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FIELD CAPACITY ESTIMATION FROM THE INFLECTION POINT OF THE SOIL MOISTURE RETENTION CURVE

T. H. Barros[1], A.J. Farias[2], A. M. de Almeida[3], E. F. Fraga Junior[4], R. D. Coelho[5]

ABSTRACT: Although the concept of field capacity has been subject to different interpretations over the years, thus it is estimated is still essential for calculations used in irrigation. This study aimed was to evaluate the potential estimating the field capacityfrom equations based on the moisture retention curve for different soil types. This work was soil profiles database developed by information extracted from the literature. The Van Genuchten (1980) equation was used for fitted a soil water retention curves. For soil profiles the corresponding inflection point was generated, using the equation represented by Dexter & Bird (2001), as well as the matricial potential corresponding to these values. Next, the Student's t test was applied between the inflows generated by the inflection and the corresponding matrix potential. Were established also correlations between multiple field moisture capacity and the clay, silt and sand samples that had this information. We conclude that the calculated inflection point can be considered as a good estimator of field capacity, which can facilitate the calculation of water availability, to be a useful tool for irrigation management seeking to improve the economy water and sustainability of agricultural production systems.

KEYWORDS: modeling soil water retention curve, soil moisture, water content.

PREDIÇÃO DA UMIDADE RETIDA A POTENCIAIS ESPECÍFICOS EM SOLOS BASEADA NO PONTO DE INFLEXÃO DA CURVA CARACTERÍSTICA.

RESUMO: Apesar de o conceito de capacidade de campo vir sofrendo interpretações variadas ao longo dos anos, sua estimativa continua sendo considerada fundamental nos cálculos utilizados na engenharia de irrigação. Objetivou-se verificar a possibilidade de estimar a capacidade de campo a partir de equações baseadas na curva retenção de umidade para diferentes de solos. Este trabalho foi desenvolvido utilizando-se um banco de dados com 162

[1] Doctor degree student at ESALQ/USP, Piracicaba - SP. E-mail:timoteo@usp.br
[2] Doctor degree student at ESALQ/USP. Piracicaba – SP. E-mail: jesusf@usp.br
[3] Master degree student at ESALQ/USP. Piracicaba – SP. E-mail: ailsoma@usp.br
[4] Professor atUFU – Monte Carmelo- MG. E-mail: eusimiofraga@ufu.br
[5] Professor at ESALQ/USP, Piracicaba - SP. E-mail: rdcoelho@usp.br

de perfis, extraído de trabalhos publicados por outros autores. Os dados de retenção de água no solo foram ajustados a uma curva pela equação de Van Genuchten (1980). Para cada perfil, gerou-se o ponto de inflexão correspondente, usando-se a equação apresentada por Dexter & Bird (2001), bem como o potencial matricial correspondente ao seu valor. A seguir, aplicou-se o teste t de Student entre as umidades geradas pela inflexão e as correspondentes potencial matricial. Estabeleceram-se, também, correlações múltiplas entre a umidade a capacidade de campo, e os teores de argila, silte e areia para as amostras que tinham essas informações. Conclui-se que o ponto de inflexão calculado pode ser considerado como um bom estimador da capacidade de campo.

PALAVRA-CHAVE: curva de retenção de água do solo, umidade do solo, conteúdo de água no solo.

INTRODUCTION

Agricultural productivity is closely related to soil physical attributes, especially those affecting the soil-water relationship, since the soil is the main water reservoir for the plants (RAJKAI; KABOS; VAN GENUCHTEN, 2004). It is worth mentioning that the proper management of irrigated crops depends on the knowledge of the agronomic, environmental and mainly the physical and chemical properties of the soil (SILVA et al., 2014). The interaction of water with these characteristics shows properties such as the upper limit of humidity that soil presents, also denominated field capacity, that presents / displays like an attribute of great importance in the processes of storage and availability of water for the plants (DEXTER; BIRD, 2001).

Although the concept of field capacity has been undergoing varying interpretations over the years, its estimation continues to be considered fundamental in calculations used in irrigation engineering. Thus, information on the variation of soil water percentages for soil preparation, irrigation project calculations, crop management (MISHRA et al., 2015) is required. Knowledge of the interactions between water, soil and plant is essential for efficient agricultural exploitation, because the water necessary for plant growth is mainly in the soil. The behavior of water in the soil depends fundamentally on its physical properties (ANDRADE; STONE, 2009).

In order to improve the knowledge of soil and water interactions (MUELLER et al., 2003), they proposed the concept of the inflection point of the soil water retention characteristic curve that corresponds to the field capacity and obtained significant results when this point Was correlated with the humidity determined at the voltage of 6 kPa.(Dexter et al., 2008), in turn, considered the point of inflection of the water retention curve adjusted by the van Genuchten model, (1980) as the optimal point for soil preparation in terms of humidity, and the capacity of Equivalent to the voltage of 10 kPa.

In the field, the determination of the field capacity requires time and cost. Its estimation, however, through mathematical models can be an economical alternative, in a short time and of recognized technical feasibility. The pedotransfer functions are equations that facilitate the estimation of edaphic characteristics, difficult to determine, from other attributes more easily obtained (MELLO et al., 2005).

The objective of this study was to estimate the field capacity from equations based on the retention curve and the inflection point for different soil conditions

MATERIALS AND METHODS

This study was developed using a database of 162 profiles, extracted from works published by other authors, which included information on textural classification, bulk density (Ds), particle density (Dp), and water retention Not alone. With the data obtained, the water retention curves for each profile were adjusted using the model proposed by (van Genuchten, (1980), according to equation 1,

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

Em que:

θ_h = Soil moisture (kg kg^{-1});

θ_r = Residual soil moisture (kg kg^{-1});

θ_s = Saturation soil moisture (kg kg^{-1});

h = absolute value of soil matric potential (MPa);

α, n, m = Estimated parameters of the van Genuchten, (1980) model;

For each profile, the corresponding inflection point was generated, using the equation presented by (DEXTER; BIRD, 2001) according to equation 2,

$$\theta_{INFL} = (\theta_s - \theta_r)\left[1+\frac{1}{m}\right]^{-m} + \theta_r. \qquad (2)$$

Multiple correlations between moisture, field capacity, and clay, silt and sand contents were also established for the samples. The analysis of variance and the multiple linear regression techniques were used to derive the quantitative expression of the moments of the hydraulic parameters as functions of the particle size distribution (percentage of sand, silt and clay content) of the soils

The regression performance was analyzed graphically and by means of the squared root mean squared error (RMSE); obtained by the following equation:

$$RMSE = \sqrt{\frac{1}{N}\sum\left(\theta_{meas} - \theta_{fitted}\right)^2} \qquad (3)$$

Where: N - number of observations; ϴfitted - estimated value by regression of interest; ϴmeas - measured value of the variable of interes. The standard error (SE) was determined by the following equation:

$$SE = \frac{\left|\theta_{meas} - \theta_{fitted}\right|}{\theta_{meas}} \qquad (4)$$

RESULTS AND DISCUSSION

The distribution of particle sizes in the data set can be observed in figure 1, where for the inflection point the lowest values were obtained for the average soils, in the sandy soils the values of the inflection point were closer to the values of field capacity.

Considering all soil samples of sandy texture, medium texture and clayey the correlations between ϴcc determined by the equations and the physical-water attributes that provided the highest values of R^2, as suggested by ANDRADE; STONE, (2009) that the inflection point is highly correlated with bulk density, total porosity, thus The use of one measured retention data point (FC) in the pedotransference fuction significantly decreased ME (RAJKAI; KABOS; VAN GENUCHTEN, 2004); as found in the soil of medium texture in the present work was: equation (A) ΘFC = -0.0000751Sand + 0.0002212Clay - 0.1300Pt - 0.3293DS + 0.9016, R^2 = 78% considering three independent variables, for sandy texture soils correlation coefficients ranged from 42.7 to 78%. For the soils of medium texture, a better correlation was obtained with an equation (A) ΘFC = 1.183292ΘINF -0.3818Pt - 0.01660; In which the lowest number of variables presented a correlation of 77.7%, the results found corroborate those found by (Ferreira; Marcos 1983; Mello et al., 2002).

Whereas the linear regression techniques were subsequently used to correlate the soil water retention curve parameters with the most significant soil properties as predictors. To make the linear regression approach more flexible, all eight independent explanatory variables were entered and maintained in the pedotransference fuction (RAJKAI; KABOS; VAN GENUCHTEN, 2004). Despite SILVA et al., (2014) obtained models the cubic polynomial regression to calculate the inflection point, presented good adjustment evaluated by the R^2 index. We found good adjustment with liner regression models in sandy soils (figure 1).

However, clayey soils were the ones with the highest correlation coefficients for determination of the moisture in the field capacity - ΘFC, the coefficients ranged from 72 to 85% among the three worked soil texture, verified a strong influence of the clay in the retention of, which is the only textural component used to adjust pedotransfer functions (Giarola et al., 2002; Silva et al., 2008; MUELLER et al., 2003) , suggested that differences in inflection point estimates are due to variations in the soil retention curve, so in soils with a very high retention curve, making it less reliable to estimate the inflection point.

CONCLUSIONS

It is concluded that the calculated inflection point can be considered as a good estimator of the field capacity for soils with high clay content, which can facilitate and expedite the calculation of water availability, being a useful tool for irrigation management Aiming at water savings and sustainability of agricultural production systems.

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Table 1. Soil structural composition, moisture of the field capacity and permanent wilting point and the estimation of the field capacity by the inflection point considering the 90 soil samples.

Soil textural classification	Sand (g Kg^{-1})	Silt (g Kg^{-1})	Clay (g Kg^{-1})	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	θ_{FC} (g g^{-1})	θ_{WP} (g g^{-1})	Θ_{INF} (g g^{-1})
Sandy Soil (n=30)								
Mean	886.267	56.967	56.767	1.164	2.614	0.327	0.223	0.391
SD	47.803	36.333	34.124	0.118	0.101	0.115	0.088	0.054
Max	974.000	132.000	150.000	1.590	2.770	0.593	0.401	0.473
Min	790.000	5.000	17.000	1.010	2.370	0.129	0.095	0.269
Loam Soil (n=30)								
Mean	604.433	162.167	233.400	1.379	2.526	0.134	0.092	0.273
SD	132.506	65.175	126.216	0.253	0.211	0.038	0.036	0.041
Max	790.000	270.000	660.000	1.941	2.690	0.229	0.186	0.333
Min	180.000	50.000	110.000	1.030	1.720	0.076	0.051	0.173
Clay Soil (n=30)								
Mean	175.233	432.367	392.400	1.465	2.612	0.371	0.211	0.308
SD	150.582	134.555	199.113	0.137	0.116	0.145	0.102	0.049
Max	510.000	700.000	740.000	1.830	2.700	0.685	0.416	0.414
Min	10.000	250.000	20.000	1.230	2.060	0.143	0.058	0.230

Table 2. Estimation of moisture in the field capacity (ΘFC) determined by the equations taking into account the clay, silt, sand, bulk density (ρ) , total porosity (Pt) and inflection point (ΘINF), and their respective R^2, RMSE, and standard error considering the 90 samples of soil.,

Equation			
Sandy Soil	SE	RMSE	R^2
(A) $\Theta FC = -0.0000751 Sand + 0.0002212 Clay - 0.1300 Pt - 0.3293\rho + 0.9016$	0.025	2.276	0.780
(B) $\Theta FC = -0.002801\ Sand - 0.002543 Silt + 0.726860 Pt + 2.680564$	0.101	9.413	0.564
(C) $\Theta FC = -0.0001866\ Sand + 0.002340\ Clay - 0.32981\ \rho + 0.8866$	0.102	9.501	0.556
(D) $\Theta FC = 1.8886 \Theta INF - 0.21117$	0.113	10.925	0.413
(E) $\Theta FC = 2.4635078 \Theta INF + 0.2427042\ \rho - 0.743845$	0.114	10.789	0.427
Loam Soil	SE	RMSE	R^2
(A) $\Theta FC = 1.183292 \Theta INF - 0.3818 Pt - 0.01660$	0.021	1.957	0.777
(B) $\Theta FC = -0.0000564\ Clay - 0.0003021\ Sand - 0.0964\ \rho + 0.45778$	0.021	1.990	0.716
(C) $\Theta FC = -0.0001909\ Clay + 0.0000234 Silt - 0.17019\ \rho - 0.20986 Pt + 0.57209$	0.020	1.871	0.750
Clay Soil	SE	RMSE	R^2
(A) $\Theta FC = -0.0003065\ Sand + 0.0002124 Silt - 0.358 Pt - 0.4384\ \rho + 1.0068$	0.048	4.344	0.851
(B) $\Theta FC = -0.000518\ Sand - 0.000195\ Clay - 0.3271\ \rho + 0.8833$	0.047	4.377	0.849
(C) $\Theta FC = 1.79111 \Theta INF - 0.373386$	0.062	5.957	0.720
(D) $\Theta FC = 1.8665 \Theta INF + 0.042710\ \rho - 0.452606$	0.063	5.950	0.721

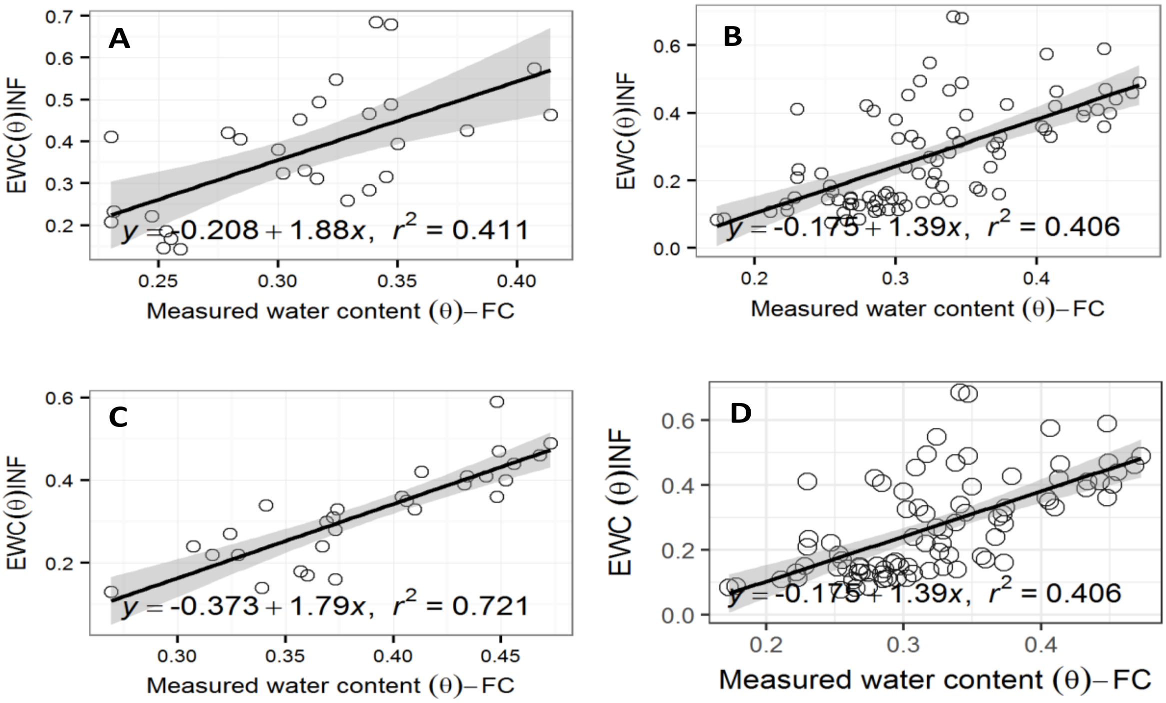

Figure 1. Correlation between estimated water content - EWC by the inflection point and the water content measured in the field capacity - sandy (C), (B) medium, (C) sandy clay, (D) the three textures