Second RUFORUM Biennial Meeting 20 - 24 September 2010, Entebbe, Uganda

Research Application Summary

Comparison of field and laboratory measured hydraulic properties of selected diagnostic soil horizons

Chimungu, J.G.[1], Hensley, M.[1] & van Rensburg, L.D.[1]
[1]University of the Free State, P. O. Box 339, Bloemfontein, Republic of South Africa
Corresponding author: josephchimungu@yahoo.co.uk

Abstract

This study characterised the hydraulic properties of two soil types in South Africa, Bainsvlei and Tukulu using both field (instantaneous profile method) and laboratory (desorption techniques). The results showed that the two approaches well defined water retention, but variation were observed due to texture differences. Also, the K-θ relationships predicted from the θ-h relationships of the soil cores corresponded well with those determined by the instantaneous profile field method for water contents. Overall, the instantaneous profile method appeared attractive when applied to relatively homogeneous soil profile where one-dimensional vertical flow can be expected after saturation. However, it is not applicable to stratified soil profiles with slowly permeable layer .

Key words: Hydraulic conductivity, instantaneous profile method, soil properties, South African soils, water retention

Résumé

Cette étude a caractérisé les propriétés hydrauliques de deux types de sol en Afrique du Sud, le Bainsvlei et le Tukulu, utilisant à la fois des méthodes sur terrain (méthode du profil instantané) et au laboratoire (techniques de désorption). Les résultats ont montré que les deux approches ont bien défini la rétention d'eau, mais la variation a été observée suite aux différences de texture. Aussi, la relation-K prédite à partir de la relation-H des noyaux du sol se sont bien convenues avec celles déterminées par la méthode sur terrain du profil instantané de la teneur en eau. Dans l'ensemble, la méthode du profil instantané est apparue intéressante lorsqu'elle est appliquée au profil de sol relativement homogène où l'écoulement vertical à une dimension peut être prévu après la saturation. Toutefois, elle n'est pas applicable aux profils de sol stratifié avec une couche peu perméable.

Mots clés: Conductivité hydraulique, méthode du profil instantané, les propriétés du sol, les sols sud-africains, la rétention d'eau

Background

An adequate characterization of soil hydraulic properties is a necessary solution for agriculturally and environmentally oriented problems such as irrigation, drainage, runoff and pollutants movement. The three approaches to determine hydraulic properties of soils are field measurements, laboratory measurements and mathematical models. *In situ* measurements, though representative, have the inherent limitation of being costly and time consuming. Laboratory and mathematical techniques are more convenient but require extensive comparison to field results as bench mark for evaluation. The objective of this study was to characterize the hydraulic properties of Bainsvlei and Tukulu soils utilizing the above mentioned three approaches and to compare the results.

Literature Summary

Several investigators have tested the van Genuchten-Mualem model by comparing the predicted to measured values of hydraulic conductivity (Dane, 1980; Paige and Hillel, 1993; Marion *et al.*, 1994). Dane (1980) reported a reasonable correspondence between instantaneous profile method-measured K-θ and predicted K-θ on sandy to loam textured soils. Paige and Hillel (1993) also found that hydraulic conductivities predicted by the van Genuchten-Mualem based on soil core data agreed closely with those obtained by the instantaneous profile method for corresponding ranges of suction and water content in a fine sandy loam. These results demonstrate that all estimation procedures, however, needs the results of direct measurements as benchmarks for validation. Futhermore, the results of these studies are not meant to represent characteristics for all soils including South African soils. It is necessary to evaluate the applicability of this model on South African soils in particular the Tukulu and Bainsvlei soils.

Study Description

Field studies and soil samples used in this study were collected from soil profiles at two experimental field stations of the University of the Free State at Kenilworth (29°01' 00'' S, 26°08' 00'' E, altitude 1354 m) and at Paradys (29°13' 25'' S, 26°12' 08'' E, altitude 1417 m). The Kenilworth soil is classified as a Bainsvlei form, *Amalia family* (Soil Classification Working Group, 1991). At Paradys, the soil is a Tukulu form, *Dikeni family* (Soil Classification Working Group, 1991). The objective of choosing the two sites was to obtain a range of normal agricultural soils that occur in this semi-arid region.

For laboratory measurements - the θ-h relationships were measured using a combination of desorption techniques in order

to provide a detailed description of the whole water retention characteristic. The hanging water column tension cup method (Dirksen, 1999) was used at lower suctions 0 - 10 kPa, and starting as close to saturation as possible to try to accurately identify the air entry suction. The pressure plate apparatus (Jury *et al.*, 1991) was used to define the water retention characteristic at higher suctions using undisturbed core samples at suctions between 10 and 100 kPa and disturbed samples for suctions between 100 and 1500 kPa.

In the case of field measurements, instantaneous profile method was used to determine unsaturated hydraulic conductivity for all selected diagnostic horizons for two soil profile and double ring method was used to determine saturated hydraulic conductivity.

Research Application

The water retention characteristics for both soils were generally well defined with little variability between replicates. The main variations were due to texture differences between the horizons. The measured water retention data corresponded well with the fitted curve via the van Genuchten (1980) model, indicating that the model can be successfully used to describe θ-h relationships for Bainsvlei and Tukulu soils.

Hydraulic conductivity was obtained by measuring the hydraulic head and water content of the Bainsvlei soil form *in situ* with tensiometers and horizon specific calibrated ECH_2O EC-20 probes, respectively. The profile was characterized with several relations of hydraulic conductivity and varied with depth. The reason for this was attributed to heterogeneous nature of the profiles due to variation in particle size distribution. The van Genuchten (1980) model laboratory method was used to predict K-θ relationships utilizing laboratory determined θ-h relationships. The K-θ relationships predicted from the θ-h relationships of the soil cores corresponded well with those determined by the instantaneous profile field method for water contents which they have in common. Thus it appears that this laboratory method is applicable to the soils studied, but the accuracy of the predicted values is quite sensitive to the matching factors. Thus, accurate measurement of these parameters is necessary for its successful use.

The instantaneous profile field method is regarded as a reference method to measure *in situ* unsaturated hydraulic conductivity for both homogenous and layered soils (Hillel *et al.*, 1972). There are, however, several site or profile characteristics that may limit

this method (Bouma, 1983). Our studies show that it is not applicable on duplex soils with slow permeable C-horizons, i.e., the Tukulu form profile at Paradys, because of negative hydraulic gradients within the profile due to impaired internal drainage. There is a need to adapt this method to duplex soils.

The van Genuchten (1980) model used together with water retention data (laboratory method) provided reliable estimates of unsaturated hydraulic conductivity that were very close to field measurements obtained from the internal drainage experiment. Hence, from a practical perspective, the prediction of K-θ relationship from water retention data can be a viable alternative for determining the hydraulic properties for free drained soil profiles such as Bainsvlei soil examined in this study.

Recommendation

The instantaneous profile method is attractive when applied to relatively homogeneous soil profile where one-dimensional vertical flow can be expected to after saturation. However it is not applicable to stratified soil profiles with slowly permeable layer and there is a need to devise a procedure for soil profile with slowly permeable layers.

References

Bouma, J. 1983. Use of soil survey data to select measurement techniques for hydraulic conductivity. *Agriculture Water Management* 6:177-190.

Dane, J. 1980. Comparison of field and laboratory determined hydraulic conductivity values. *Soil Sci. Soc. Am. J.* 44:228-231.

Dirksen, C. 1999. Soil physics measurements. GeoEcology paperback, Catena Verlag GMBH, 35447 Reiskirchen, Germany.

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

Jury, W., Gardner, W. and Gardner, W. 1991. Soil physics. John Wiley & Sons, New York.

Marion, J., Or, D., Rolston, D., Kavvas, M. and Biggar, J. 1994. Evaluation of methods for determining soil-water retentivity and unsaturated hydraulic conductivity. *Soil Sci.* 158:1-13.

Paige, G. and Hillel, D. 1993. Comparison of three methods for assessing soil hydraulic properties. *Soil Science* 155:175-189.

Soil Classification Working Group, 1991. Soil classification - a taxonomic system for South Africa. Department of Agricultural Development, Pretoria, South Africa.

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