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 = f_agg,
  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} (dimensionless)
Delta_z_min	minimal soil thickness if no organic matter was present (cm)
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, $(\frac{cm^3 of water}{cm^3 of soil})$

Value

one single value

`f_som` *Soil C concentration*

Description

This function calculates the soil C concentration. It relies on `Msm` to calculate the mineral mass.

Usage

```
f_som(My_mic, Mo_mic, My_mes, Mo_mes, Delta_z_min, phi_min, gamma_m)
```

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)
`Delta_z_min`	minimal soil thickness if no organic matter was present (cm)
`phi_min`	minimal porosity, ($\frac{cm^3 of water}{cm^3 of soil}$)

Value

one single value

See Also

`Msm`

`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	fraction of clay content (dimensionless, between 0 and 1)
phi_min	minimal porosity, ($\frac{cm^3 of water}{cm^3 of soil}$)

Value

one single value

---

gamma_b *Soil bulk density*

Description

This function calculates the soil bulk density. It relies on Msm to calculate the mineral mass.

Usage

```
gamma_b(
  My_mic,
  Mo_mic,
  My_mes,
  Mo_mes,
  Delta_z_min,
  phi_min,
  gamma_o,
  gamma_m,
  f_agg,
  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)
Delta_z_min	minimal soil thickness if no organic matter was present (cm)
phi_min	minimal porosity, $(\frac{cm^3 of water}{cm^3 of soil})$
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} (dimensionless)
phi_mac	macroporosity, $(\frac{cm^3 of water}{cm^3 of soil})$

Value

one single value

See Also

Msm

Msm *Mineral mass*

Description

This function calculates the mineral mass

Usage

```
Msm(Delta_z_min, phi_min, gamma_m)
```

Arguments

Delta_z_min	minimal soil thickness if no organic matter was present (cm)

Value

one single value

See Also

Delta_z_min, gamma_b, f_som

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,
  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)
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} (dimensionless)
Delta_z_min	minimal soil thickness if no organic matter was present (cm)
phi_min	minimal porosity, $(\frac{cm^3 of water}{cm^3 of soil})$
phi_mac	macroporosity, $(\frac{cm^3 of water}{cm^3 of soil})$

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 = f_agg,
  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)
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} (dimensionless)
clay	fraction of clay content (dimensionless, between 0 and 1)
Delta_z_min	minimal soil thickness if no organic matter was present (cm)
phi_min	minimal porosity, $(\frac{cm^3 of water}{cm^3 of soil})$
phi_mac	macroporosity, $(\frac{cm^3 of water}{cm^3 of soil})$

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,
  f_agg
)
```

Arguments

phi_mac	macroporosity, $(\frac{cm^3 of water}{cm^3 of soil})$
clay	fraction of clay content (dimensionless, between 0 and 1)
Delta_z_min	minimal soil thickness if no organic matter was present (cm)
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_min	minimal porosity, $(\frac{cm^3 of water}{cm^3 of soil})$

Value

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

See Also

phi_mic, phi_mat, f_som

Porous *The SOC decomposition model **STILL TESTING; NOT YET WORKING, use the deSolve function instead***

Description

This function implements with the SoilR model development framework the dual porosity model described in Meurer et al. (2020). THis function provides just the model definition, that needs then to be run with specific SoilR functions. A more comfortable wrapper for doing this automatically is provided in the package (run_Porous). 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 terms T_Y and T_Y are calculated in the original paper as $k_{mix} \cdot \frac{(My_{mic} - My_{mes})}{2}$ and $k_{mix} \cdot \frac{(Mo_{mic} - Mo_{mes})}{2}$, but in a later model development the term 2 disappeared and are now calculaged as $T_Y = k_{mix} \cdot (My_{mic} - My_{mes})$ and $T_O = k_{mix} \cdot (Mo_{mic} - Mo_{mes})$.

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 substituting 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 :

$$I_m(t) + I_r(t) \cdot N(C,t) + A(t) \cdot P(t) \cdot C(t)$$

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,
  ko,
  kmix,
  e,
  Im,
  Ir,
  F_prot,
  phi_mac,
```

```
    phi_min,
    clay,
    Delta_z_min,
    gamma_o,
    proportion = NULL,
    f_text_mic = NULL,
    f_agg
)
```

Arguments

ky	decomposition constant of the Young pool $frac1year$
ko	decomposition constant of the Old pool $frac1year$
kmix	mixing rate $frac1year$
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) (dimensionless)
F_prot	protection provided by the micropore space (dimensionless)
phi_mac	macroporosity, ($\frac{cm^3 of water}{cm^3 of soil}$)
phi_min	minimal porosity, ($\frac{cm^3 of water}{cm^3 of soil}$)
clay	fraction of clay content (dimensionless, between 0 and 1)
Delta_z_min	minimal soil thickness if no organic matter was present (cm)
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)
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} (dimensionless)

Value

two values, the proportion (between 0 and 1) 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.

See Also

run_Porous

`Porous_test` *The SOC decomposition model*

Description

Purely for testing purposes

Usage

```
Porous_test(
  ky,
  ko,
  kmix,
  e,
  Im,
  Ir,
  F_prot,
  phi_mac,
  phi_min,
  clay,
  Delta_z_min,
  gamma_o,
  proportion = NULL,
  f_text_mic = NULL,
  f_agg
)
```

Arguments

`ky`	decomposition constant of the Young pool $frac1year$
`ko`	decomposition constant of the Old pool $frac1year$
`kmix`	mixing rate $frac1year$
`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) (dimensionless)
`F_prot`	protection provided by the micropore space (dimensionless)
`phi_mac`	macroporosity, $(\frac{cm^3 of water}{cm^3 of soil})$
`phi_min`	minimal porosity, $(\frac{cm^3 of water}{cm^3 of soil})$
`clay`	fraction of clay content (dimensionless, between 0 and 1)
`Delta_z_min`	minimal soil thickness if no organic matter was present (cm)
`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)
`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} (dimensionless)

Value

two values, the proportion (between 0 and 1) 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.

See Also

`run_Porous`

`run_Porous` *Run Porous **STILL TESTING; NOT YET WORKING, use the deSolve function instead***

Description

This function is a wrapper for running the main model `Porous`, which is a wrapper for the dual porosity decomposition model (equations 1 to 6) described in Meurer et al. (2020) implemented in ‘SoilR‘. It then feeds the simulated SOC stocks to the functions `gamma_b` and `f_som` to calculate the variation of bulk density and C concentrations

Usage

```
run_Porous(
  ky,
  ko,
  kmix,
  e,
  Im,
  Ir,
  F_prot,
  phi_mac,
  phi_min,
  clay,
  Delta_z_min,
  gamma_o,
  gamma_m,
  proportion = NULL,
  f_text_mic = NULL,
  f_agg,
  init,
  sim_length,
  sim_steps
)
```

Arguments

ky	decomposition constant of the Young pool $frac1year$
ko	decomposition constant of the Old pool $frac1year$
kmix	mixing rate $frac1year$
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) (dimensionless)
F_prot	protection provided by the micropore space (dimensionless)
phi_mac	macroporosity, $(\frac{cm^3 of water}{cm^3 of soil})$
phi_min	minimal porosity, $(\frac{cm^3 of water}{cm^3 of soil})$
clay	fraction of clay content (dimensionless, between 0 and 1)
Delta_z_min	minimal soil thickness if no organic matter was present (cm)
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)
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} (dimensionless)
sim_steps	steps of the simulation (fraction of one year)
sim_lenght	length of the simulation (years)

Value

a data frame with the simulation of C stocks for each of the four pools, soil respiration for each of the four pools, bulk density variation and SOC concentration.

See Also

Porous, gamma_b, f_som

`run_Porous_deSolve` *The SOC decomposition model implemented as an system of differential equations with the* `deSolve` *package.*

Description

This function implements the dual porosity model described in Meurer et al. (2020). The model is the same as in `run_Porous` and `Porous` but it is implemented differently, directly as a wrapper of the system of equations within the `deSolve` package. This implementation was designed during the development of the package, as a more transparent way of running the model and check for errors, but it does run correctly and is perfectly usable. This command relies on the same functions than `Porous` to calculate the partitioning of the inputs between meso- and micropores. This version currently do not provide separately the respiration fluxes but only the soil C stocks.

Usage

```
run_Porous_deSolve(
  ky,
  ko,
  kmix,
  e,
  Im,
  Ir,
  F_prot,
  phi_mac,
  phi_min,
  clay,
  Delta_z_min,
  gamma_o,
  gamma_m,
  proportion = NULL,
  f_text_mic = NULL,
  f_agg,
  init,
  sim_length,
  sim_steps,
  constant = FALSE
)
```

Arguments

ky	decomposition constant of the Young pool $frac1year$
ko	decomposition constant of the Old pool $frac1year$
kmix	mixing rate $frac1year$
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) (dimensionless)
F_prot	protection provided by the micropore space (dimensionless)
phi_mac	macroporosity, $(\frac{cm^3 of water}{cm^3 of soil})$
phi_min	minimal porosity, $(\frac{cm^3 of water}{cm^3 of soil})$
clay	fraction of clay content (dimensionless, between 0 and 1)
Delta_z_min	minimal soil thickness if no organic matter was present (cm)
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)
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} (dimensionless)
constant	boolean, if TRUE then the solver run in constant input mode, otherwise in variable input mode. Default is FALSE.

Details

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 terms T_Y and T_Y are calculated in the original paper as $k_{mix} \cdot \frac{(My_{mic}-My_{mes})}{2}$ and $k_{mix} \cdot \frac{(Mo_{mic}-Mo_{mes})}{2}$, but in a later model development the term 2 disappeared and are now calculaged as $T_Y = k_{mix} \cdot (My_{mic} - My_{mes})$ and $T_O = k_{mix} \cdot (Mo_{mic} - Mo_{mes})$.

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.

Value

two values, the proportion (between 0 and 1) 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.

See Also

`run_Porous`

`run_Porous_nonlinear_deSolve`
The SOC decomposition model implemented as an system of differential equations with the `deSolve` *package.*

Description

This function implements the dual porosity model described in Meurer et al. (2020). The model is the same as in run_Porous and Porous but it is implemented differently, directly as a wrapper of the system of equations within the deSolve package. This implementation was designed during the development of the package, as a more transparent way of running the model and check for errors, but it does run correctly and is perfectly usable. This command relies on the same functions than Porous to calculate the partitioning of the inputs between meso- and micropores. This version currently do not provide separately the respiration fluxes but only the soil C stocks.

Usage

```
run_Porous_nonlinear_deSolve(
  ky,
  ko,
  kmix,
  e,
  Im,
  Ir,
  F_prot,
  phi_mac,
  phi_min,
  clay,
  Delta_z_min,
  gamma_o,
  gamma_m,
  proportion = NULL,
  f_text_mic = NULL,
  f_agg,
  Tref,
  Tmin,
  Ts,
  init,
  sim_length,
  sim_steps,
  constant = FALSE
)
```

Arguments

ky	decomposition constant of the Young pool $frac1year$
ko	decomposition constant of the Old pool $frac1year$
kmix	mixing rate $frac1year$
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) (dimensionless)
F_prot	protection provided by the micropore space (dimensionless)
phi_mac	macroporosity, $(\frac{cm^3 of water}{cm^3 of soil})$
phi_min	minimal porosity, $(\frac{cm^3 of water}{cm^3 of soil})$
clay	fraction of clay content (dimensionless, between 0 and 1)
Delta_z_min	minimal soil thickness if no organic matter was present (cm)

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)
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} (dimensionless)
Tref	reference temperature for the temperature scaling function $^{\circ}C$
Tmin	temperature at which mineralization ceases for the temperature scaling function $^{\circ}C$
Ts	soil temperature for the temperature scaling function $^{\circ}C$
constant	boolean, if TRUE then the solver run in constant input mode, otherwise in variable input mode. Default is FALSE.

Details

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 terms T_Y and T_Y are calculated in the original paper as $k_{mix} \cdot \frac{(My_{mic}-My_{mes})}{2}$ and $k_{mix} \cdot \frac{(Mo_{mic}-Mo_{mes})}{2}$, but in a later model development the term 2 disappeared and are now calculaged as $T_Y = k_{mix} \cdot (My_{mic} - My_{mes})$ and $T_O = k_{mix} \cdot (Mo_{mic} - Mo_{mes})$.

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.
This particular version (nonlinear) includes a modification of the original to include second order microbial interactions:

$k_{(u,mes)} = max\left(0, (1 - \frac{A_a}{\epsilon k_t \left(k_y \frac{Y_{(mes)}}{\Delta z} + k_o \frac{O_{(mes)}}{\Delta z}\right)})\right)$ and:

$$k_{(u,mic)} = max\left(0, (1 - \frac{A_a}{\epsilon k_t F_{prot} \left(k_y \frac{Y_{(mic)}}{\Delta z} + k_o \frac{O_{(mic)}}{\Delta z}\right)})\right)$$

This version implements also a temperature reduction function:

$$k_t = \begin{cases} \frac{(T_s - T_{\min})^2}{(T_{\text{ref}} - T_{\min})^2} & \text{if } T_s \geq T_{\min} \\ 0 & \text{if } T_s < T_{\min} \end{cases}$$

where

$$Ts$$

is the soil temperature,

$$Tref$$

is a reference temperature and

$$Tmin$$

is the temperature at which the mineralization of soil organic matter ceases. The terms

$$k_{u,i}$$

and

$$k_t$$

are linear multipliers of all kinetic terms

Value

two values, the proportion (between 0 and 1) of input in the mesopore and micropore Y pools

References

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See Also

run_Porous

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