Package 'Porous'

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Type Package

Title Dual porosity SOC decomposition model (draft)

Version 0.1.0

Author Lorenzo Menichetti

Maintainer Lorenzo Menichetti <Lorenzo.Menichetti@slu.se>

Description This package contains a draft version of the dual porosity SOC decomposition model developed by Meurer and Jarvis. The model is being actively developed.
Original description in: Meurer, Katharina Hildegard Elisabeth, Claire Chenu, Elsa Coucheney, Anke Marianne Herrmann, Thomas Keller, Thomas Kätterer, David Nimblad Svensson, and Nicholas Jarvis. "Modelling Dynamic Interactions between Soil Structure and the Storage and Turnover of Soil Organic Matter." Biogeosciences 17, no. 20 (October 19, 2020): 5025–42. https://doi.org/10.5194/bg-17-5025-2020.

Imports SoilR

Suggests knitr,
rmarkdown

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Encoding UTF-8

LazyData true

RoxygenNote 7.2.3

VignetteBuilder knitr

R topics documented:

Delta_z *Variation of the thickness of soil layer*

Description

This function calculates the variation of the thickness of soil layer as a function of organic matter. The parameter f_{agg} should be estimated from data on the relationship between bulk density (or its inverse, the specific volume) and soil organic matter content (see eq. 19 and fig. 4 in Meurer et al., 2020; from this data and other studies, a good average value of fagg should be around 3, which is the default value)

Usage

```
Delta_z(
  f_agg = 3,
  Delta_z_min,
  My_mic,
  Mo_mic,
  My_mes,
  Mo_mes,
  phi_mac,
  gamma_o
)
```

Arguments

f_agg	an aggregation factor (m3 pore space m-3 organic matter) defined as the slope of the linear relationship assumed between the volume of aggregation pore space V_{agg}, and the volume of organic matter V_{s_o}
Delta_z_min	minimal soil thickness if no organic matter was present
My_mic	One of the four model pools (they are all summed up in this function for calculating the total)
Mo_mic	One of the four model pools (they are all summed up in this function for calculating the total)
My_mes	One of the four model pools (they are all summed up in this function for calculating the total)
Mo_mes	One of the four model pools (they are all summed up in this function for calculating the total)
phi_mac	macroporosity
gamma_o	density of organic matter

Value

one single value

`f_text_mic_func` *Proportion of micropores*

Description

This function calculates the proportion of the textural pore space that comprises micropores. It is used in `pore_frac`. This parameter was intended in the original paper (Meurer et al., 2020) as user defined, but its estimation has been developed further by N. Jarvis (personal communication). The method for its estimation is based on a Brooks-Corey soil water retention model:

$$f_{mic_{text}} = \left(\frac{\psi_{mes \backslash mac}}{\psi_{mic \backslash mes}} \right)^{\lambda_{mat(t)}}$$

where $\psi_{mes \backslash mac}$ is the pressure head defining the largest mesopore (set to -0.3) and $\psi_{mic \backslash mes}$ is the pressure head defining the largest micropore (set to -0.6). The parameter $\lambda_{mat(t)}$ is in turn estimated as:

$$\lambda_{mat(t)} = \frac{log\left(\frac{\theta_w}{\phi_{min}}\right)}{log\left(\frac{\psi_{mes \backslash mac}}{\psi_w}\right)}$$

where psi_w is the wilting oint pressure head (set to -150 m) and θ_w is estimated from a pedotransfer function:

$$\theta_w = 0.004 + 0.5 \cdot f_{clay}$$

where f_{clay} is the soil clay content ($kg\ kg^{-1}$).

Usage

```
f_text_mic_func(clay, phi_min)
```

Arguments

`clay`	soil clay fraction
`phi_min`	minimal porosity, user defined

Value

one single value

phi_mat *Matrix porosity*

Description

This function calculates the matrix porosity ϕ_{mac} based on the variation of organic matter in the soil. It is used in pore_frac to calculate mesoporosity $\phi_{mes} = \phi_{mat} - \phi_{mic}$

Usage

```
phi_mat(
  My_mic,
  Mo_mic,
  My_mes,
  Mo_mes,
  gamma_o,
  f_agg = 3,
  Delta_z_min,
  phi_min,
  phi_mac
)
```

Arguments

My_mic	One of the four model pools (they are all summed up in this function for calculating the total)
Mo_mic	One of the four model pools (they are all summed up in this function for calculating the total)
My_mes	One of the four model pools (they are all summed up in this function for calculating the total)
Mo_mes	One of the four model pools (they are all summed up in this function for calculating the total)
gamma_o	density of organic matter
f_agg	an aggregation factor (m3 pore space m-3 organic matter) defined as the slope of the linear relationship assumed between the volume of aggregation pore space V_{agg}, and the volume of organic matter V_{s_o}
Delta_z_min	minimal soil thickness if no organic matter was present
phi_mac	macroporosity

Value

one single value

phi_mic *Microporosity*

Description

This function calculates the microporosity ϕ_{mic} based on the variation of organic matter in the soil. It is used in pore_frac

Usage

```
phi_mic(
  My_mic,
  Mo_mic,
  My_mes,
  Mo_mes,
  gamma_o,
  f_agg = 3,
  clay,
  Delta_z_min,
  phi_min,
  phi_mac,
  f_text_mic
)
```

Arguments

My_mic	One of the four model pools (they are all summed up in this function for calculating the total)
Mo_mic	One of the four model pools (they are all summed up in this function for calculating the total)
My_mes	One of the four model pools (they are all summed up in this function for calculating the total)
Mo_mes	One of the four model pools (they are all summed up in this function for calculating the total)
gamma_o	density of organic matter
f_agg	an aggregation factor (m3 pore space m-3 organic matter) defined as the slope of the linear relationship assumed between the volume of aggregation pore space V_{agg}, and the volume of organic matter V_{s_o}
clay	fraction of clay content
Delta_z_min	minimal soil thickness if no organic matter was present
phi_min	minimal porosity, user defined
phi_mac	macroporosity

Value

one single value

pore_frac *The main accessory function of the model*

Description

This function calculates the proportion of inputs in each of the two youg pools deending on the organic matter content

Usage

```
pore_frac(
  phi_mac,
  clay,
  Delta_z_min,
  gamma_o,
  My_mic,
  Mo_mic,
  My_mes,
  Mo_mes,
  phi_min,
  f_text_mic = NULL
)
```

Arguments

phi_mac	macroporosity
clay	fraction of clay content
Delta_z_min	minimal soil thickness if no organic matter was present
gamma_o	density of organic matter
My_mic	One of the four model pools (they are all summed up in this function for calculating the total)
Mo_mic	One of the four model pools (they are all summed up in this function for calculating the total)
My_mes	One of the four model pools (they are all summed up in this function for calculating the total)
Mo_mes	One of the four model pools (they are all summed up in this function for calculating the total)

Value

two values, the proportion of input in the mesopore and micropore Y pools

`Porous` *The SOC decomposition model*

Description

This function implements with the SoilR model development framework the dual porosity model described in Meurer et al. (2020). The model is an evolution of a two-pool linear SOC model, with two pools (young and old material) running in parallel for micro- and mesopores. While aboveground inputs are rooted in the mesopores, root inputs are distributed between micro and mesopores depending on porosity, which is in turn influenced by organic matter. This makes the model nonlinear, although it still behaves similarly to a linear model within a reasonable calibration range. The model is described by a series of four equations:

$$\frac{dM_{Y_{(mes)}}}{dt} = I_m + \left(\frac{\phi_{mes}}{\phi_{mes}+\phi_{mic}}\right) \cdot I_r - k_Y \cdot M_{Y_{(mes)}} + T_Y$$
$$\frac{dM_{O_{(mes)}}}{dt} = \left(\epsilon \cdot k_Y \cdot M_{Y_{(mes)}}\right) - \left((1-\epsilon) \cdot k_O \cdot M_{O_{(mes)}}\right) + T_O$$
$$\frac{dM_{Y_{(mic)}}}{dt} = \left(\frac{\phi_{mic}}{\phi_{mes}+\phi_{mic}}\right) \cdot I_r - k_Y \cdot F_{prot} \cdot M_{Y_{(mes)}} - T_Y$$
$$\frac{dM_{O_{(mic)}}}{dt} = \left(\epsilon \cdot k_Y \cdot F_{prot} \cdot M_{Y_{(mes)}}\right) - \left((1-\epsilon) \cdot k_O \cdot F_{prot} \cdot M_{O_{(mes)}}\right) - T_O$$

Please refer to the original paper for more details.

The two porosity terms, $\phi_{mes} = f(M_{Y_{(mes)}}, M_{O_{(mes)}}, M_{Y_{(mic)}}, M_{O_{(mic)}})$ and $\phi_{mic} = f(M_{Y_{(mic)}}, M_{O_{(mic)}})$, are dependent on the variation of the different C pools and everything is variable over time, introducing a nonlinearity in the system and defining the biggest peculiarity of this model.
After substitutung the terms $\left(\frac{\phi_{mes}(t)}{\phi_{mes}(t)+\phi_{mic}(t)}\right) = \varphi_{mes}$ and $\left(\frac{\phi_{mic}(t)}{\phi_{mes}(t)+\phi_{mic}(t)}\right) = \varphi_{mic}$, The model can be rewritten in matrix form as :

$I_m(t) + I_r(t) \cdot N(C,t) + A(t) \cdot P(t) \cdot C(t)$
Or, more explicitly:

$$\frac{dC}{dt} = \begin{bmatrix} I_m \\ 0 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} I_r \\ 0 \\ I_r \\ 0 \end{bmatrix} \cdot \begin{bmatrix} \varphi_{mes} & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \varphi_{mic} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} + \begin{bmatrix} -k_y & \epsilon & 0 & 0 \\ 0 & -k_o & 0 & 0 \\ T_Y & 0 & -k_y & \epsilon \\ 0 & T_O & 0 & -k_o \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & F_{prot} & 0 \\ 0 & 0 & 0 & F_{prot} \end{bmatrix} \cdot \begin{bmatrix} M_{Y_{mes}} \\ M_{O_{mes}} \\ M_{Y_{mic}} \\ M_{O_{mic}} \end{bmatrix}$$

The model is implemented with the `SoilR` package, but it is relying on a more conventional ODE definition (not its matrix form).

Usage

```
Porous(
  ky = 0.8,
  ko = 0.035,
```

```
  kmix = 0.05,
  e = 0.143,
  Im = 1.1,
  Ir = 0.5,
  F_prot = 0.1,
  phi_mac = 0.152,
  clay = 0.2,
  Delta_z_min = 4,
  gamma_o = 1.2,
  proportion = NULL,
  phi_min = 0.35,
  f_text_mic = NULL
)
```

Arguments

ky	decomposition constant of the Young pool
ko	decomposition constant of the Old pool
kmix	mixing rate
e	efficiency, which is the transfer term between the pools and corresponds to the term h in the ICBM model in Kätterer et al. (2001)
Im	Inputs from aboveground
Ir	Inputs from roots, which is partitioned between micropore and mesopores with the function pore_frac
F_prot	protection provided by the micropore space
phi_mac	macroporosity
clay	fraction of clay content
Delta_z_min	minimal soil thickness if no organic matter was present
gamma_o	density of organic matter
proportion	this is a linearization term to make the proportion of the inputs between micro- and mesopores constant. If NULL (or not specified, since default is NULL) then the model is running as nonlinear, as in the original paper. If specified (must be between 0 and 1) then the model is linearized adopting this value as fixed proportion of inputs from roots going into the mesopore space (and its reciprocal into the micropore)
phi_min	minimum matrix porosity, user defined

Value

two values, the proportion of input in the mesopore and micropore Y pools

References

Meurer, Katharina Hildegard Elisabeth, Claire Chenu, Elsa Coucheney, Anke Marianne Herrmann, Thomas Keller, Thomas Kätterer, David Nimblad Svensson, and Nicholas Jarvis. "Modelling Dynamic Interactions between Soil Structure and the Storage and Turnover of Soil Organic Matter."

Biogeosciences 17, no. 20 (October 19, 2020): 5025–42. https://doi.org/10.5194/bg-17-5025-2020.
Kätterer, Thomas, and Olof Andrén. "The ICBM Family of Analytically Solved Models of Soil Carbon, Nitrogen and Microbial Biomass Dynamics — Descriptions and Application Examples." Ecological Modelling 136, no. 2–3 (January 2001): 191–207. https://doi.org/10.1016/S0304-3800(00)00420-8.

Index