# Soil Hydraulic Properties of Cuban Soils

Maria Elena Ruiz[1] and Hanoi Medina

*Agrophysics Research Unit, Agrarian University of Havana,*
*San Jose de las Lajas. Habana, Cuba*

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LNS0418029

[1] mruiz80@yahoo.com

**Abstract**

Because soil hydraulic properties are indispensable for determining soil water retention and soil water movement, their input for deterministic crop simulation models is essential. From these models is possible to access the effect of the weather changes, soil type or different irrigation schedules on crop yields. With these models, possibilities are provided to answer questions regarding virtual "what happen if" experiments with a minimum of fieldwork. Nevertheless, determining soil hydraulic properties can be very difficult owing to unavailability of necessary equipment or the lack of personal with the proper knowledge for those tasks. These deficiencies are a real problem in developing countries, and even more so when there is not enough financial possibilities for research work. This paper briefly presents the way these properties have been accessed for Cuban soils, which methods have been used and the work now in progress.

## Introduction

Soil hydraulic properties i.e., soil water retention curve SWRC and hydraulic conductivity function K[θ(h)], are the main soil properties for determining the water retention and movement in soils. In the literature, different methods are presented to access the hydraulic properties (Klute, 1986). Nevertheless, some these methods require expensive and very specific devices. Others need personnel with special skills while others are very laborious and time consuming. Hence, the same methods are not used in all the countries. Moreover, the soil type will be a reason for selecting one or another method.

SWRC determination in Cuba began in the seventies with the introduction of Richards chamber equipment at the Cuban Institute of Soils. At that time all the SWRCs were determined using disturbed soil samples. In the eighties and in the frame of a research project supported by FAO the first sandbox apparatus was introduced at the Institute of Irrigation and Drainage Research IIRD. It was then when undisturbed soil samples were beginning to be analyzed. Subseq uentially, many SWRCs were made for soils of the most important agriculture farms of the country and where irrigation systems were installed. A wide range of soils was represented in these determinations. By that time, the first "in situ" SWRCs were determined for Cuban Rhodic Ferralsol and the comparison of several analytical models for fitting the SWRCs data collected (Ruiz et al., 1991; Ruiz and Utset, 1992). It should be noted that Rhodic Ferralsol is the most representative of the agricultural areas in Cuba.

The first determinations of the non-saturated hydraulic conductivity were made in Rhodic Ferralsol using the methodology of calculation appearing in Nielsen et al (1973). The method was used at the experimental station of the IIRD (Utset and Ruiz, 1985) and at the National Institute of Agricultural Science (Ruiz, et al., 1994). This method was followed later in other soils (Villaragut, 1995) and using a neutron probe for moisture content determinations (Lopez, 1996). Because that internal drainage method is time consuming and very laborious, another alternative was used: determining hydraulic conductivity function from the SWRC using the combination Mualem-Van Genuchten theory and analytical model for SWRC (Mualem, 1976; Van Genuchten, 1980). The results were presented in Ruiz, et al. (1994).

After the possibilities of the GIS-simulation model approach for land evaluation, indirect methods for SWRC and K[θ(h)] have been introduced to extend the results to regional areas. Pedotransfer functions (Bouma and Lanen, 1987) are being used more and more around the world. In Cuba, the first work about pedotransfer functions was related with Ferralsols (Medina et al., 2000). In this paper some of the results reached in determining SWRC and soil hydraulic conductivity function in Cuba are presented.

**Materials and Methods**

The methods used for determining SWRC and K[θ(h)] are shown in Table I.

Table I. Methods used in Cuba for determining SWRC and K[θ(h)].

| | | | |
|---|---|---|---|
| SWRC | Direct methods | In "situ" | TDR, tensiometers, neutron probe |
| | | In lab | Using disturbed and undisturbed soil samples |
| | Indirect methods | | Pedotransfer functions |
| Kns | Direct methods | "in situ" | Internal drainage method |
| | Indirect methods | From SWRC using Mualem-van Genuchten approach | |
| Ks | Direct methods | "in situ" | Auger hole, ring infiltrometers, piezometers |
| | | In lab | Permeameter from undisturbed samples |

A total of 176 undisturbed SWRCs determined by sandbox apparatus and Richards chamber were collected belonging to different soils. The following models were compared:

| | | |
|---|---|---|
| $\theta = \theta_r + \dfrac{\theta_s - \theta_r}{\left(1 + \alpha h^n\right)^m}$ | $\theta(h) = \theta r + (\theta s - \theta r)\left(\dfrac{h}{h_b}\right)^{-\lambda}$ $\quad \dfrac{h}{h_b} \geq 1$ <br> $\theta(h) = \theta s$ $\quad \dfrac{h}{h_b} < 1$ | $h = a \cdot \theta^{-b}$ |
| van Genuchten (1980) | Brooks and Corey (1966) | Gardner (1970) |

In these equations $\theta_r$ is the residual water content; $\theta_S$ the saturated water content; α, n, m are adjustment parameters; λ the soil depending parameter; $h_b$ the soil bubbling pressure and a, b are the adjustment parameters.

The models of Rawls (1982), Vereecken (1988), Batjes (1996) and Tomasella et al. (2000) were used for analyzing the validity of pedotransfer functions for Cuban Ferralsols.

**Results**

Values of van Genuchten parameters for the soil groups are shown in Table II. Clear physical meanings for the parameter values are not apparent in some cases.

Table II. van Genuchten parameters for some Cuban soils

| Soils | $\theta_r$ | $\alpha$ (□□$^{-1}$) | $n$ | $m$ | $\theta_s$ |
|---|---|---|---|---|---|
| Ferralsols | 0.176 | 0.016 | 1.867 | 0.375 | 0.388 |
| Cumbisols | 0.184 | 0.014 | 1.902 | 0.430 | 0.378 |
| Fluvisols | 0.179 | 0.012 | 1.858 | 0.427 | 0.447 |
| Arenosols | 0.125 | 0.016 | 1.892 | 0.456 | 0.390 |
| Vertisols | 0.315 | 0.008 | 1.795 | 0.409 | 0.631 |

The determined SWRCs appearing in Fig. 1 were used as input for the simulation model SWAP. Because the “in situ” method is excessively laborious and time consuming, undisturbed soil samples were used successfully in the laboratory to determine the van Genuchten parameters (Ruiz, 1998).

The measured SWRC and those estimated with all of the models from pedotransfer functions are shown in Fig. 2. Note that the curve derived from the Tomasella et al. (2000) model is very similar to the experimental data. Although a wider soil database remains to be tested, Medina et al. (2000) concluded that the equations of Tomasella et al. (2000) appear promising for Cuban Ferralsols. Further analysis should also focus on the inclusion of additional variables such as iron and aluminum oxide contents.

The results obtained by the internal drainage method for Rhodic Ferralsols for the years 1988 and 1990 and for all measured depths appear in Fig. 3. The uniformity of these soils is illustrated by most of the data grouping together along a single line. Only a narrow range of K values was obtained because of the very good drainage of these soils.

Finally the indirect method using the Mualem-van Genuchten approach is shown in Fig. 4. In Fig 4a the value of Ks = 28.4 m/day was determining using the auger hole method whilst in Fig 6b, the value of Ks = 57.5 m/day was obtained from undisturbed samples analysed in the laboratory. Obviously, values of Ks depended on the method used for its determination.

**Conclusions**

- Additional studies of hydraulic properties of Cuba soils are needed.
- A data bank of K and SWRC functions for Cuba soils needs to be organized.
- “Simple” methods for determining the hydraulic conductivity need to be introduced,
- Indirect methods for determining K from other soil physical properties or inverse methods need to be explored.

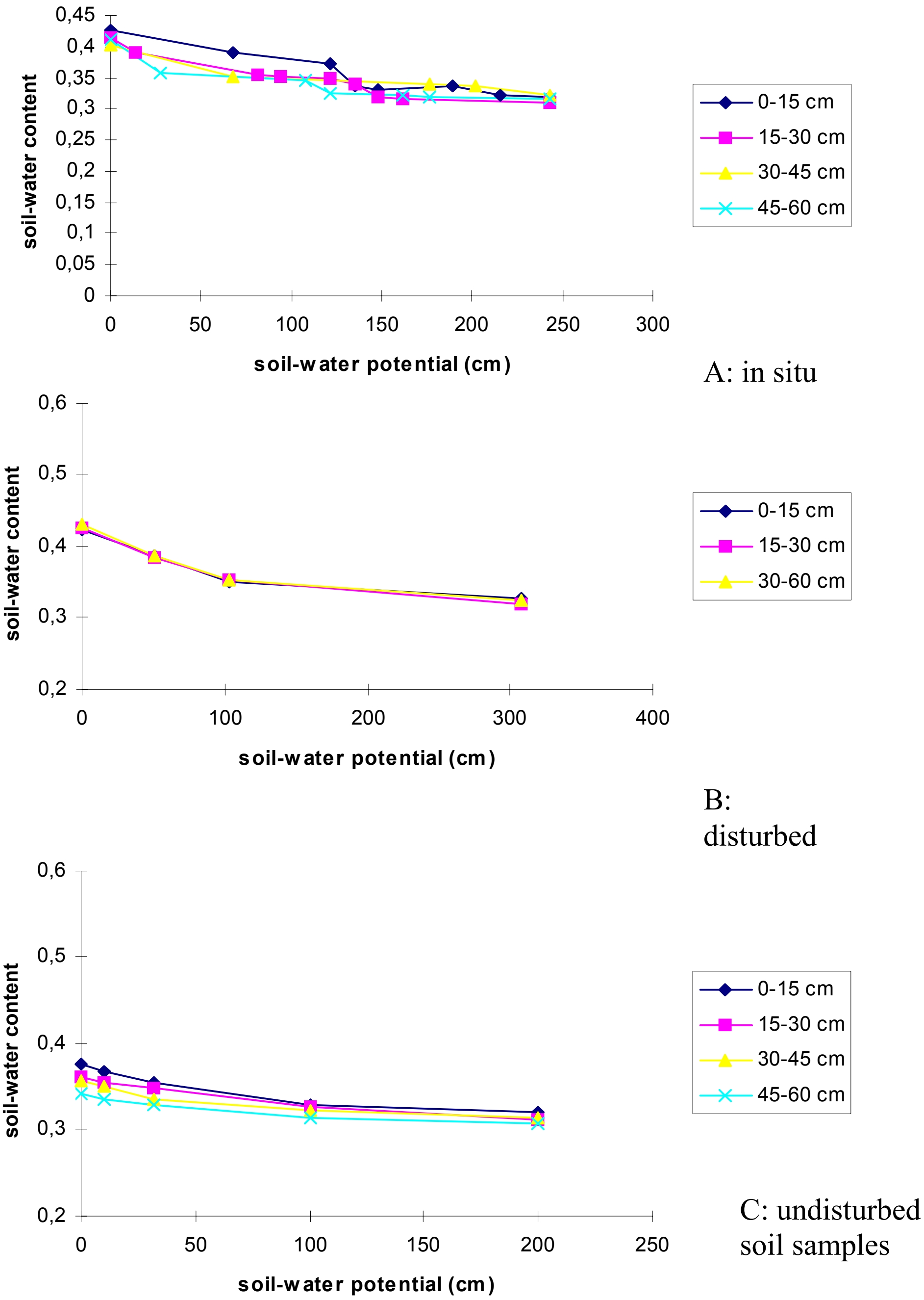



Fig. 1. SWRCs obtained A) “in situ”; B) from disturbed samples and C) for undisturbed samples for a Rhodic Ferralsol.

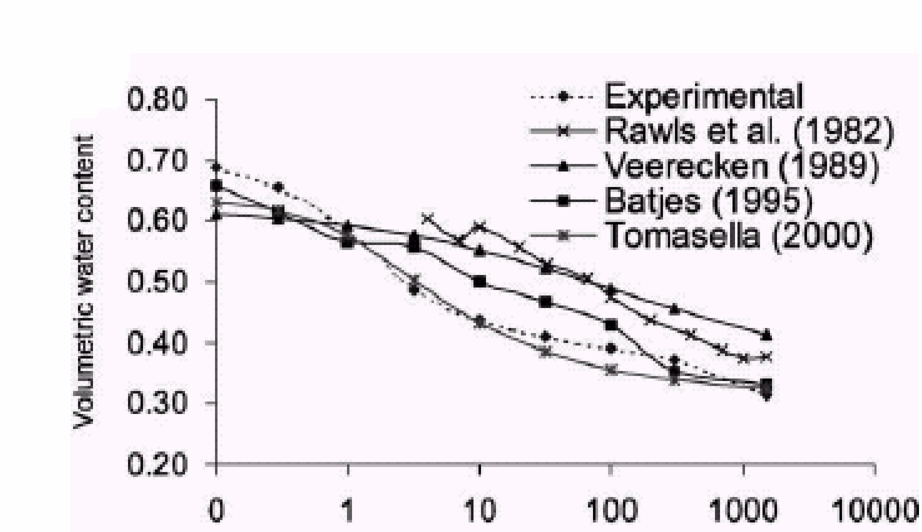



Fig. 2 Estimated and measured soil water retention curves using Rawls (1982), Vereecken (1988), Batjes (1996) and Tomasella et al (2000) after Medina et al (2002).

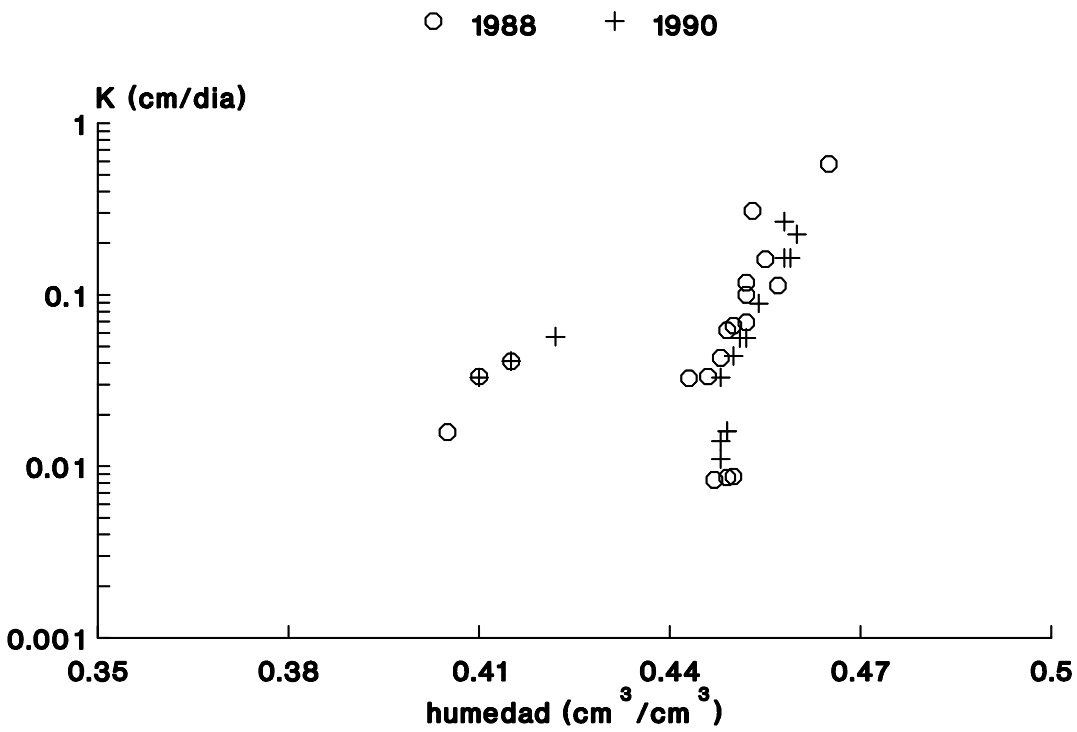
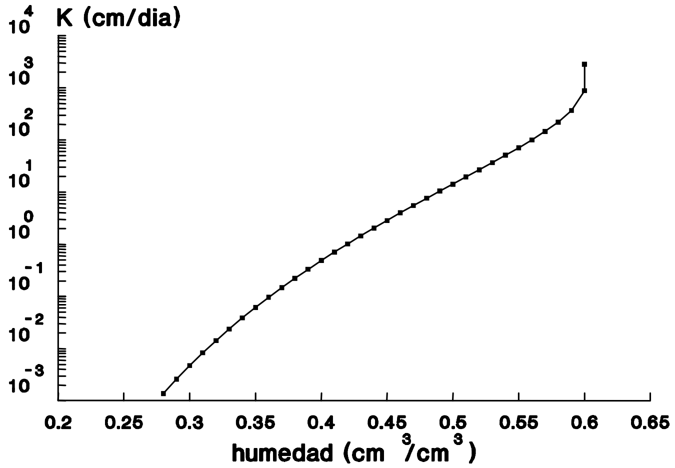



Fig. 3 Results obtained for the internal drainage methods in a Rhodic Ferralsol for years 1988 and 1990 and all the depths studied (0-15: 15-30; 30-45; 45-60 and 60-75 cm)



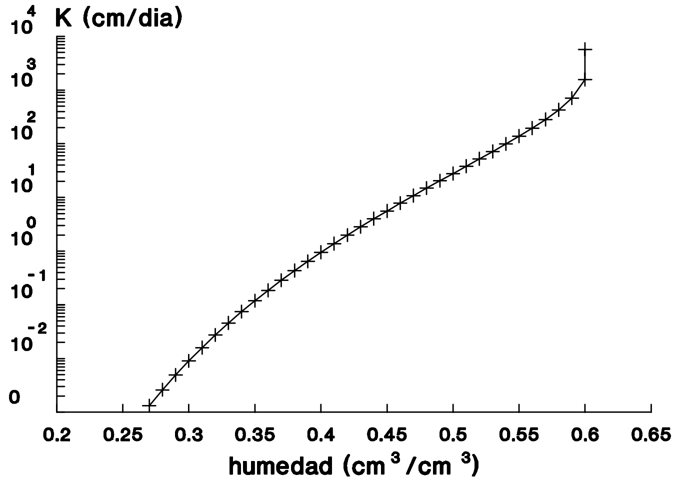




Fig.4 Hydraulic conductivity function obtained from Mualem-van Genuchten using as Ks the values determined by the auger hole method in the field (28.4 m/d) and the permeameter method in the laboratory (57.5 m/d).

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