User's manual of SWRC Fit

1. About SWRC Fit

SWRC Fit is a program which performs nonlinear fitting of following 5 models by Levenberg-Marquardt method (Seki, 2007).

(1) BC model (Brooks and Corey, 1964)
(2) VG model (van Genuchten, 1980)
(3) LN model (Kosugi, 1996)
(4) DB model (Durner, 1994)
(5) BL model (Seki, 2007)

Website: http://purl.org/net/swrc/
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Version of this distribution: 1.1 (HESSD version)

2. Distributed package

SWRC Fit package is distributed in zip and tar.gz format. By extracting the archive, following files are obtained.

(1) swrc.m … Fitting of unimodal models (BC, VG and LN)
(2) bimodal.m … Fitting of bimodal models (DB and BL)
(3) swrc.xls … Microsoft Excel worksheets for checking the result.
(4) manual.pdf … User's manual of SWRC Fit (this file)
(5) Readme.txt … Short description
(6) history.txt … Version history
(7) license.txt … GNU General Public License

This release, version 1.1, is called HESSD version because the programs, swrc.m and bimodal.m, are identical to the program published as a supplementary file of HESSD journal (Seki, 2007).

3. Installation of GNU Octave

The two types of software, swrc.m and bimodal.m, are written in GNU Octave, and, therefore, GNU Octave should be installed in the system. GNU Octave is a high-level language, primarily intended for numerical computations, available for downloading from the GNU Octave Website (http://www.gnu.org/software/octave/). The installation instructions are given in the Website. It works on various operating systems including Windows, Mac OS X, Linux and OS/2. After installing GNU Octave, some necessary packages for running SWRC Fit, leasqr.m, dfdp.m and normcdf.m, should be installed from the octave-forge package (http://octave.sourceforge.net/).

Installing Octave Workshop (http://www.math.mcgill.ca/loisel/octave-workshop/) will provide you with all necessary environment for the GNU Octave itself and the Octave-forge package.

4. Preparation of data

The input data, i.e., the soil water retention curve, should be prepared as a text file with two columns, using the file name swrc.txt. The first column is the suction head and the second column is the volumetric water content, where space is used as a delimiter. For example;

```
0 0.2628
20 0.237
30 0.223
40 0.211
50 0.2035
70 0.1855
100 0.169
200 0.151
430 0.1399
640 0.131
1050 0.1159
```

Lines beginning with "#" are regarded as comment and neglected. Any unit can be used as the input data, and the calculated data depends on the unit used as the input data.

5. Calculation options

This section is for users who would like to control the way of fitting. If you are not interested in it, you can bypass this section and go directly to the next section, and come back to this section when necessary. The programs swrc.m and bimodal.m have "Setting" block in the program itself as follows.

```
1: # Setting
2: output_precision=7;
3: qsin = max(y); # initial value of qs
4: cqs=1; # cqs=1; qs is variable, cqs=0; qs is constant
5: qrin = min(y); # initial value of qr
6: cqr=1; # cqr=1; qr is variable, cqr=0; qr is constant
7: # qrin=0; cqr=0; # For setting qr=0 as a constant
8: pqr=0; # pqr=1; qr >= 0, pqr=0; qr can be negative
```

The setting block can be edited directly with a text editor. By editing this "Setting" block, calculation option can be controlled.

The first line, "# Setting", is a comment. It indicates that this is a setting block. GNU Octave language ignores the rest of a line following a sharp sign ("#").

The second line sets the precision of the ouput. In GNU Octave, the variable output_precision specifies the minimum number of significant figures to display for numeric output.

The lines 3-4 specify the variable θ_s, the saturated water content. In this program, θ_s is shown as "qs". Two parameters, qsin and cqs, controls how the program treats this variable. qsin is the initial value of θ_s and cqs is a parameter which decides θ_s is constant or variable; when cqs is set as 0, θ_s is treated as a constant, and when cqs is 1, θ_s is treated as a variable. By default, initial value of θ_s is set as the maximum value of the soil water content, and it is set as a variable, but it can be changed by editing this section. For example, for setting $\theta_s = 0.35$ as a constant, following line can be added after the third line;

qsin=0.35; cqs=0;

The lines 5-8 specify the variable θ_r, the residual water content. In this program, θ_r is shown as "qr". Three parameters, qrin, cqr and pqr, controls how the program treats this variable. qrin is the initial value of θ_r, cqr is a parameter which decides θ_r is constant or variable; when cqr is set as 0, θ_r is treated as a constant, and when cqr is 1, θ_r is treated as a variable, and pqr is a variable which decides if the restriction of $\theta_r \geq 0$ is imposed. By default, initial value of θ_r is set as the minimum value of the soil water content, and it is set as a variable without the restriction of $\theta_r \geq 0$, but it can be changed by editing this section. For example, for seting $\theta_r = 0$ as a constant value, the 7th line is to be commented out,, i.e., the first "#" mark is to be deleted. For setting $\theta_r = 0.05$ as a constant value, following line can be added after the 7th line;

qrin=0.05; cqr=0;

To impose the restriction of $\theta_r \geq 0$, the 8th line, pqr=0, is to be changed to pqr=1.

6. Running the program

The programs (swrc.m and bimodal.m) and data (swrc.txt) should be placed in the same directory (folder). In that directory, "swrc.m" should be typed to run the fitting of unimodal (BC, VG, and LN) models, and "bimodal.m" should be typed to run the fitting of the DB and BL models. In the UNIX system "./swrc.m" and "./bimodal.m" is preferred, and the executable file mode should be set. The result is shown in the standard output as follows.

```
=== BC model ===
qs = 0.2627996
qr = 0.05846708
hb = 13.11246
lambda = 0.2780126
R2 = 0.9946961
=== VG model ===
qs = 0.2633070
qr = 0.1041973
alpha = 0.03760151
n = 1.598337
R2 = 0.9953371
=== LN model ===
qs = 0.2639328
qr = 0.1205137
hm = 63.63318
sigma = 1.392247
R2 = 0.9924899
```

7. Checking the result

Using the Microsoft Excel worksheet, swrc.xls, the fitted curves can be checked (**Fig. 1**). By copying and pasting the result of the program output onto the yellow part and the measured data onto the blue part of the spreadsheet, The fitted curves are drawn in the graph of the same spreadsheet.

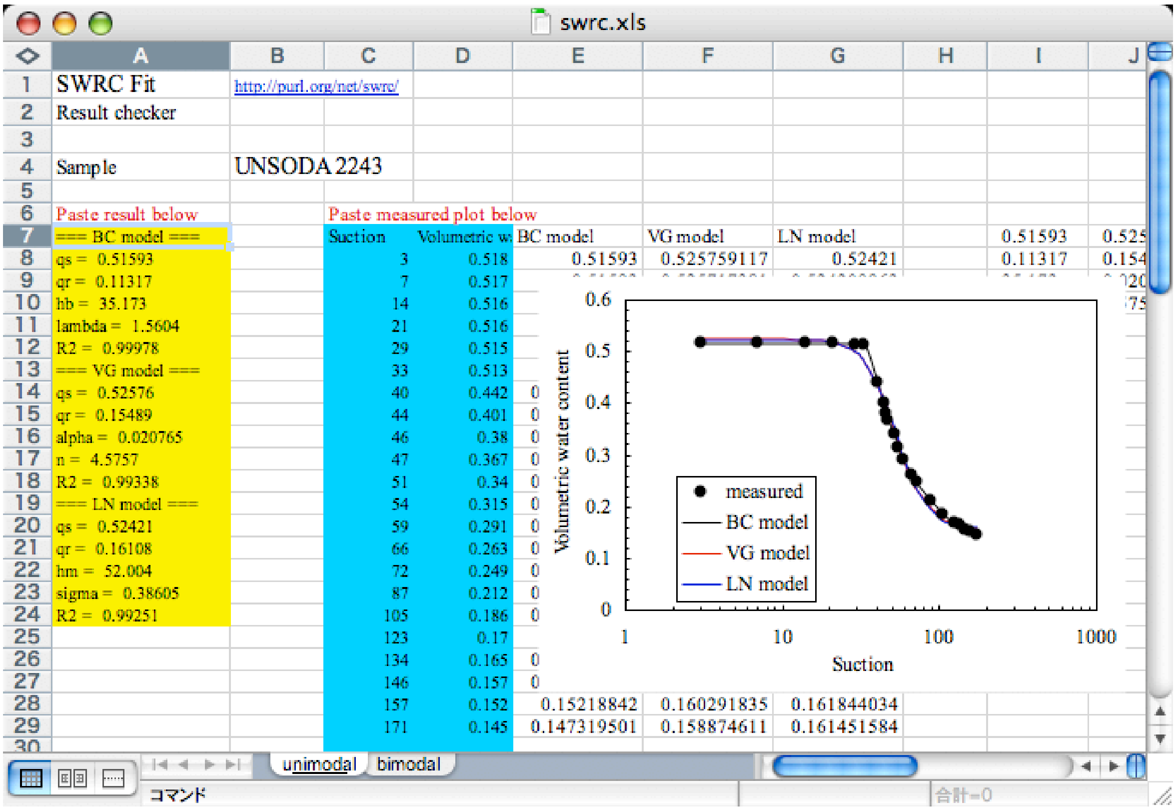


Fig. 1 Spreadsheet for checking the result

8. Web interface of the SWRC Fit

The Web interface of the SWRC Fit (http://purl.org/net/swrc/) is written in the program language perl and works as a cgi program. The perl program invokes GNU octave and executes the calculation engine of swrc.m and bimodal.m.

The screenshot of the user interface is shown in **Fig. 2**. Soil water retention data, prepared as the same format as swrc.txt in section 5 of this manual, is to be copied and pasted in the textbox. It can also be selected from the sample soil water retention data in the UNSODA database (Nemes et al., 2001). In other textboxes, the description of the soil sample, soil texture, and name can be written. The description written here appears in the results screen. The calculation options of θ_r=0 can be set by checking appropriate boxes. By default, only unimodal (BC, VG and LN) models are used, and when the users select the "Bimodal models" checkbox, bimodal (DB and BL) models will also be used. After that, the calculation starts by pressing the "Calculate" button.

In the result screen, the result of the nonlinear fit is shown as **Fig. 3**. The models, equations, parameters, and R^2 values are shown in tabular form, and the fitting curves with measured data points are also shown in a graph. If the bimodal model is selected, the results of the bimodal models are shown separately. By looking at the results, the accuracy of the fit with different models can be compared in both R^2 values and fitting curves. The description of the soil sample and the original data is also displayed in the results screen so that the users can print out and store all the necessary information.

Reference

Brooks, R. H., and Corey, A.T.: Hydraulic properties of porous media. Hydrol. Paper 3. Colorado State Univ., Fort Collins, CO, USA, 1964.

Durner, W.: Hydraulic conductivity estimation for soils with heterogeneous pore structure. Water Resour. Res., 30(2): 211--223, 1994.

Kosugi, K.: Lognormal distribution model for unsaturated soil hydraulic properties. Water Resour. Res. 32(9), 2697--2703, 1996.

Nemes, A., M.G. Shaap, F.J. Leij, and J.H.M. Wosten: Description of the unsaturated soil hydraulic database UNSODA version 2.0. J. Hydrol. (Amsterdam) 251:151--162, 2001.

Seki, K. SWRC fit - a nonlinear fitting program with a water retention curve for soils having unimodal and bimodal pore structure. Hydrol. Earth Syst. Sci. Discuss., 4: 407-437, 2007. http://www.hydrol-earth-syst-sci-discuss.net/4/407/2007

van Genuchten, M.T.: A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J. 44, 892--898, 1980.

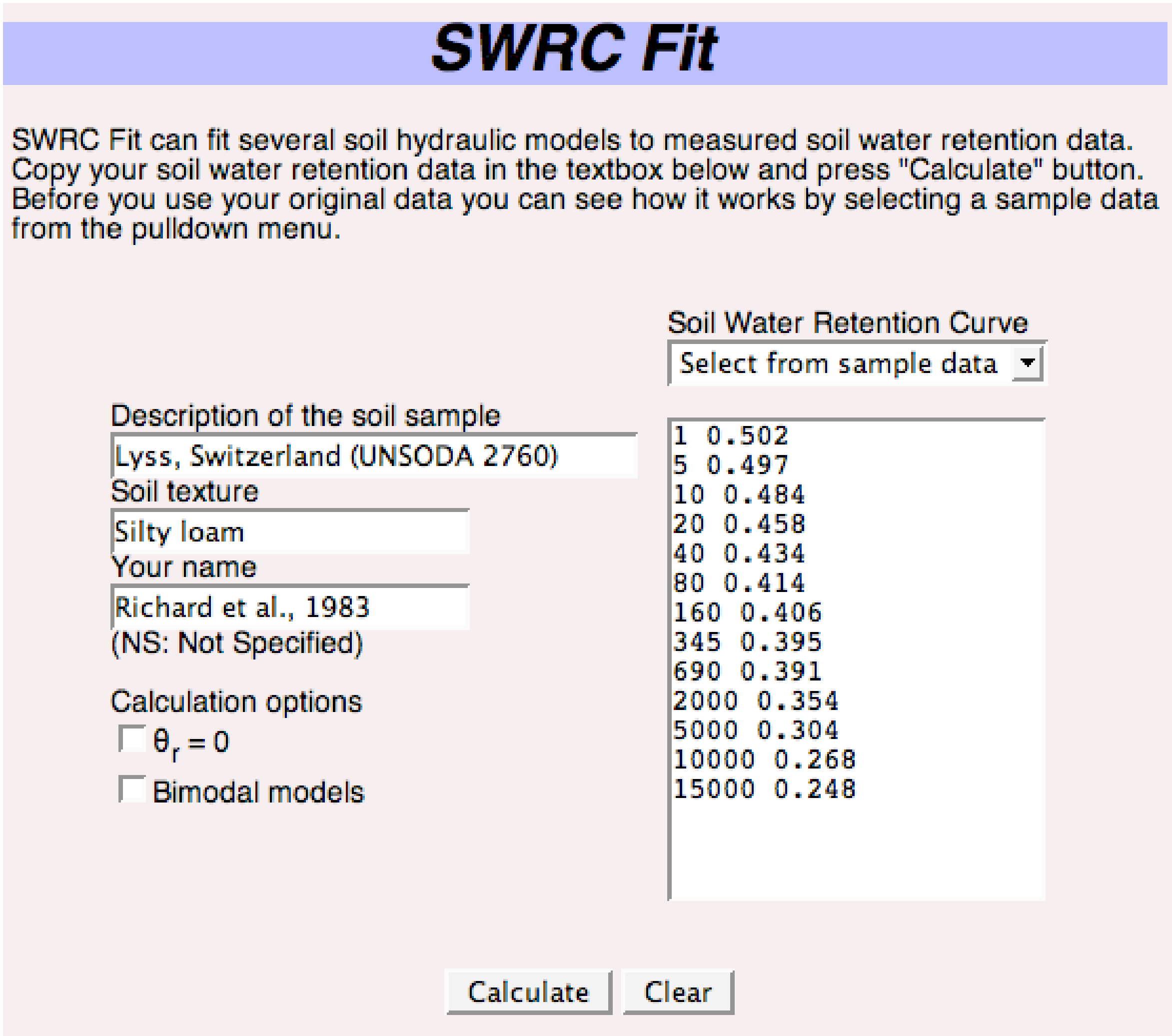


Fig. 2 Screenshot of the input display of the SWRC Fit (http://purl.org/net/swrc/)

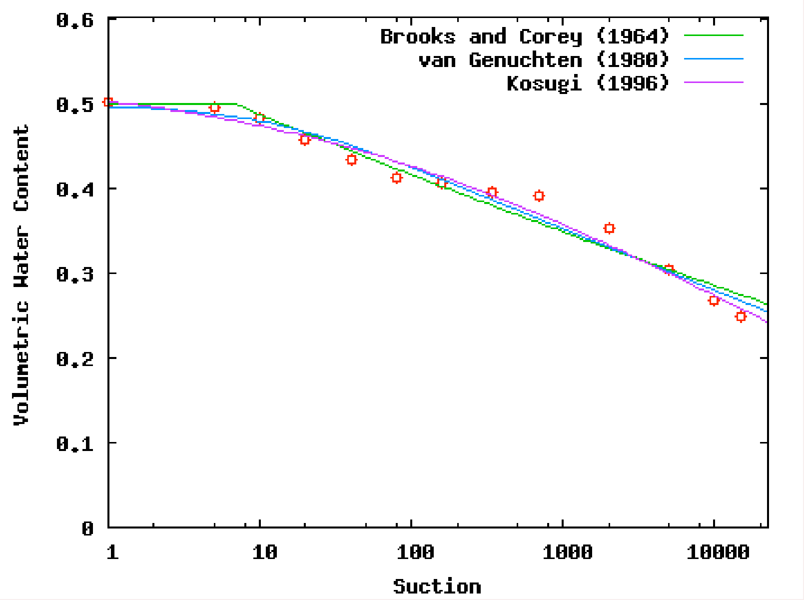
SWRC Fit - Result -

- Soil sample: Lyss, Switzerland (UNSODA 2760)
- Texture: Silty loam
- Name: Richard et al., 1983

Unimodal models

Model	Equation	Parameters	R^2
Brooks and Corey	$S_e = \begin{cases} \left(\frac{h}{h_b}\right)^{-\lambda} & (h > h_b) \\ 1 & (h \le h_b) \end{cases}$	θ_s = 0.49950 θ_r = -0.83167 h_b = 7.0139 λ = 0.024094	0.96284
van Genuchten	$S_e = \left[\frac{1}{1+(\alpha h)^n}\right]^m$ (m=1-1/n)	θ_s = 0.49940 θ_r = -1.7319 α = 0.077912 n = 1.0155	0.96816
Kosugi	$S_e = Q\left[\frac{\ln(h/h_m)}{\sigma}\right]$	θ_s = 0.52729 θ_r = -0.033693 h_m = 2.0203e+04 σ = 5.7830	0.97788

where $S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r}$, i.e., $\theta = \theta_r + (\theta_s - \theta_r)S_e$
and Q(x) is the complementary cumulative normal distribution function, defined by Q(x)=1-Φ(x), in which Φ(x) is a normalized form of the cumulative normal distribution function.



- Brooks, R.H., and A.T. Corey (1964): Hydraulic properties of porous media.

Fig. 3 Screenshot of the results display of the SWRC Fit (http://purl.org/net/swrc/).