}{4\pi K_s r_o}\Big/\left(1 + \frac{\alpha r_o}{2}\right) - \frac{1}{\alpha}. \tag{8}$$

A third correction concerns the assumption of a *Gardner*'s [1958] soil. It is, of course, clear that such a soil is a very useful approximation, although if one postulates (3), α can then be measured and is not constant [*Parlange and Hogarth*, 1985b]. A simple modification to Gardner's law, first proposed by *Rijtema* [1965], yields (see also *Steenhuis et al.* [1991])

$$\begin{aligned} K &= K_s \exp \alpha(\psi - h_{\text{str}}) \qquad \Psi \le h_{\text{str}} \\ K &= K_s \qquad \Psi \ge h_{\text{str}} \end{aligned} \tag{9}$$

where $h_{\text{str}} < 0$ is a water entry pressure. This modification leads to significant improvement on infiltration predictions [*Haverkamp et al.*, 1990]. As a result, (6) and (7) have to be slightly modified. Altogether then, (7), for instance, is changed to

$$P + r_o - h_{\text{str}} = \frac{Q}{4\pi K_s r_o}\Big/\left(1 + \frac{\alpha r_o}{2}\right) - \frac{1}{\alpha}. \tag{10}$$

Since $1/\alpha$ is the intercept for $Q = 0$ and both r_o and $-h_{\text{str}}$ are in the centimeter range, they could affect the value of α significantly.

Finally, it should be pointed out that, in general, the use of steady state solutions is dangerous. Minute changes may be hard to detect and may lead to erroneous results if steady state and homogeneous soils are assumed. For instance, *Smettem et al.* [1994a] discussed that point within the context of twin disc

[1]Department of Agricultural and Biological Engineering, Cornell University, Ithaca, New York.
[2]Laboratoire d'Etude du Transfert en Hydrologie et Environnement, CNRS, Grenoble, France.
[3]Department of Environmental Engineering, Centre for Water Research, University of Western Australia, Nedlands.
[4]Environmental Faculty, Griffith University, Brisbane, Queensland, Australia.
[5]Division of Soils, CSIRO, Davies Laboratory, Townsville, Queensland, Australia.
[6]Department of Soil Science and Plant Nutrition, University of Western Australia, Nedlands.

Paper number 96WR00677.
0043-1397/96/96WR-00677$09.00

infiltrometers and the application of *Wooding*'s [1968] equation, which is also used by *Shani and Or* [1995] for comparison purposes. Transient results can then be valuable, if properly interpreted [*Smettem et al.*, 1994b; *Haverkamp et al.*, 1994].

References

Gardner, W. R., Some steady state solutions to the unsaturated moisture flow equation with applications to evaporation from a water table, *Soil Sci.*, *85*, 228–232, 1958.

Haverkamp, R., J.-Y. Parlange, J. L. Starr, G. Schmitz, and C. Fuentes, Infiltration under ponded conditions, 3, A predictive equation, *Soil Sci.*, *149*, 292–300, 1990.

Haverkamp, R., P. J. Ross, K. R. J. Smettem, and J.-Y. Parlange, Three-dimensional analysis of infiltration from the disc infiltrometer, 2, Physically based infiltration equation, *Water Resour. Res.*, *30*, 2931–2935, 1994.

Parlange, J.-Y., Theory of water movement in soils, 4, Two and three dimensional steady infiltration, *Soil Sci.*, *113*, 96–101, 1972.

Parlange, J.-Y., Gravity correction due to a variation of pressure head within a cavity, *Soil Sci. Soc. Am. Proc.*, *38*, 15–17, 1974.

Parlange, J.-Y., and W. L. Hogarth, Comment on steady infiltration from spherical cavities, *Soil Sci. Soc. Am. J.*, *49*, 788, 1985a.

Parlange, J.-Y., and W. L. Hogarth, Steady state infiltration: Consequences of α dependent on moisture content, *Water Resour. Res.*, *21*, 1283–1284, 1985b.

Rijtema, P. E., An analysis of actual evapotranspiration, *Rep. 659*, 107 pp., Cent. for Agric. Publ. and Doc., Wageningen, Netherlands, 1965.

Shani, U., and D. Or, In situ method for estimating subsurface unsaturated hydraulic conductivity, *Water Resour. Res.*, *31*, 1863–1870, 1995.

Smettem, K. R. J., P. J. Ross, R. Haverkamp, and J.-Y. Parlange, Application of a twin disk infiltrometer, in *Water Down Under*, pp. 183–186, Inst. of Eng., Australia, 1994a.

Smettem, K. R. J., J.-Y. Parlange, P. J. Ross, and R. Haverkamp, Three-dimensional analysis of infiltration from the disc infiltrometer, 1, A capillary-based theory, *Water Resour. Res.*, *30*, 2925–2929, 1994b.

Steenhuis, T. S., J.-Y. Parlange, and K.-J. S. Kung, Comment on "The diversion capacity of capillary barriers" by Benjamin Ross, *Water Resour. Res.*, *27*, 2155–2156, 1991.

Wooding, R. A., Steady infiltration from a shallow circular pond, *Water Resour. Res.*, *4*, 1259–1273, 1968.

D. A. Barry, Department of Environmental Engineering, Centre for Water Research, University of Western Australia, Nedlands, Western Australia 6907, Australia.

R. Haverkamp, Laboratoire d'Etude du Transfert en Hydrologie et Environnement, CNRS, B.P. 53, 38041 Grenoble, France.

W. L. Hogarth, Environmental Faculty, Griffith University, Brisbane, Queensland 4111, Australia.

J.-Y. Parlange and T. S. Steenhuis, Department of Agricultural and Biological Engineering, Cornell University, Ithaca, NY 14853-5701.

P. J. Ross, Division of Soils, Davies Laboratory, CSIRO, Townsville, Queensland 4814, Australia.

K. R. J. Smettem, Department of Soil Science and Plant Nutrition, University of Western Australia, Nedlands, Western Australia 6907, Australia.

(Received October 2, 1995; accepted February 28, 1996.)