Scaling soil water retention functions using particle-size distribution

Paolo Nasta[1], Tamir Kamai[2], Giovanni B. Chirico[1], Jan W. Hopmans[2] and Nunzio Romano[1]

[1] Department of Agricultural Engineering, University of Naples Federico II, Napoli - Italy
[2] Department of Land, Air and Water Resources, University of California at Davis, California - U.S.A.

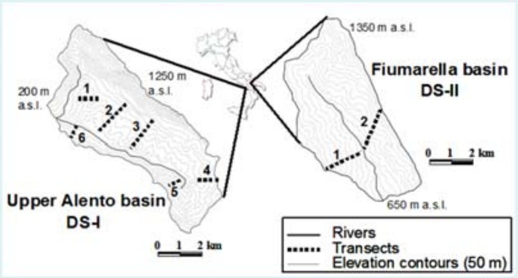
paolo.nasta@unina.it; tkamai@ucdavis.edu; gchirico@unina.it; jwhopmans@ucdavis.edu; nunzio.romano@unina.it;

1. Objectives and Methodology

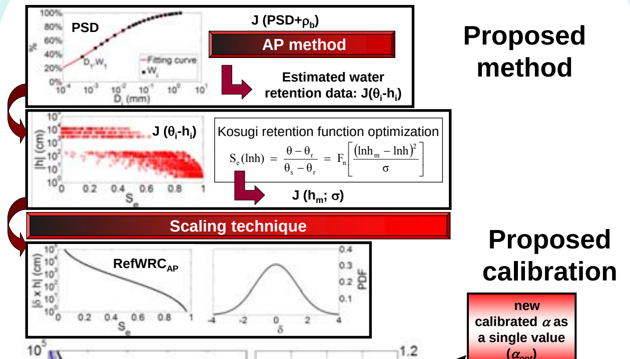
The application of spatially distributed hydrological models is a challenging problem, particularly because of the difficulties arising in the identification of the model parameters describing the soil hydraulic properties and their spatial variability. Generally soil data are available just for a limited number of locations across the study area and very often the available data consist of soil physical and chemical properties rather than direct measurements of the soil hydraulic properties. Thus indirect methods are often required for an assessment of model parameters describing the soil hydraulic properties, based on a limited number of measurements.

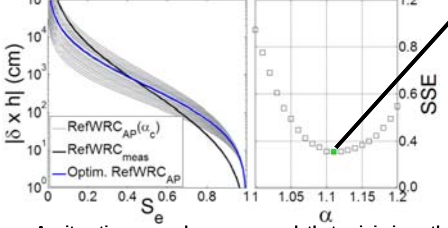
This study presents a methodology for assessing the variability of soil water retention from soil texture and bulk density measurements, based on a combination of the scaling approach proposed by Kosugi and Hopmans (1998) and the Arya-Paris (AP) physico-empirical pedotransfer function. The approach proposed by Kosugi and Hopmans (1998) represents the spatial variability of soil hydraulic properties by scaling factors which relate the soil hydraulic functions in any location to a single reference function, provided that soils are characterised by geometric similitude within the study area. The Arya-Paris (AP) physico-empirical pedotransfer function estimates the soil water retention from the soil particle-size distribution and bulk density.

2. Experimental sites



3. Proposed calibration



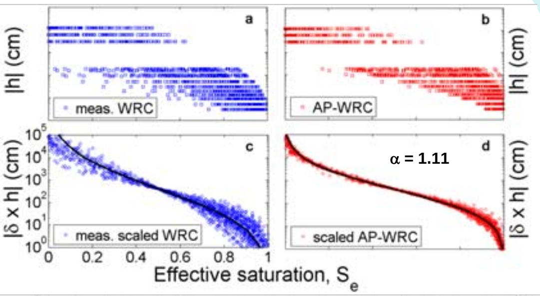


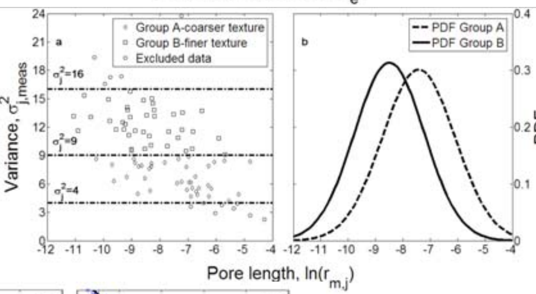
The AP-reference soil water retention curve ($RefWRC_{AP}$) was determined from optimization of the AP-tortuosity parameter α assumed as a single value for all diameter classes and for entire dataset.

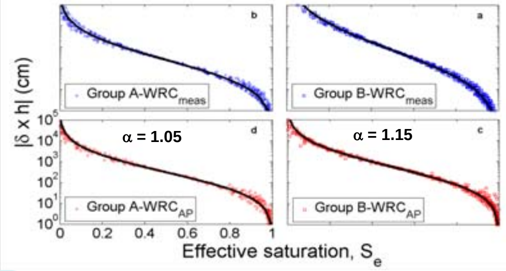
An iterative procedure was used that minimizes the squared differences between the measured reference retention function ($RefWRC_{meas}$) and the reference soil water retention functions as obtained from the AP-model ($RefWRC_{AP}$),

4. Results in DS-I

Laboratory-measured and AP-predicted reference water retention functions are compared by evaluating the lognormal distributions of the corresponding scaling factors and comparing the unscaled measured, unscaled AP-predicted with the scaled measured and scaled AP-predicted soil water retention data. The solid black lines represent the scaled-mean reference water retention functions. To improve the scaling results of the DS-I dataset, we grouped the soil samples of this dataset in classes of 4 < $\sigma^2_{j,meas}$ < 9 (Sub-group A – coarser-textured soils) and 9 < $\sigma^2_{j,meas}$ < 16 (Sub-group B – finer-textured soils), and removed a few samples outside either of these two intervals. These 2 groups are identified by black diamonds for sub-group A and black solid circles for sub-group B, corresponding with J_A = 40 for sub-group A and J_B = 43 for sub-group B; the crosses represent the excluded data for this analysis (22 soil samples).



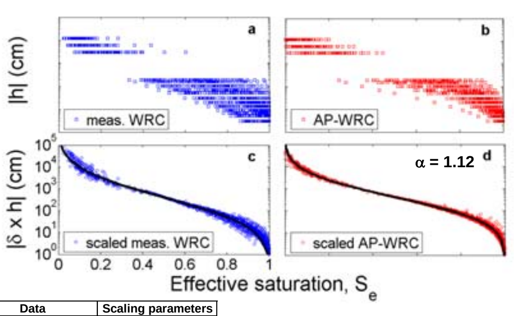




Data grouping

Hydrological Response Unit

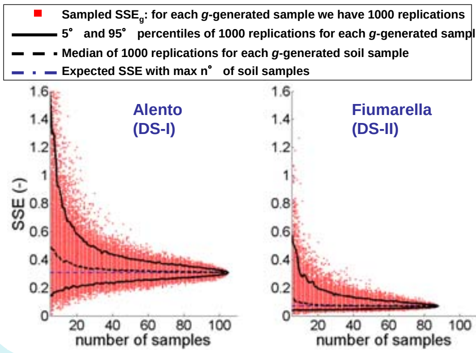
5. Validation in DS-II



Data	Scaling parameters	
measured in LAB	$h_{m,ref}$	416
	σ_{ref}	2.49
	$\mu(\delta_i)$	1.46
	$SD(\delta_i)$	1.32
	RMSE	0.0925
estimated by AP-model	$h_{m,ref}$	421
	σ_{ref}	2.07
	$\mu(\delta_i)$	1.29
	$SD(\delta_i)$	1.11
	RMSE	0.0114

The proposed technique has been validated using data gathered in a basin located in Basilicata Region (Fiumarella Basin, DS-II). This area is characterized by climatic and environmental conditions that differ from those of the Alento basin. Both parametric and functional evaluations have shown that the proposed method is efficient and robust

6. Minimum number of required soil cores



For evaluating the minimum number of soil water retention functions required, we randomly selected a fixed number of sampling locations in the range from 5 to 105 and to 88, for the DS-I and DS-II datasets, respectively. With *g* representing the number of samples used, the SSE_g was computed for each randomly generated sample using 1000 replications to ensure unbiased results. In this analysis, we used the optimized α_{opt}-values. we can conclude that the minimum number of soil samples required for determining the AP-tortuosity parameter α is about 30, as the SSE values are within the 95% confidence interval for this minimum sample size. Hence, for a minimum of 30 soil cores one must measure both soil water retention and PSD, to characterize variability of soil water retention by scaling factors.

7. Conclusions

Prediction performance of hydrologic models strongly depends on fundamental parameters which characterize the soil hydraulic behavior at large scales. The proposed method represents a step forward to use simplified approaches based on physical interpretation to estimate hydraulic properties and their variability at large scales. This approach was verified in parametric terms, evaluating efficiency of the proposed method in respect with the traditional method based on laboratory measurements which is more difficult, time consuming and expensive.

P. Nasta, T. Kamai, G.B. Chirico, J.W. Hopmans, N. Romano, 2009. Scaling soil water retention functions using particle-size distribution. Journal of Hydrology, 374:223-234