Using Available Soil Data to Populate Models to Address Public Concerns

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INTRODUCTION, OBJECTIVES

Simulation modeling provides a feasible alternative to field monitoring when large scale environmental concerns are to be addressed. However, various model inputs exist that cannot be collected – at least not in a feasible manner - at large scale. Soil physical and hydraulic properties are among those. In such cases simulation models mostly rely on using information collected from small-scale (point) samples. This practice, however, raises the need for an accurate and reliable up-scaling protocol. Water quality assessments, crop simulation studies and research projects/programs like CEAP (Conservation Effects Assessment Project) and TMDL (Total Maximum Daily Load) typically utilize such up-scaled information. We provide an overview of potential pitfalls while up-scaling, with the objective to call attention to potential misuse of publicly available soil data.

PROBLEM DEFINITION

- There is no measurement technique or pedotransfer function (PTF) that will directly provide effective soil properties at large scale – therefore some up-scaling protocol is required.
- There are many potential pitfalls en route to obtaining large scale soil information.

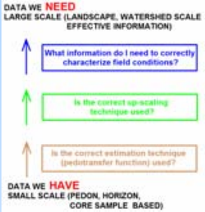

Figure 1. The up-scaling dilemma.

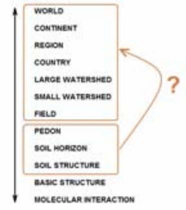

Figure 2. Diagram of scales of interest in soils related research and applications (Adapted from Bouma and Hoosbeek, 1996)

Potential sources of uncertainty (after Shirmohammadi et al. 2006):

- input variability: measurement technique, expertise, heterogeneity
- model algorithm: - empirical – portability
  - theoretical – calibration/validation
- model calibration/validation: data uncertainty
- application scale : - model procedure consistent with application scale?
  - spatial data used – aggregation/generalization

POTENTIAL PITFALLS

Is the right data set and approach used to construct and use pedotransfer functions (PTFs)?

- biased database (e.g. temperate vs. tropical climate)
- incorrect/insufficient PTF type (e.g. complexity of equation)
- incorrect input selection (e.g. lack of influential properties)
- differences in measurement methods (e.g. definitions, methodology)
- differences in classification (e.g. FAO vs. ISSS particle-size distribution)

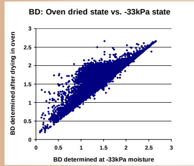

Figure 3. BD determined under different states of soil wetness. Data from NRCS NSSC.

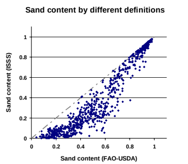

Figure 4. Soil texture (sand content) according to different definitions. Data from the HUNSODA database, Hungary (Nemes et al 2002.).

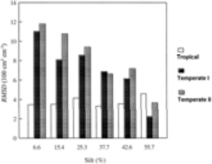

Figure 5. Root mean square difference (RMSD) of estimations by a tropical and two temperate climate PTFs for tropical soils; grouped by 10% intervals of silt content. (adapted from Tomasella et al. 2000.)

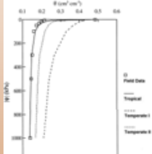

Figure 6. Comparison of performance of a tropical and two temperate climate PTFs for tropical soils. An example water retention curve. (adapted from Tomasella et al. 2000.)

Do we know the true distribution of properties?

- rare events may actually control most of the domain's effective behavior, but their distribution may not be known

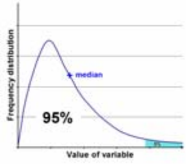

Figure 7. Distribution of properties within a domain

How should we aggregate properties to represent larger scale behavior?

- Weighted average?
- Dominant soil type?
- Geometric vs. arithmetic mean?
- Correlation between soil hydraulic characteristic parameters are reported differently

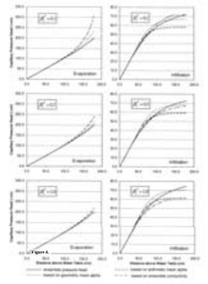

Figure 8. Capillary pressure head vs. distance above water table. Left: Evaporation, given a steady rate of 0.25 qmax. Right: Infiltration, given a steady rate of 0.25 Ks for the Brooks-Corey model. (Zhu and Mohanty, 2002).

Do we know what property we really need?

- -33kPa water retention – or in fact that at any other fixed pressure – does not seem to be a uniformly good approximation of field capacity

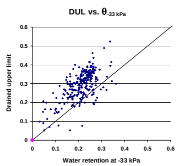

Figure 9. Field measured DUL vs. lab determined -33 kPa water retention for 260 samples – a data subset of Ritchie et al. (1987) was used.

- Laboratory measured saturated hydraulic conductivity (Ks) will not necessarily be a good approximation of the effective Ks term in the Green-Ampt infiltration formula (after Rawls et al, 1993):

(*a*) - presence of macroporosity

$$K_s(eff) = A\,K_s$$

$$A = \exp(2.82 - 0.099\,Sand + 1.94\,BD) \quad - rangeland$$
$$A = \exp(0.96 - 0.032\,Sand + 0.04\,Clay - 0.032\,BD)$$
$$- agricultural\ areas$$
$$(but\ A \geq 1)$$

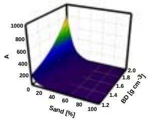

Figure 10. Macroporosity factor for rangelands (after Rawls et al. (1993))

(*b*) - surface crust formation

$$K_s(eff) = K_s \frac{SC}{1 + (\psi_i / L)} \quad ,$$

$$L = depth\ of\ wetting\ front\ [cm]$$
$$\psi_i\ and\ SC\ as\ in\ Table\ 1$$

Table 1. Mean steady-state matric potential drop, Ψ_i, across surface seals

Soil texture	Matric potential drop, Ψ_i [cm]	Reduction factor for subcrust conductivity (SC)
Sand	2	0.91
Loamy sand	3	0.89
Sandy loam	6	0.86
Loam	7	0.82
Silt loam	10	0.81
Sandy clay loam	5	0.85
Clay loam	8	0.82
Silty clay loam	10	0.76
Sandy clay	6	0.8
Silty clay	11	0.73
Clay	9	0.75

source: Rawls et al. (1993)

Additional concerns:

- Heterogeneity of soil units (related: Table 2)
- Dynamic soil properties (e.g. BD, Ks) (related: Tables 3 and 4)

Table 2. Simulated water deficit [mm] for the vegetation in the period May 15 - October 15 - under different irrigation schemes - for 3 points (profiles) within a field near Dunaharaszti, Hungary. (Adapted from Nemes et al. 2006)

	Profile 1		Profile 2		Profile 3	
Irrigation scheduling scenarios	MEAN	(STD)	MEAN	(STD)	MEAN	(STD)
no irrigation	544.68	(52.64)	413.66	(49.18)	172.64	(76.62)
field observation assisted scheduling	317.26	(23.64)	144.44	(20.51)	14.17	(20.05)
simulation assisted scheduling	296.19	(16.71)	100.90	(10.52)	2.26	(0.19)

Table 3. Variation of BD [g cm⁻³] during the season and by management type on a sandy Loam brown forest soil near Gödöllő, Hungary (Adapted from Farkas 2002).
Non-capital letters: significance between treatments (vertical comparison);
Capital letters: significance between dates (horizontal comparison)

	depth: 5-10 cm			depth: 15-20 cm		
Tillage	March	June	August	March	June	August
no till	1.66 aA	1.68 aA	1.50 aB	1.63 aA	1.68 aA	1.61 aA
ploughing	1.37 bA	1.46 bB	1.43 aB	1.39 bA	1.62 bB	1.53 aC
loosening + ploughing	1.37 bA	1.70 acB	1.73 bB	1.62 aA	1.66 aA	1.72 bB
disking	1.60 aA	1.73 acB	1.78 bB	1.65 aA	1.77 cB	1.69 bC
loosening + disking	1.52 cA	1.78 cB	1.47 aB	1.52 cA	1.69 aB	1.72 bB

Table 4. Variation of Ks [mm d⁻¹] during the season and by management type on a sandy Loam brown forest soil near Gödöllő, Hungary (Adapted from Farkas 2002)

Tillage	12-Mar	20-Apr	12-Jun	10-Jul	25-Aug	Mean
no till	278	588	1145	242	194	480
ploughing	994	778	641	240	223	576
loosening + ploughing	936	874	461	350	230	576
disking	103	319	883	149	516	384
loosening + disking	132	446	1764	185	370	624

RESEARCH NEEDS

1. Typical errors (bias and variance) for widespread upscaling methods (e. g. 33 kPa to infer field capacity) have to be summarized.
2. Propagation of those errors through widespread hydrologic and crop models needs to be evaluated (e.g. errors in Ksat may not be important for a crop model).
3. Functional evaluation of coarse scale models has to include the uncertainty caused by using publicly available data as inputs.
4. It is not known currently how the hydrologic information uncertainty may affect risk-informed management and policy decisions.

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