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Hydrodynamic characterization using the disc infiltrometer of Loukkos soils (Morocco)

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Abstract
Soil hydraulic properties are necessary to study the transfer of water and solute through the vadose zone, but often cannot be measured because of practical and material constraints. The focus of this work is the hydrodynamic characterization in-situ of the Loukkos basin soils, located in the North of Morocco, by analyzing the soil water retention and hydraulic conductivity functions of unsaturated soils. The study of hydric transfer requires, in the first place, knowing the hydrodynamic parameters $(\theta_r, \theta_s, \alpha, n, K_s)$ of the unsaturated zone and to establish characteristic curves $K (h)$ and $\theta (h)$ reflecting the evolution of the hydraulic conductivity (K) and water retention (θ) versus pressure (h). As a first step, we have used tension disc infiltrometer associated with a transient axisymmetric infiltration method of Haverkamp et al. (1994) to determine the hydraulic conductivity. This procedure reduces the time of the measurements, thus allowing to characterize a large area and to make several measurements. The measurements of infiltration were carried out, during in the dry season the month July 2013, on two sites Rmel and M'risa in the area of Loukkos, whose soils have different textures respectively: sand and clay-loam. In a second step, we used the cumulative infiltration $I (t)$ measured, associated with a Levenberg Marquardt algorithm to estimate the hydrodynamic parameters $(\theta_r, \theta_s, \alpha, n, K_s)$. Experimental and simulation results of this study indicated that the tension infiltrometer is suitable for the hydrodynamic characterization of the soils Loukkos basin. The value of R^2>0.8 and RMSE=0.043 are highest.

Keywords: soil, hydrodynamic parameters, infiltration, modeling.

1. Introduction
Interest in the unsaturated (vadose) zone has increased in recent years, because of growing evidence and public concern that the quality of the subsurface environment is being adversely affected by industrial, municipal and agricultural activities. In soil science, reliable application of computer models to field-scale flow and transport problems demands a commensurate effort in quantifying a large number of model parameters. As increasingly more complicated flow and transport models are being developed, the accuracy of numerical simulation depends upon the accuracy with which various model parameters are estimated. Knowledge of the unsaturated soil hydraulic properties is especially important when numerical models are used to simulate variably saturated water flow and contaminant transport. Accurate measurement of these hydraulic properties is confounded by the extreme spatial heterogeneity of the subsurface environment. The hydraulic properties frequently also show significant variations in time because of cultivation or other agricultural activities, shrink-swell phenomena of fine-textured soil, the effect of particle dispersion and soil crusting, and changes in the concentration and ionic composition of the soil solution [1-4]. Such simulation requires information about the soil water retention $\theta(h)$, and unsaturated hydraulic conductivity, $K(h)$, functions involving the water content θ, the hydraulic conductivity K, and the soil-water pressure head h. A large number of analytical soil water retention and hydraulic

conductivity functions have been proposed, among the most used, we can cite the models of Brooks-Corey (1964) [5] and Van Genuchten (1980) [6]. Because of their simplicity and ease of use, these models have become very popular in numerical studies of unsaturated flow. These relationships involve hydrodynamic parameters $(\theta_r, \theta_s, \alpha, n, K_s)$ that characterize the porous medium. Among the hydrodynamic parameters, there are only two parameters K_s and θ_s which are physically measured while the others cannot be measured directly, by against influence the shape of the relationship $K(h)$ and $\theta(h)$. However, the in-situ measurements presents some difficulties related mainly to the spatial variability of scale parameters (such as the saturated hydraulic conductivity K_s), and the soil heterogeneity. Accurate in situ measurement of the unsaturated hydraulic conductivity has remained especially cumbersome and time-consuming. Thus, cheaper and more expedient methods for estimating the hydraulic properties are needed if we are to implement improved practices for managing water and chemicals in the unsaturated zone.

Tension disc infiltrometer has become a very popular device for the in situ estimates of soil surface hydraulic properties [7]. Their use for measuring solute-water transfer parameters of soils are now well established too. The disc has been used extensively in characterizing in situ soil hydraulic properties as well as in various other applications in soil science research. Jean-Pierre Vandervaere (1995) [8] was hardly the first who highlighted the advantages of implementation of disc infiltrometers. This method has the benefits of being simple to do, inexpensive, and fast. This permits building an experimental database the cumulative infiltration and as well as water content θ and hydraulic conductivities K. This study reviews the application of disc infiltrometer in soil science, the analysis of the data, and models describing water flow from the disc.

The perimeter Loukkos basin, situated in the North of Morocco, is considered the highest area for agricultural activity in Morocco. This study area was chosen according to the final result which was published in the report of the Regional Direction of Agriculture Development [9, 10] concerning the Loukkos area, the problem of pollution is a major factor causing damage to groundwater. That's to say, the massive use of fertilizers and pesticides in agricultural affect the area negatively.

The purpose of this article is the estimation of soil hydraulic properties $(\theta_r, \theta_s, \alpha, n, K_s)$ of two typical agricultural soil textures (sandy and clay loam) the Loukkos basin soils. Identification of these parameters can be done by minimizing an objective function representing the quadratic deviation between simulated and measured values by using the Levenberg-Marquardt optimization algorithm [11]. This study describes the method of hydraulic characterization in-situ for Loukkos basin soils by analyzing the soil water retention and hydraulic conductivity functions of unsaturated soil. These hydraulic properties are key parameters in any quantitative description of water flow into and through the unsaturated zone soil. The method uses the disc infiltrometer associated with the parametric models of Van Genuchten-Mualem and Brooks-Corey to predict the hydrodynamic parameters $(\theta_r, \theta_s, \alpha, n, K_s)$ from observed cumulative infiltration and soil water retention data. We are giving a detailed discussion of the analytical expressions used for quantifying the soil water retention and hydraulic conductivity. A brief review is also given of the nonlinear least-squares parameters optimization method used for estimating the unknown coefficients in the hydraulic models.

2. Study Site

Loukkos basin, which covers more than 2.560 km^2, is located in North-West of Morocco between regions Tangerois and Gharb and is bounded by the Atlantic Ocean to the West (**Figure 1**). This area benefits considerable water resources as groundwater in the areas of the Rmel and M'risa. It is characterized by a diversity of cultures. A pedological study of the areas studied show that of soils Rmel have an essentially sandy texture and M'risa soils are generally established by clays and loam [12]. **Tables 1** and **2** present the grain-size and texture of the soils studied.

3. Materials and methods

3.1. The disc infiltrometer and its application

The disc infiltrometer (**Figure 2**) [13, 14] because of its relative ease of use, is one of the most popular device for characterizing in situ saturated and unsaturated surface soil hydraulic properties. This allows to characterize a large area and to make several measurements. In this part, a short introduction is devoted to the background theory and some examples are given to show how the theory can be used to determine hydraulic conductivity and sorptivity from measured cumulative infiltration.

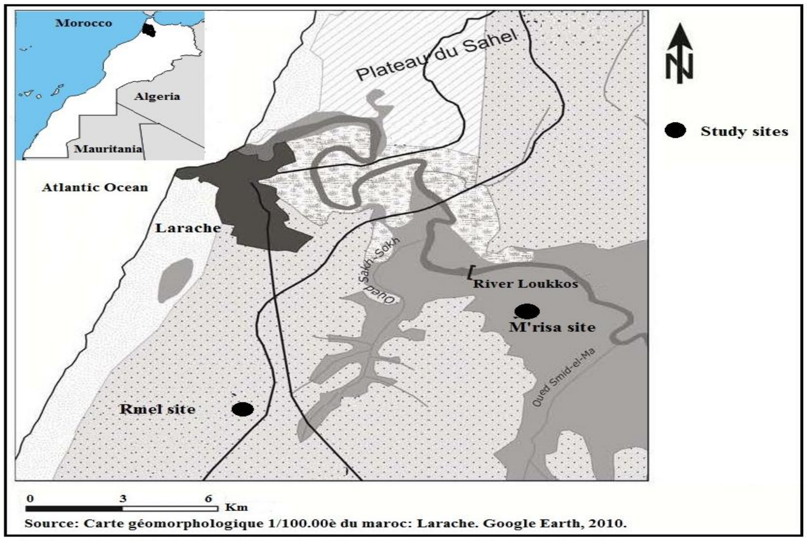

Figure 1: The Loukkos basin zone

Table 1. Grain-size and texture of the soil Rmel.

Depth (cm)	0-30	30-50	50-100
Great Sand(%)	19.8	19.8	25.1
Fine Sand(%)	71.6	72.7	69.9
Total Sand (%)	91.4	92.9	95.0
Loam (%)	2.0	1.5	1.0
Clay (%)	5.5	5.5	6.5
Silt - Clay(%)	7.5	7.0	7.5
Total (%)	98.9	99.9	100.5
Texture class	**Sandy**		

Table 2. Grain-size and texture of the soil M'risa.

Depth (cm)	0-20	60-80	150-180
Great Sand(%)	0	0	0.9
Fine Sand(%)	1.20	1.00	4.20
Total Sand (%)	1.20	1.00	5.10
Loam (%)	45.50	42.80	38.00
Clay (%)	54.50	57.80	56.60
Silt - Clay(%)	100	100.6	94.6
Total (%)	101.20	101.6	99.7
Texture class	**Loamy-Clay**		

The method of analysis of cumulative infiltration is based on quasi-analytical solutions of the flow equation for a homogeneous soil profile. The disc infiltrometer comprises of a nylon mesh supply membrane, a water reservoir and a bubbling tower. The bubbling tower is connected to the reservoir and controls the potential applied to the membrane. It can be used to supply potential -20 cm $\leq h_0 \leq 0$ cm. For each experiment, we fixed a value of the pressure $h_0=h_2-h_1$ (height of water column) and, during infiltration, we note the difference of the water in the tank to calculate the cumulative infiltration $I\ (t)$. After the experiment was completed, we took immediately samples from the soil under the disc to determine the water content associated with the imposed suction h_0.

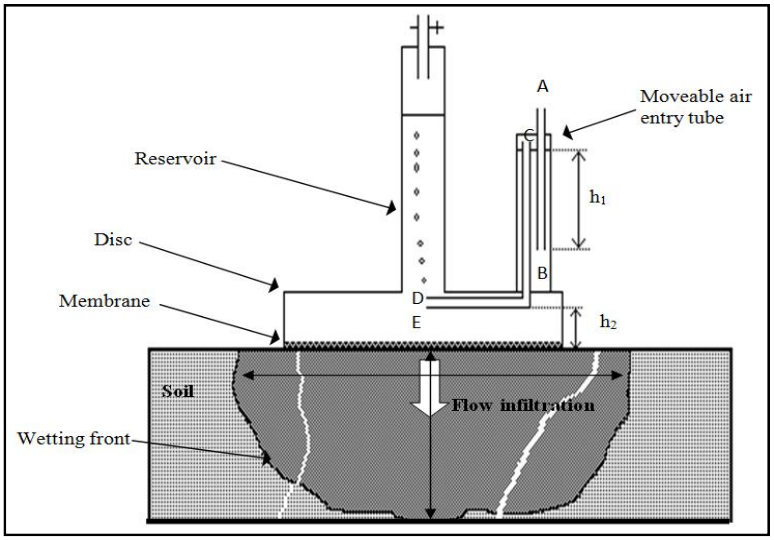

Figure 2: Design of the disc infiltrometer.

As a first step, we carry out infiltration experiments on two sites Rmel and M'risa in the basin Loukkos, whose soils have different textures, respectively: sand and clay-loam, in the dry season during the month July 2013. The disc diameter of the infiltrometer used is 20 cm; the experiments were performed in different locations with various suctions h_0, while remaining in the agricultural parcel of 10 m^2. At this level, we have not performed measures with suctions beyond -20 cm. As this constraint is linked the type of infiltrometer used. Testing has been completed once the infiltration flow begins to stabilize. The duration of the experiment is on average 12 min and does not exceed 30 minutes depending on the regime desired. Generally, for each test, applying a suction h_0 and calculating the cumulative infiltration $I\ (cm)$, well as the water content θ_0 and the hydraulic conductivity K_0. Certain hydrodynamic parameters of the soil were also measured independently using direct method standard laboratory on samples of soil. **Table 3** summarizes the results for the initial water content θ_i (m^3/m^3), porosity $P(m^3/m^3)$ and bulk density $\rho_d\ (kg/m^3)$. The value of initial water content, very small, indicates the soil is very dry initially. The value of porosity gives prior idea about the estimated value of the saturated water content θ_s.

Table 3. Measured value of initial water content θ_i, porosity P and bulk density ρ_d of the studied soils.

	Rmel area	**M'risa area**
ρ_d [10^3kg/m^3]	1.4937	1.5409
P [m^3/m^3]	0.4211	0.4118
θ_i [m^3/m^3]	0.0229	0.1854

3.2. Principle of numerical methods

Soil hydraulic properties measured in the field are important parameters describing water and solute transport dynamics. There are several models of determining the hydraulic conductivity $K\ (m/s)$ from the cumulative infiltration measurements [15, 16]. We choose among the recent models available, the Haverkamp et al. (1994) [17] model which is developed using previous findings of others researchers, is simple and is based on parameters with sound physical meanings. For short to medium times, the Haverkamp model can be expressed as:

$$I(t) = S(\theta_0, \theta_i).\sqrt{t} + A.t \quad (1)$$

The expression of the infiltration flux density $q=\frac{dI}{dt}$ is straightforward from Eq. (1):

$$q = \frac{S}{2\sqrt{t}} + A \quad (2)$$

with :

$$A = \frac{\gamma S^2}{r(\theta_0 - \theta_i)} + \frac{2-\beta}{3} K(h_0) \quad (3)$$

if $K(h_i)<<K(h_0)$. θ_i (m^3/m^3) the initial water content and θ_0 (m^3/m^3) water content of each imposed suction h_0. γ is a constant equal to 0.75. β is a parameter between 0 and 1, depends on the soil type and potential h_0 for infiltration. The big advantage of this method is that it does not require the estimated flow of steady state and is less time consuming. By contrast, it provides only an interval of values of $K(h_0)$, between K_{min} for $\beta=0$ and K_{max} for $\beta=1$. Vandervaere (1995) [8] proposes to use the median $\beta=0.6$ in the calculation of $K(h_0)$, which will be affected by the uncertainty factor of ± 1.4. On the other hand, the coefficients $S(\theta_0, \theta_i)$ and A can be estimated through linear fitting technique for the following differential equation:

$$\frac{\partial I}{\partial \sqrt{t}} = S + 2A\sqrt{t} \quad (4)$$

We calculated the derivative of the cumulative infiltration I *(cm)* versus the square root of time $\sqrt{t}$ by the following formula:

$$\frac{dI}{d\sqrt{t}} = \frac{\Delta I}{\Delta\sqrt{t}} = \frac{I_{i+1} - I_i}{\sqrt{t_{i+1}} - \sqrt{t_i}} \qquad (i = 1...n-1) \quad (5)$$

Where n is the number of data points.

For the linear graph between $\frac{\Delta I}{\Delta\sqrt{t}}$ versus $\sqrt{t}$, S and A equal to the intercept and half of the slope, respectively. Hydraulic conductivity K_0 and their uncertainty ΔK_0 are then calculated by:

$$K(h_0) = \frac{3}{2-\beta}\left[A - \frac{\gamma S^2}{r(\theta_0 - \theta_i)}\right] \quad (6)$$

$$\Delta K(h_0) = \frac{3}{2-\beta}\left[\Delta A - \frac{2\gamma S}{r(\theta_0 - \theta_i)}\Delta S\right] \quad (7)$$

On the other hand, for fitting of experimental data for the water content θ (m^3/m^3) and the hydraulic conductivity K *(m/s)*, we use the following models:

- ✓ *Combined model of Van Genuchten (1980)-Mualem (1976)- (VGM)* [6, 18]:

$$\begin{cases} S_e(h) = \dfrac{\theta(h) - \theta_r}{\theta_s - \theta_r} = \left[1 + (\alpha h)^n\right]^{-m} & h < 0 \\ \theta(h) = \theta_s & h \geq 0 \end{cases} \quad (8)$$

- ✓ *Model Brooks & Corey (1964) – (BC)* [5] :

$$K(\theta) = K_s\left(\frac{\theta - \theta_r}{\theta_s - \theta_r}\right)^{\eta} \quad (9)$$

Where, θ *(m^3/m^3)* is the soil water content, θ_s *(m^3/m^3)* is the soil saturated water content, θ_r *(m^3/m^3)* is the soil residual water content, *h (cm)* is pressure head, α *(1/m)* is a scale parameter inversely proportional to mean pore diameter, *n (-)* and *m (-)* are the shape parameters of soil water characteristic, $m=1-1/n$, $0<m<1$. *K (m/s)* is the hydraulic conductivity. K_s *(m/s)* is the saturated hydraulic conductivity, η *(-)* is the shape parameter.
Initial and boundary conditions for fitting are a constant suction h_0 on the soil surface under disc infiltrometer and a profile of the initial water content θ_i:

$$\begin{aligned} &h=h_0 \quad \text{for} \quad z=0 \quad \text{and} \quad t>0 \\ &\theta=\theta_i \quad \text{for} \quad z\geq 0 \quad \text{and} \quad t=0 \end{aligned} \tag{10}$$

We have to use a nonlinear least-squares optimization approach to estimate the unknown hydrodynamic parameters (θ_r, θ_s, α, n, K_s) from observed retention and conductivity data in our study. The best fit parameters are based on minimizing the objective function which expresses the discrepancies between the simulated and observed values, using the Levenberg-Marquardt algorithm [11]. The objective function can be written as:

$$\min \ \Phi = \sum_{i=1}^{n} w_i \left[\theta_{mes}(h_i) - \theta_{fit}(h_i, p)\right]^2 + W \sum_{i=1}^{n} w_i \left[\ln K_{mes}(h_i) - \ln K_{fit}(h_i, p)\right]^2 \tag{11}$$

Where n is the number of different measurements at pressure h_i: θ_{mes} is the measured water content at the suction h, K_{mes} is the measured hydraulic conductivity for the water content θ_{mes}. θ_{fit} and K_{fit} are the model simulation for the vector of optimized parameters $p=\{\theta_r, \theta_s, \alpha, n, K_s\}$. w_i is the weight associated with a particular measurement set. W is the weight that insures that proportional weight is given to the two different types of data; that is, it corrects for the difference in number of data points and for the effect of having different units for θ and K [19, 20, 21]:

$$W = \frac{\sum_{i=1}^{n} w_i \theta_{mes}(h_i)}{\sum_{i=1}^{n} w_i \ln\left|K_{mes}(h_i)\right|} \tag{12}$$

4. Goodness of fit

The maximum-likelihood leads to optimized parameters for a selected model without questioning the adequacy of the given model. Different criteria may be used to characterize the goodness of fit. The most popular criteria are given below [22]:

(a) Root mean square error (RMSE):

$$RMSE = \sqrt{\frac{1}{n}\left(\sum_{i=1}^{n} P_i - M_i\right)^2} \tag{13}$$

(b) Determination coefficient (R^2):

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left(M_i - P_i\right)^2}{\sum_{i=1}^{n}\left(M_i - \bar{M}\right)^2} \tag{14}$$

Where, P_i and M_i are the predicted and measured values of the i^{th} measured data, respectively; $\bar{M}$ is the mean of measured values.

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(c) Have been calculated the correlation matrix specifying the degree of correlation between estimated parameters. The correlation coefficients (in absolute value) must be less than the critical value 0.95 [23].

5. Results and discussion

5.1 Cumulative infiltration

Figures 3 (a) and 3 (b) illustrates the cumulative infiltration *I (cm)* measured versus time the different suctions h_0 for the both locations Rmel and M'risa. There have been increasing infiltration flows where the suction h_0 increases. This increase in flow is due to the implementation of the pore sized increasingly large, progressively as the soil approaches saturation. The cumulative infiltration is becoming quickly more constant (steady state) at the M'risa site than at the Rmel site. All this shows that clay loam soils become saturated more rapidly than sandy soils.

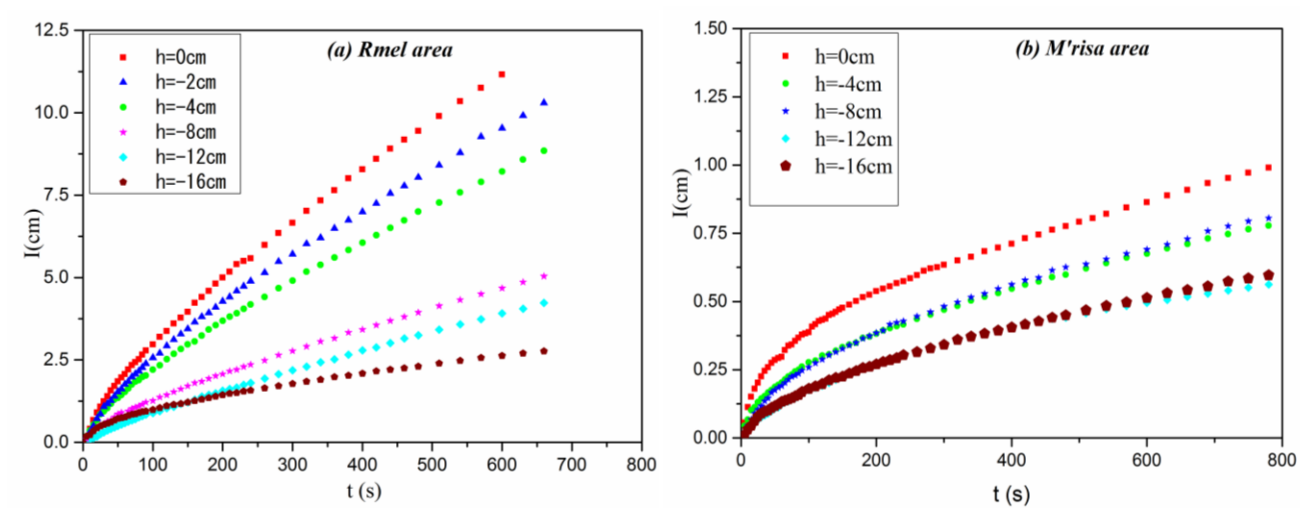

Fig. 3: Measured cumulative infiltration *I* versus the time with various suctions *h*: **(a)** Rmel and **(b)** M'risa areas

During the infiltration tests, we calculate the derivative of the cumulative infiltration *I (cm)* versus time to obtain the flux density *q=dI/dt*. Infiltration flow curves *q (cm/s)* obtained are illustrated in the **figures 4 (a)** and **4 (b)**.

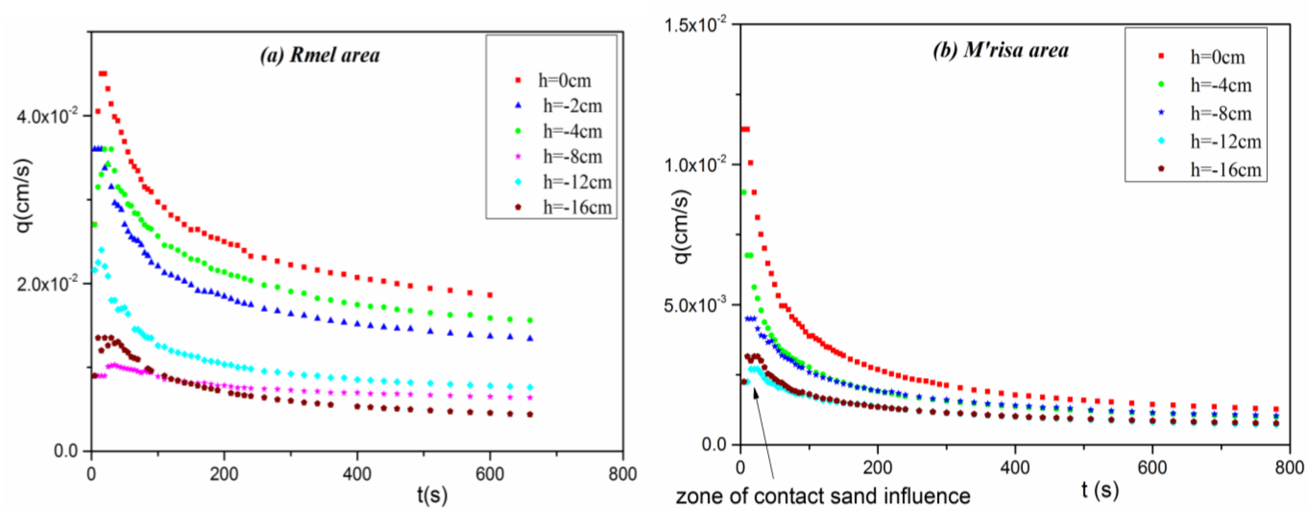

Figure 4: Plot of infiltration rate at each suction *h*: **(a)** Rmel and **(b)** M'risa areas.

We can see the transitional aspect of the infiltration. The cumulative infiltration and infiltration flux are treated by the equations (1) and (2). Theoretically, for the time $t = 0$, $q \to \infty$ and for the time $t \to \infty$, $q \to K$, where K is the constant hydraulic conductivity which is dependent on the suction h_0 condition on the surface (e.g. if the suction $h_0=0$ then $K \approx K_s$). From the M'risa site, we see that there is a disturbance in the measurement at the beginning of infiltration that was due to the influence of contact sand and the soil texture. The infiltration flux decreases and quickly remains more constant in the M’risa soil than in the Rmel soil. This is explained by the influence of soil texture the water infiltrates. We conclude that Rmel sandy soils are highly more permeable to water than M’risa soil. This has an influence on the values of the water content and the hydraulic conductivity of the soil.

5.2 Estimation of hydrodynamic parameters

In this part, we combine the experimental data of the water content θ and hydraulic conductivity K with the values calculated by the Levenberg Marquardt algorithm of optimization to determine the hydrodynamic parameters. Thus, we minimize the objective function; it reflects the squared of the difference between the calculated and measured values, an iterative process starting from the initial values of the parameters until stopping criterion of the objective function which is of the order 10^{-6}. This determines the desired parameters $(\theta_r, \theta_s, \alpha, n, K_s)$.

5.2.1 Retention curves θ (h)

At the end of each test, we take a sample of the soil immediately below the disc to measure the final water content in order to reconstitute a part of the experimental point for both locations. To minimize the error associated with the experiment, several tests were performed. Moreover, the measurement points of water content θ were adjusted using an algorithm the Levenberg Marquardt based on the model of Van Genuchten-Mualem (Eq. 8). **Table 4** shows the values of the hydrodynamic parameters $(\theta_r, \theta_s, \alpha, n)$ fitted.

Table 4. Fitted soil hydraulic parameters for the retention curves plotted in figure 5.

	Rmel area				**M’risa area**			
Parameters	Initial	Fitted	Standard Error	R^2	Initial	Fitted	Standard Error	R^2
θ_r [m^3/m^3]	0.045	0.078	0.0676	0.96	0.070	0.24	0.3025	0.83
θ_s [m^3/m^3]	0.43	0.335	0.0075		0.48	0.447	0.0094	
α [1/cm]	0.145	0.104	0.0122		0.005	0.110	0.0803	
n [-]	2.68	3.01	0.7645		1.09	1.89	1.4106	

Table 5 presents one of the calculated correlation matrices which give an idea about the correlation between the adjusted parameters. We get closer to landmarks ±1, more a better linear correlation is obtained between the estimated parameters. While a value of 0 indicates no correlation. A strong correlation between the parameters indicates that these cannot be identified in a unique way. Generally, we have a relatively good correlation between the parameters estimated.

Table 5. Correlation matrix between the fitted parameters.

Rmel area				
Parameters	θ_r	θ_s	α	n
θ_r	1	-0.48	-0.10	-0.63
θ_s	-0.48	1	0.89	0.94
α	-0.10	0.89	1	0.71
n	-0.63	0.94	0.71	1

The **Figures 5(a)** and **5(b)** summarizes the results of fitting for both M'risa and Rmel sites. We note that, on the retention curve $\theta(h)$, the experimental points of the water content of the area Rmel are well described by Van Genuchten-Mualem model with a coefficient of R^2=0.96 compared to M'risa area R^2=0.83.

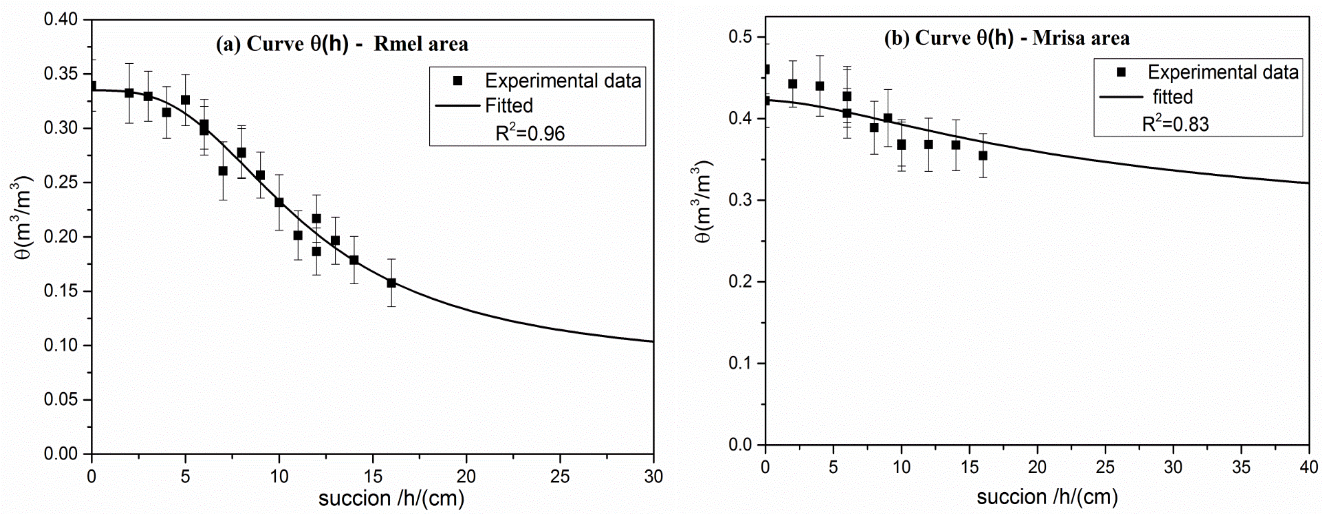

Figure 5: Measured and fitted water retention curves *θ(h)*: **(a)** Rmel and **(b)** M'risa areas.

The experimental points cover only the area of the curve that is pronounced for some value of $h, -20 \leq h_0 \leq 0cm$. This constraint is related to the type of infiltrometer that we used. We see, in **figure 5**, there is a considerable variation of water content with the suction *h* in the Rmel soil than in the M'risa soil. This is explained by the fact that sandy soils are highly permeable to water and therefore have a very low capacity to hold water compared to clay-loam soils.

5.2.2 Determination of hydraulic conductivity K

Measurements of the width and depth of the wetting front are given in **table 6**. These measures give an initial idea on the influence of soil texture and the behavior of the hydraulic conductivity in the soil.

Table 6. wetting front measured.

		Rmel area	M'risa area
Width (cm)	Min	34	26
	Max	40	30
Depth (cm)	Min	14	4
	Max	22	6

Hydraulic conductivity is a characteristic of the soil which cannot be measured directly as the retention curve (quasi-static property). It is a function related to the movement of water during the infiltration. We calculate the values of hydraulic conductivity K_0 from the equation (6) and their uncertainties by equation (7) can include pairs *(S; A)*. To determine the parameters S and A, we do a linear regression of calculated values of the derivative of the cumulative infiltration $\frac{\Delta I}{\Delta\sqrt{t}}$. During the regression, the first points are removed, which are not located on the line that is due to the influence of the contact sand. After fitting, the coefficients *S* and *A* are determined with *S* equal to the intercept and *A* equal to half of the slope. If the data set is not linear, Eq. (1) must be considered inappropriate, and it would be likely that fitted values of the coefficients *S* and *A* would have no physical meaning. **Figure 6** shows an example of this regression.

The calculated values of hydraulic conductivity *K* were adjusted based on Brooks & Corey (Eq. 9) models. **Table 7** and **figures (7 and 8)** summarize the results of the fitting. Generally, the result of the model is very close to the observed values of the hydraulic conductivity with a best value R^2=0.90 of M'risa area than R^2=0.90 of Rmel area. In **figures 7 and 8**, it is observed that the hydraulic conductivity takes significant values in the Rmel soil. In addition, K_s parameter has a totally different value in both soils. This clearly indicates that the sandy soils are very permeable to water and clay-loam soils have high water retention as compared to sandy soils. These results show that the flow of water in sandy soils is very important and this may amplify the transport of agrochemicals contaminants in the soil and pollute the groundwater.

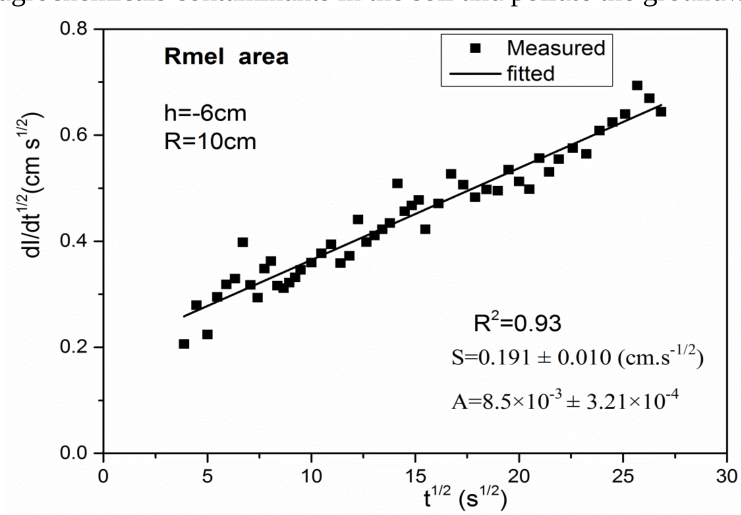

Figure 6: Example of fitting linear regression of the experimental data for *dI/d√t* for an infiltration test.

Table 7. Fitted K_s and η for the hydraulic conductivity curves *K(θ)* plotted in figures 7 and 8.

	Rmel area			**M'risa area**		
Parameters	Fitted	Standard Error	R^2	Fitted	Standard Error	R^2
K_s [m/s]	1.13×10^{-4}	3.4471×10^{-5}	0.63	1.97×10^{-6}	1.1319×10^{-7}	0.90
η [-]	6.11	1.6567		3.43	0.5427	

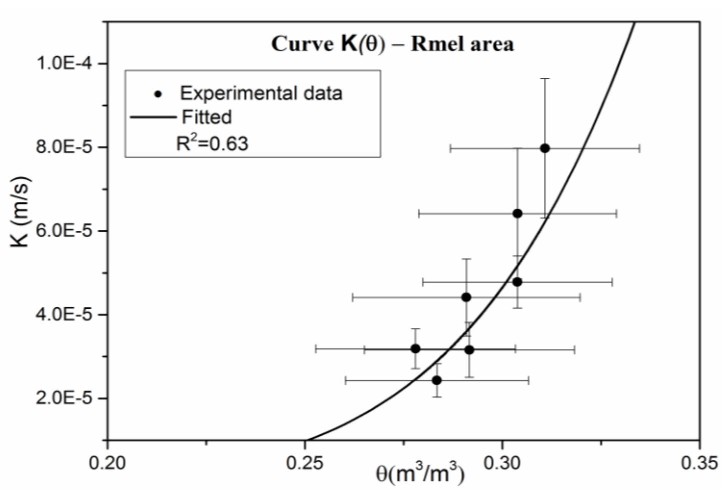

Figure 7: Measured and fitted hydraulic conductivity curves *K(θ)* for the Rmel area.

A comparative study was carried out by comparing our results with another study done by Saâdi [24, 25] for other types of sandy soils located in the Mnasra area. The latter had used the scaling method. The parameters n and θ_s are calculated using the principle of similarity between the retention curves and grain size. The parameter η is deducted from n by the concept of capillary sorptivity and infiltration capacity. α and K_s are linked to the water dynamics, their optimization based on the adjustment of the equation of Green and Ampt and some measures of infiltration positive charge of h. The results achieved represent an average of measurements taken [26]. **Table 8** summarizes the parameters estimated from both studies. The agreement of the results is quite good, especially for n, η and θ_s, since they are linked to the soil texture. The difference noted in the value of K_s can be explained by measurement errors in the determination of parameters S and A carried out for both soils.

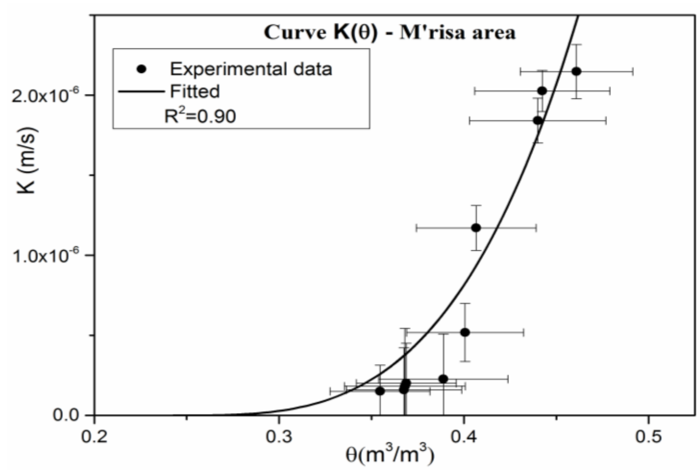

Figure 8: Measured and fitted hydraulic conductivity curves $K(\theta)$ for the M'risa area.

Table 8. Comparison of estimated parameters with another study

Soil texture			Comparison		
	Rmel area	Mnasra area	Estimated parameters	Rmel area	Mnasra area
Sand (%)	91.4	88	θ_r [m^3/m^3]	0.078	0
Loam (%)	2.0	9	θ_s [m^3/m^3]	0.335	0.4
Clay (%)	5.5	3	α [/cm]	0.104	0.036
			n [-]	3.01	2.42
			K_s [m/s]	1.13×10^{-4}	8.7×10^{-5}
			η [-]	6.11	6.58

Figure 9 presents a comparison of the measured water content and those fitted by the model of Van Genuchten-Mualem using adjusted parameters, shows that these values are close to those observed. The graph thus represented follows well the regression linear $\theta_{cal}=0.99\theta_{meas}$ with the exception of a few points.

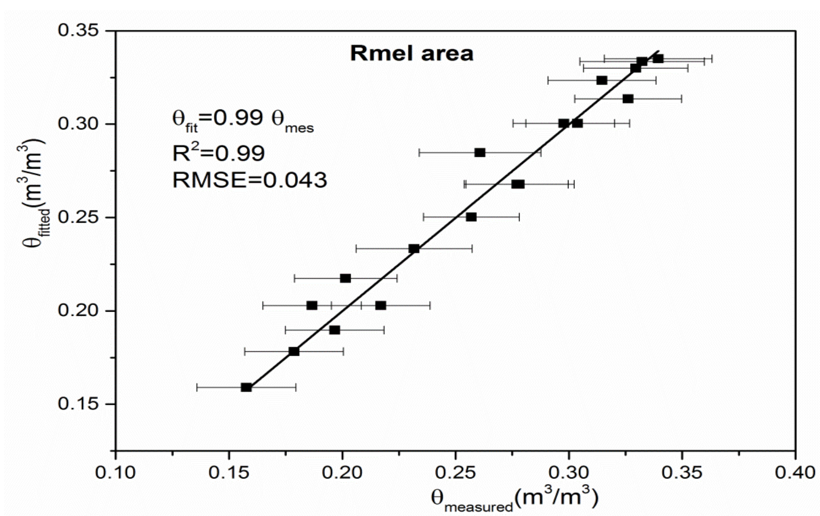

Figure 9: Comparison of the fitted water content with that of measurement.

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Conclusion

This paper describes the approach for evaluating the hydraulic properties of unsaturated soils the Loukkos basin area, we used two complementary methods: In the first time, we have used tension disc infiltrometer associated with a transient axisymmetric infiltration method. In the second time, five soil hydraulic parameters *(θ_r, θ_s, α, n, K_s)* were estimated by optimization method from experimental measurements. Experimental and simulation results presented in tables and in the figures are shown that the hydrodynamic parameters are well estimated and indicate to be useful of the models the Van Genuchten-Mualem and Brocks-Corey which are well suited for the description water content and hydraulic conductivities. Also, the fitted results were compared with another study. Although the experimental results give a good estimation of some parameters of the soil, such as the content of saturated water θ_s and saturated hydraulic conductivity K_s, they allow determining a portion of the curves *θ (h)* and *K (θ)*. This is clearly demonstrated when we introduce in relations *θ (h)* and *K (θ)* the estimated hydrodynamic parameters. All these results show the influence of the texture of the soil on the flow of water in the soil, which is important in sandy soils.

The results presented in this study are only preliminary approach to determine the hydrodynamic characteristics of the soils Loukkos basin. This work, it appears especially useful for theoretical and applied scientists, engineers, and others, concerned with the movement of water into and through the unsaturated (vadose) zone.

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