`soilwaterfun`, water rentiention and hydraulic conductivity functions

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Contents

1 Forewords

1.1 What is `soilwaterfun`?

`soilwaterfun` is an R[4] package providing functions that implements the van Genuchten (1980)[5] water retention function, the van Genuchten / Mualem (1976)[3] hydraulic conductivity function, Brooks and Corey (1964) [1] water retention and hydraulic conductivity functions, and Campbell (1974)[2] water retention and hydraulic conductivity functions.

This package show how to use these functions and how to plot them. It mostly present the same content as the help page of each function, in a sligtly more friendly way.

If you are interested in this package, you may well be interested in the package `soilwaterptf` that provides pedotransfer functions for both van Genuchten (1980) and van Genuchten / Mualem (1976) functions. This package is not presented in this vignette.

1.2 Credits and License

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2 Install and load `soilwaterfun`

Method 1: If you have the latest R version, open R, and then type:

```
install.packages(
    pkgs  = "soilwaterfun",
    repos = "http://R-Forge.R-project.org" )
```

Method 2: Otherwise, try to install the package from the binaries. First download the binaries from `http://soilwater.r-forge.r-project.org/`. Save the package binaries in your working directory, and then open R and type:

```
install.packages(
    pkgs  = "soilwaterfun_1.0.0.zip",
    repos = NULL )
```

Then you can load `soilwaterfun`:

```
library( "soilwaterfun" )
```

3 Water Rentention functions

3.1 van Genuchten 1980

Genuchten 1980 function for water retention is the following:

$$\theta = S_e.(\theta_S - \theta_R) + \theta_R$$

Where θ_S is the saturated water content [-], θ_R is the residual water content [-] and S_e, the effective saturation, is defined as:

$$S_e = 1/((1 + (\alpha.h)^n)^m)$$

With m generally defined as $m = 1 - 1/n$, n is a dimensionless shape parameter related to pore size distribution, α another shape parameter [m^{-1}], and h is the pressure head [m] (positives). Pressure head is reated to matrix potential (negative) ψ with $\psi = -h$.

In practice R implementation of this function uses $|h|$ (`abs(h)`), so using h or ψ makes no difference.

To predict soil water content from soil pressure head h, and from van Genuchten 1980 parameters alpha, n, thetaS and thetaR, follow this example:

```
pTheta <- fun.vangenuchten.theta.h(
    h       = c(0,0.01,0.1,1,10,100,158),  # [meter]
    alpha   = 3.561099,                    # [meter-1]
    n       = 1.212074,                    # [-]
    thetaS  = 0.4162380,                   # [-]
    thetaR  = 0                            # [-]
)   #
#
pTheta
```

```
[1] 0.4162380 0.4149725 0.3983120 0.3073250 0.1946693 0.1197170
[7] 0.1086555
```

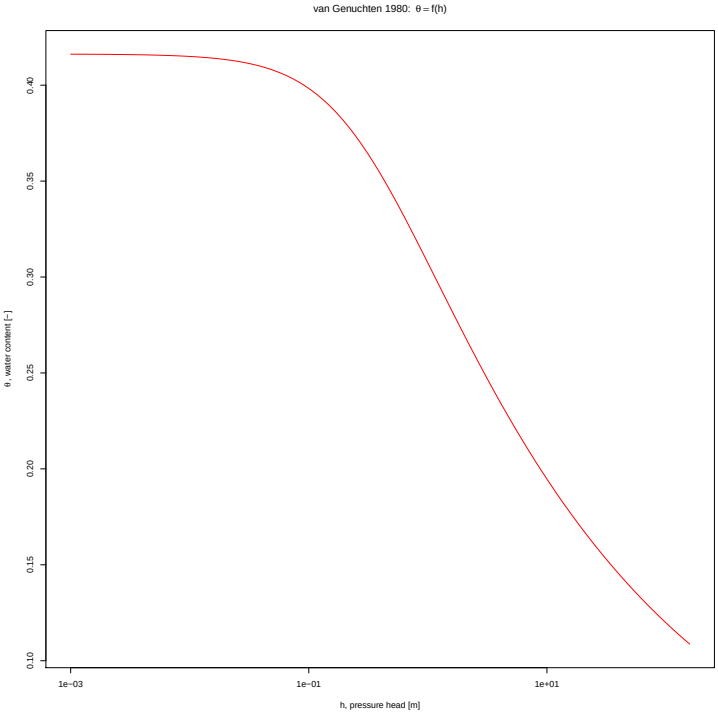
To predict the reverse, soil pressure head h from soil water content from use the following example, for a rather loamy soil:

```
ph <- fun.vangenuchten.h.theta(
    theta   = pTheta,
    alpha   = 3.561099,                    # [meter-1]
    n       = 1.212074,                    # [-]
    thetaS  = 0.4162380,                   # [-]
    thetaR  = 0                            # [-]
)   #
#
ph
```

```
[1]   0.00   0.01   0.10   1.00  10.00 100.00 158.00
```

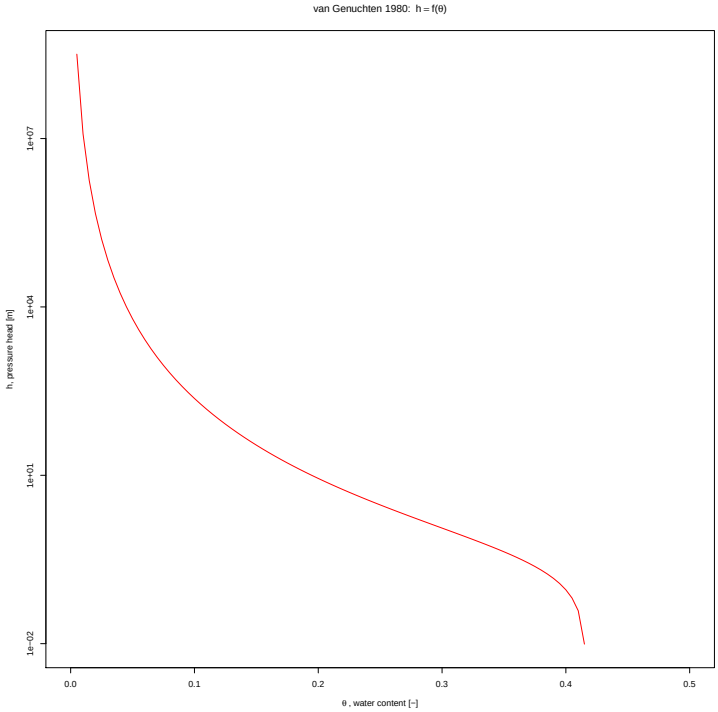
These functions can be plotted:

```
curve(
    fun.vangenuchten.theta.h(
        h       = x,
        alpha   = 3.561099,
        n       = 1.212074,
        thetaS  = 0.4162380,
        thetaR  = 0
    ),  #
    xlim = c(0.001,158),
    col  = "red",
    log  = "x",
    xlab = "h, pressure head [m]",
    ylab = expression( theta~", water content [-]" ),
    main = expression( 'van Genuchten 1980: '~theta=='f(h)' )
)   #
```



and for $h(theta)$

```
curve(
    fun.vangenuchten.h.theta(
        theta   = x,
        alpha   = 3.561099,
        n       = 1.212074,
        thetaS  = 0.4162380,
        thetaR  = 0
    ),  #
    xlim = c(0,0.5),
    col  = "red",
    log  = "y",
    ylab = "h, pressure head [m]",
    xlab = expression( theta~", water content [-]" ),
    main = expression( 'van Genuchten 1980: '~h==f('*theta*')' )
)   #
```



3.2 Brooks and Corey 1964

Brooks and Corey (1964) model for water retention in soils is the following:

$$\theta = \begin{cases} S_e.(\theta_S - \theta_R) + \theta_R & \text{when } h > h_A \\ \theta_S & \text{when } h <= h_A \end{cases}$$

Where θ_S is the saturated water content [-], θ_R is the residual water content [-] and S_e, the effective saturation, is defined as:

$$S_e = (h/h_A)^{-\lambda}$$

Where h is the pressure head, h_A is the pressure head at the air entry point, and λ is a dimensionless parameter related to pore size distribution, which determines the slope of the $\theta(h)$ relationship on the log scale.

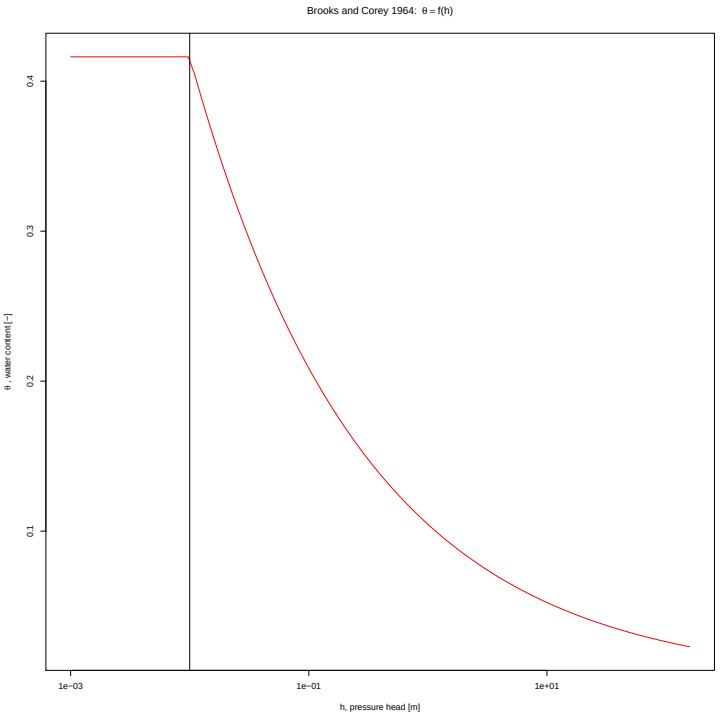
To predict soil water content from soil pressure head h, and from Brooks and Corey (1964) parameters hA, thetaS, thetaR and lambda:

```
pTheta <- fun.brooks.corey.theta.h(
    h       = c(0,0.01,0.1,1,10,100,158),   # [meter]
    hA      = 0.01,                         # [meter]
    thetaS  = 0.4162380,                    # [-]
    thetaR  = 0,                            # [-]
    lambda  = 0.3                           # [-]
)   #
#
pTheta
```

```
[1] 0.41623800 0.41623800 0.20861317 0.10455426 0.05240126
[6] 0.02626284 0.02289521
```

This functions can be plotted:

```
curve(
    fun.brooks.corey.theta.h(
        h       = x,
        hA      = 0.01,                     # [meter]
        thetaS  = 0.4162380,                # [-]
        thetaR  = 0,                        # [-]
        lambda  = 0.3                       # [-]
    ),
    xlim = c(0.001,158),
    col  = "red",
    log  = "x",
    xlab = "h, pressure head [m]",
    ylab = expression( theta~", water content [-]" ),
    main = expression( 'Brooks and Corey 1964: '~theta=='f(h)' )
)   #
abline( v = 0.01 )
```



3.3 Campbell 1974

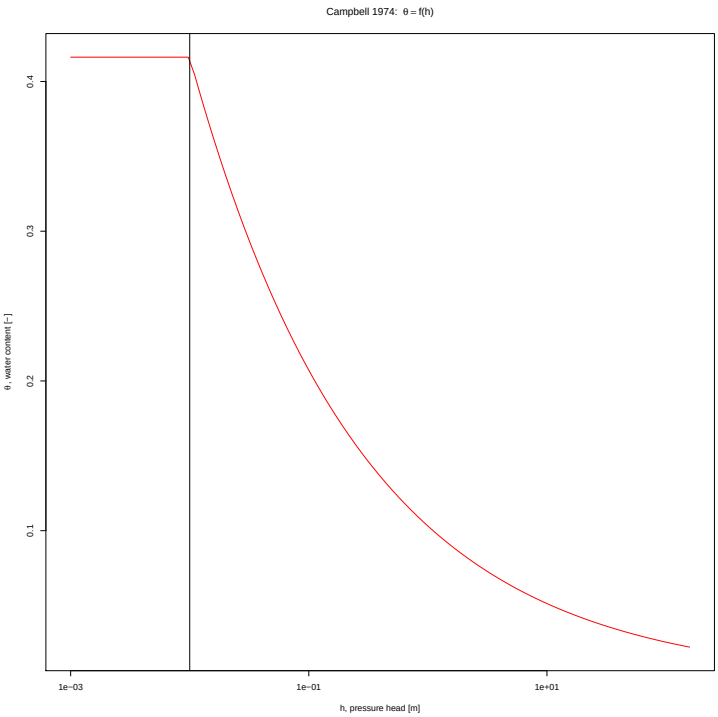
To predict soil water content from soil pressure head h, and from Campbell 1974 parameters hA, thetaS, thetaR and lambda:

```
pTheta <- fun.campbell.theta.h(
    h       = c(0,0.01,0.1,1,10,100,158),  # [meter]
    hA      = 0.01,                        # [meter]
    thetaS  = 0.4162380,                   # [-]
    bPar    = 3.3                          # [-]
)   #
#
pTheta
```

```
[1] 0.41623800 0.41623800 0.20716263 0.10310533 0.05131577
[6] 0.02553998 0.02223419
```

This functions can be plotted:

```
curve(
    fun.campbell.theta.h(
        h       = x,                       # [meter]
        hA      = 0.01,                    # [meter]
        thetaS  = 0.4162380,               # [-]
        bPar    = 3.3                      # [-]
    ),
    xlim = c(0.001,158),
    col  = "red",
    log  = "x",
    xlab = "h, pressure head [m]",
    ylab = expression( theta~", water content [-]" ),
    main = expression( 'Campbell 1974: '~theta=='f(h)' )
)   #
abline( v = 0.01 )
```



The function is actually the same as Brooks and Corey 1964, but the parameter bPar (equal to $1/lambda$) is also used in the hydraulic conductivity function, which reduce the number of parameters to measure / estimate.

4 Hydraulic conductivity functions

4.1 Mualem (1976) + van Genuchten 1980

[TO BE WRITTEN – WORK ON PROGRESS]

References

[1] Brooks and Corey. Hydraulic properties of porous media. Technical report, Colorado State University, Fort Collins, USA. Hydrology paper, 3, 1964.

[2] Campbell. A simple-method for determining unsaturated conductivity from moisture retention data. *Soil Science*, 117:6:311–314, 1974.

[3] Y. Mualem. A new model for predicting the hydraulic conductivity of unsaturated porous media. *Water Resources Research*, 12:513–522, 1976.

[4] R Development Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria, 2011. ISBN 3-900051-07-0.

[5] M. Th. van Genuchten. A closed form equation for predicting the hydraulic conductivity of unsaturated soils. *Soil Science Society of America Journal*, 44:892–898, 1980.