

Performance of the Arya and Paris water retention model with the UNSODA database



Agricultural Instrumentation

C.M.P. VAZ*, J.M. NAIME, V.T. SHINYA, Embrapa, Agricultural Instrumentation, Brazil
M. VAN GENUCHTEN, Salinity Laboratory, ARS-USDA Riverside, EUA

Introduction

- Determination of soil water retention data (h vs θ) is time consuming
- Models to estimate h vs θ from simple taxonomic data:
 - Pedotransfer functions – PTF
 - Artificial Neural Network
 - Similarity between particle size distribution (PSD) and SWRC (ex: Arya & Paris model)

Objectives

- Develop a software for determination of soil water retention data from particle size distribution using the Arya and Paris (A&P) model.
- Apply the A&P model for the UNSODA database. Compare water content values predicted with the A&P model with measured values (laboratory and field data).
- Determine an scaling factor α for the A&P model for the UNSODA database

Materials and Methods

Unsoada database

Table 1. Limits and average values of some selected soil parameters of UNSODA database

	minimum	maximum	average	SD
ρ_{bulk} (Mgm ³)	0.170	2.10	1.50	0.20
$\rho_{particle}$ (Mgm ³)	1.98	2.87	2.65	0.08
Clay (%)	0	65.0	18.2	14.5
Silt (%)	0	87.0	30.5	22.3
Sand (%)	0.50	100	50.3	29.9
Porosity (m ³ m ⁻³)	0.175	0.915	0.473	0.108

Arya and Paris Model

$$h_i = \frac{2\sigma \cos\theta}{\rho_w g r_i} \left\{ \begin{array}{l} \sigma \text{ (N m}^{-1}\text{)} : \text{ surface tension} \\ \theta : \text{ contact angle} \\ \rho_w \text{ (kg m}^{-3}\text{)} : \text{ water density} \\ g \text{ (m s}^{-2}\text{)} : \text{ acceleration of gravity} \\ r_i \text{ (m)} : \text{ porous radius.} \end{array} \right.$$

$$\theta_i = \left(\frac{\rho_p - \rho_s}{\rho_p} \right) \sum_{j=1}^i w_j$$

i : fraction
 ρ_p (kg m⁻³) : soil particle density
 ρ_p (kg m⁻³) : soil density
 w : soil mass fraction.

Arya and Paris Model - continuation

$$r_i = R_i \sqrt{4en_i^{1-\alpha} / 6} \quad \left\{ \begin{array}{l} n_i = \frac{3w_i}{4\pi R_i^3 \rho_p} \\ e = \frac{\rho_p - \rho_s}{\rho_p} \end{array} \right.$$

R_i : particle radius
 n_i : number of particles
 e : void ratio
 α : fitting parameter

$$h = \frac{2\sigma \cos\theta}{\rho_w g R_i \left[\frac{4}{6} \left(\frac{\rho_p - \rho_s}{\rho_p} \right) \left(\frac{3w_i}{4\pi R_i^3 \rho_p} \right)^{1-\alpha} \right]^{\frac{1}{2}}}$$

$$\theta_i = \left(\frac{\rho_p - \rho_s}{\rho_p} \right) \sum_{j=1}^i w_j$$

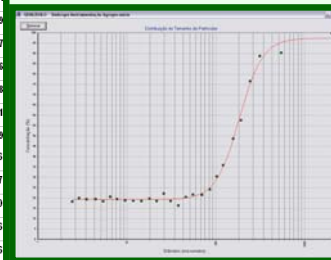
Results

- Software for prediction of SWR data from PSD (A&P model)

QUALISOLO Embrapa Instrumentação Agropecuária			
Densidade Global 1.50 (g.cm-3)			
Abrir Arquivo	Calcular	Salvar Resultado	Sair
Dímetro	Concentração	Umidade	Pressão
1	2000	100	0.062804348182; 12544.9285595
2	541.59113	72.65891	0.062855311577; 3108.55361858
3	312.63582	88.80327	0.063638846518; 1790.86030074
4	242.16667	76.63832	0.065195494433; 949.529946719
5	191.44956	57.59978	0.069184672222; 386.448519497
6	156.31791	48.75593	0.077479513175; 143.391521376
7	121.08333	36.00609	0.086162792142; 73.7402631078
8	102.33409	30.51095	0.095191235649; 44.7709833241
9	85.61685	24.18218	0.104519001988; 29.8831668979
10	69.90749	21.51124	0.123881983093; 16.4148512260
11	55.00292	21.77302	0.153978759527; 8.20399240067
12	45.7652	20.40828	0.204036468927; 5.73255778860
13	37.8465	16.46794	0.250335688194; 2.25500290396
14	30.85489	18.55870	0.323536953782; 1.20604695110
15	25.94643	22.17425	0.370445378311; 0.84978959879
16	21.57392	18.60045	0.413182150535; 0.55283615926
17	17.85276	19.64970	0.425843251504; 0.42651131390
18	14.47223	18.56816	0.429568998601; 0.35383647359
19	14.47223	18.56816	0.429568998601; 0.35383647359
20	11.73853	18.76293	0.430916417085; 0.24522855135
21	9.5427	18.95211	0.430973825385; 0.19862105666
22	7.89915	19.51204	
23	6.44044	20.56626	
24	5.35641	18.45989	
25	4.4312	19.50577	
26	3.51063	19.41645	
27	2.89445	19.98666	

Input parameters of A&P

- Particle size distribution
- Bulk and particle density



Results

- Performance of A&P model with the UNSODA database

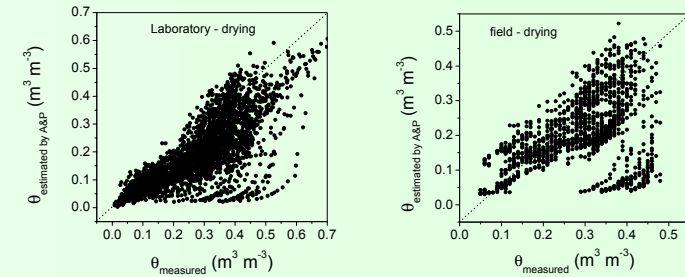
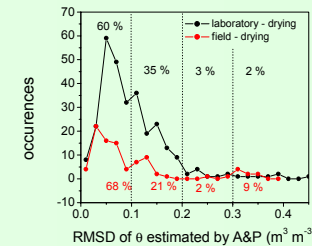


Figure 1. Soil water content predicted by A&P model and measured in the soil water retention data presented in UNSODA database.

RMSD of predicted θ (m³m⁻³)

- laboratory data (n=411): 0.100
- field data (n=107): 0.094

Figure 2. Frequency distribution of θ RMSD obtained with the A&P model in the UNSODA database. Percentages indicate amount of soils within that RMSD range



- Determination of α scaling factor for UNSODA database

Data set	type	α_{mode}	number of soils
Brazilian	laboratory-drying	1.02	110
	laboratory-wetting	1.17	411
UNSODA	laboratory-wetting	1.11	11
	Field-wetting	1.03	107
all		1.12	639

Figure 3. Frequency distribution of α values obtained with 639 soil from Brazilian and UNSODA database.

Conclusions

There was an average θ RMSD of 10 % in the determination of the retention data with the A&P model in the UNSODA database. However for a group of 247 soils (60%) the RMSD was 0.059 m³ m⁻³, that was very close the data obtained by Vaz et al. 2005 SSSAJ v. 69, n. 3, 577-583 (RMSD of 0.062 m³ m⁻³). A group of 164 soils (40%) presented θ RMSD from 0.1 to 0.4 m³ m⁻³ indicating problems with the A&P model for some specific group of soils or inconsistencies in the PSD and/or SWR data.