Carmela Marangi

Modelling of Soil Organic Carbon dynamics in wetlands

Joint work of V. Bohaienko, F. Diele, C. Marangi, A. Martiradonna, A. Provenzale

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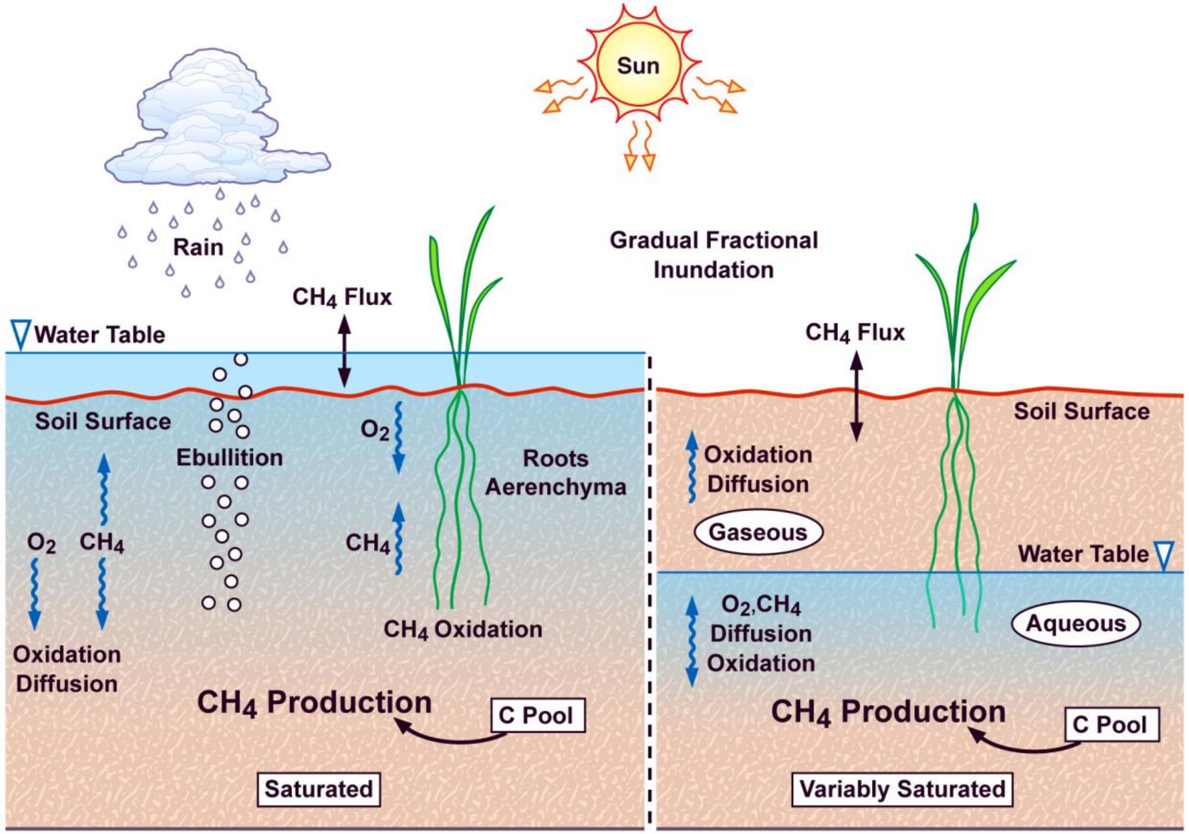
Modelling of Soil Organic Carbon Dynamics in Wetlands



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RESTORE4Cs

Riley, W. J., Subin, Z. M., Lawrence, D. M., Swenson, S. C., Torn, M. S., Meng, L., ... & Hess, P. (2011). Barriers to predicting changes in global terrestrial methane fluxes: analyses using CLM4Me, a methane biogeochemistry model integrated in CESM. *Biogeosciences*, *8*(7), 1925-1953.

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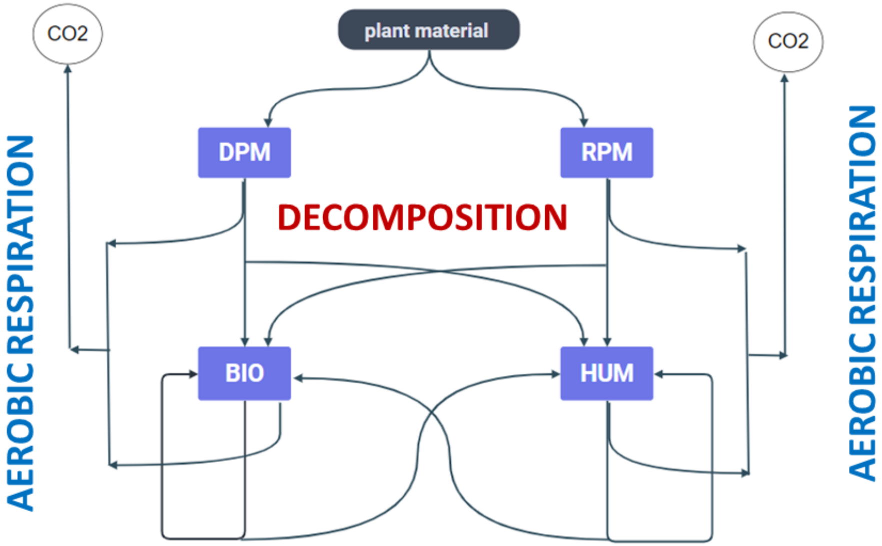
RothC Model

Model's assumption:

In unsaturated zones of soil SOC decomposition is performed by bacteria that respire CO_2



CO2

plant material

CO2

DPM

RPM

DECOMPOSITION

BIO

HUM

AEROBIC RESPIRATION

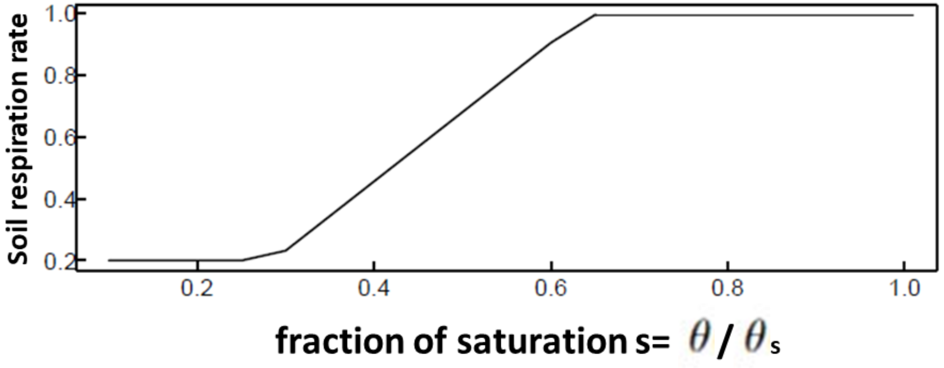
AEROBIC RESPIRATION

Diele, F., Marangi, C., & Martiradonna, A. (2021). Non-standard discrete RothC models for soil carbon dynamics. *Axioms*, *10*(2), 56.

Carbon decomposition is modeled by:

Intrinsic respiration rates that describe the transition from bacteria activity resulting in CO_2 generation

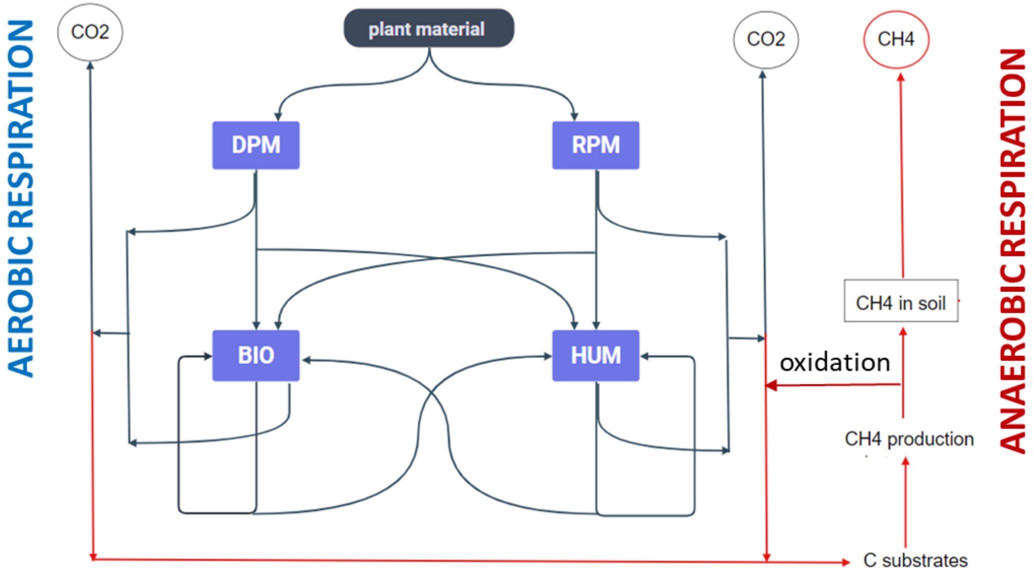
Modifying rate factor for soil moisture



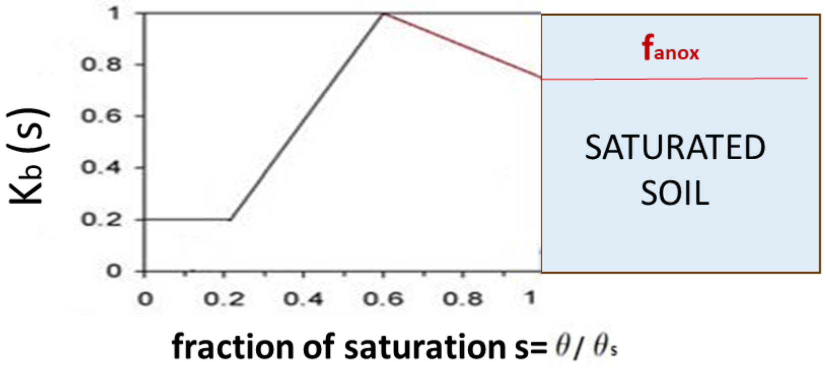
Model’s assumptions

Model's assumption:

In large saturated zones of soil SOC decomposition is performed by different bacteria that respire CO_2 or CH_4



Zhang, Y., Li, C., Trettin, C. C., Li, H., & Sun, G. (2002). An integrated model of soil, hydrology, and vegetation for carbon dynamics in wetland ecosystems. *Global biogeochemical cycles*, *16*(4), 9-1.

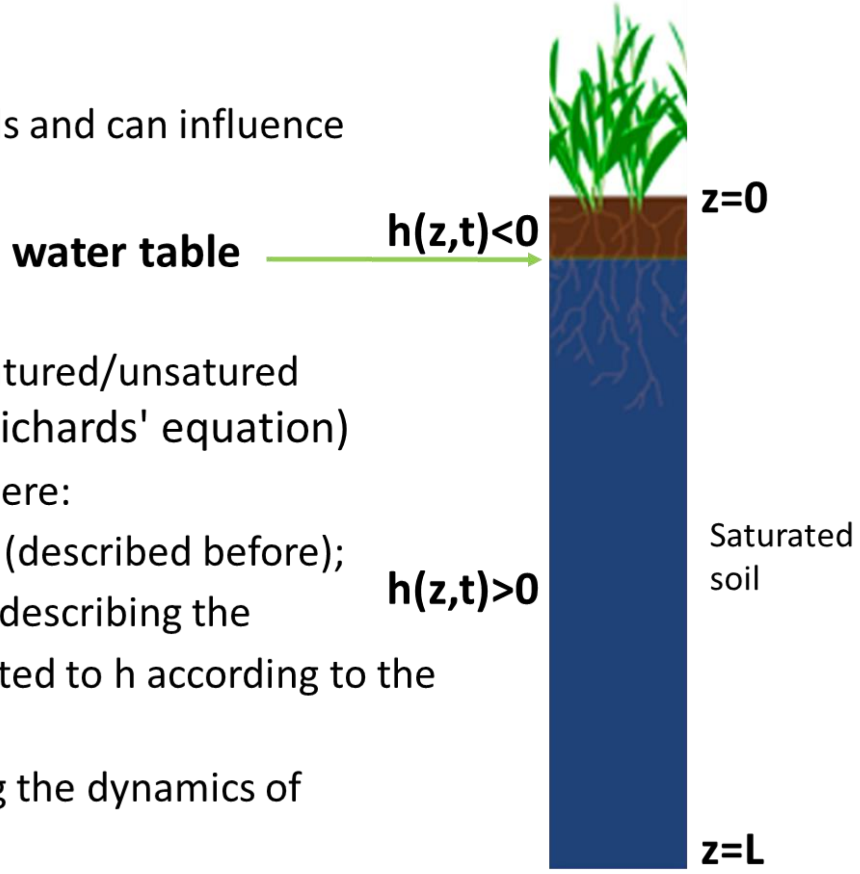


Modifying rate factor for soil moisture

$$K_b(s) = \begin{cases} 0.2, & \text{if } s(t) \le s_{min} \\ 1 - 0.8\dfrac{s_0 - s(t)}{s_0 - s_{min}}, & \text{if } s_{min} < s(t) \le s_0 \\ 1 - (1 - f_{anox})\dfrac{s(t) - s_0}{1 - s_0}, & \text{if } s_0 < s(t) \le 1 \end{cases}$$

In-depth RothC for wetlands

The vertical water flow can be significant in wetlands and can influence the dynamics of in-depth SOC concentration

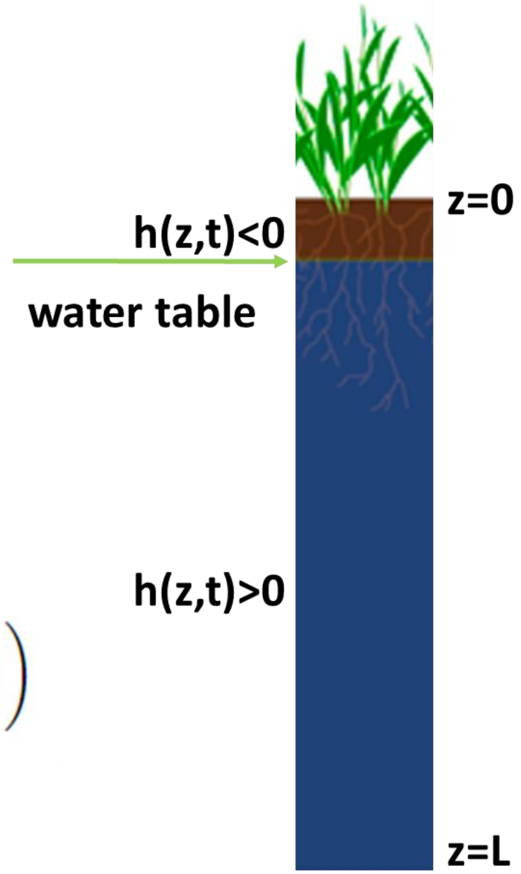


Model's structure

- Water head pressure **h=h(z,t)** [L] dynamics in satured/unsatured soil described by **Richardson equation** (1D Richards' equation)
- **SOC diffusion-advection-reaction equations** were:
  reaction given by **modified RothC for wetland** (described before);
  advection term $v(z,t) = K(h)\left(\frac{\partial h}{\partial z} - 1\right)\ [\mathrm{LT}^{-1}]$ for describing the transport of SOC due to vertical water flow related to h according to the Darcy's law
- **temperature transport equation** for describing the dynamics of in-depth temperature distribution

In-depth RothC for wetlands

The vertical water flow can be significant in wetlands and can influence the dynamics of in-depth SOC concentration



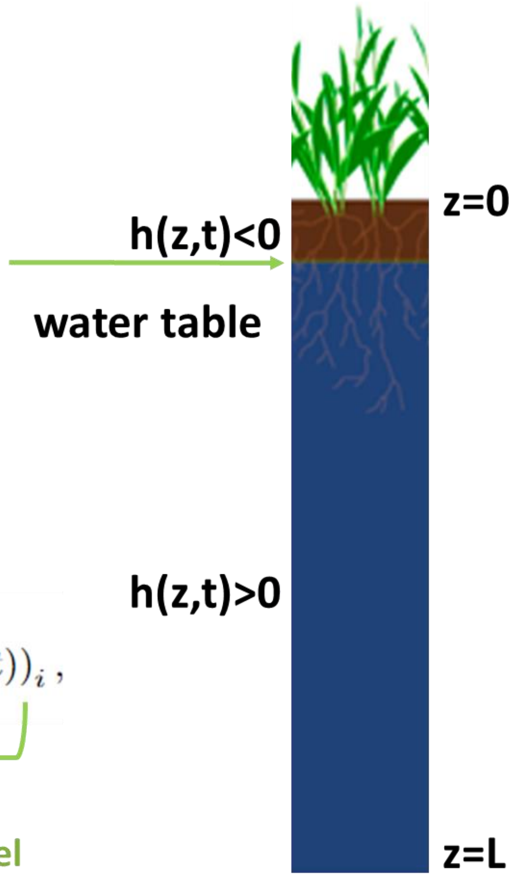
Model’s structure

- Water head pressure **h=h(z,t)** [L] dynamics
  Richardson equation (1D Richards' equation)

$$\left(C(h,z)+\frac{\theta(h,z)}{\theta_s(z)}S_s(z)\right)\frac{\partial h(z,t)}{\partial t}=\frac{\partial}{\partial z}\left(k(h,z)\left(\frac{\partial h(z,t)}{\partial z}-1\right)\right)$$

In-depth RothC for wetlands

The vertical water flow can be significant in wetlands and can influence the dynamics of in-depth SOC concentration



Model's structure

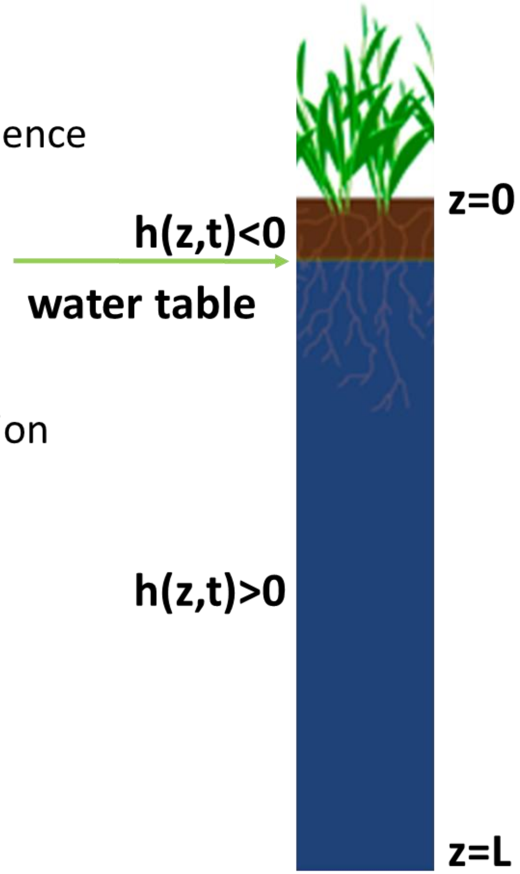
- SOC compounds diffusion-advection-reaction equations, the reaction part of which is in the form of RothC model for wetland;

$$\sigma \frac{\partial c_i(z,t)}{\partial t} = D_i \frac{\partial^2 c_i(z,t)}{\partial z^2} - v(z,t)\frac{\partial c_i(z,t)}{\partial z} + \underbrace{(\rho(z,t)\, A\, \mathbf{c}(z,t) + \mathbf{b}(z,t))_i}_{\text{Original RothC model}},$$

$$i = 0, \ldots, 3$$

In-depth RothC for wetlands

The vertical water flow can be significant in wetlands and can influence the dynamics of in-depth SOC concentration



Model's structure

- Temperature transport equation (to consider in depth distribution of temperature influence of microbial activity).

$$C_T \frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(\lambda \frac{\partial T}{\partial z}\right) - v(z)\frac{\partial T}{\partial z}$$

$$T\big|_{z=0} = T_a, \quad \frac{\partial T}{\partial z}\Big|_{z=L} = 0$$

Boundary conditions

In-depth RothC for wetlands.

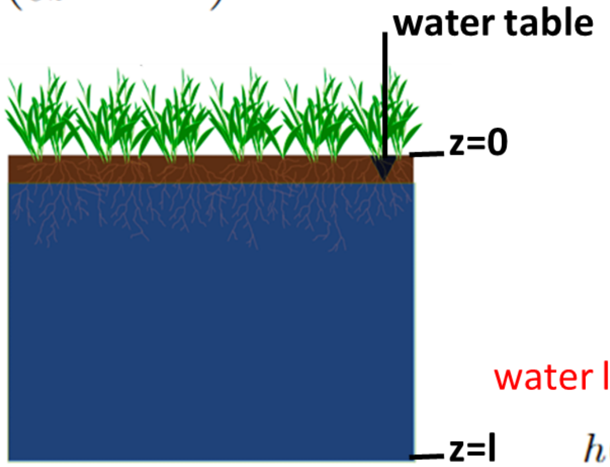
Boundary conditions that can take into account periodical flooding

h(z,t): water head pressure

Non submerged soil:

prescribed flow (Neumann condition)

$$-K(h(0,t))\left(\frac{\partial h}{\partial z}(0,t)-1\right)=P(t)-E(t)$$



$$l_e(t)$$

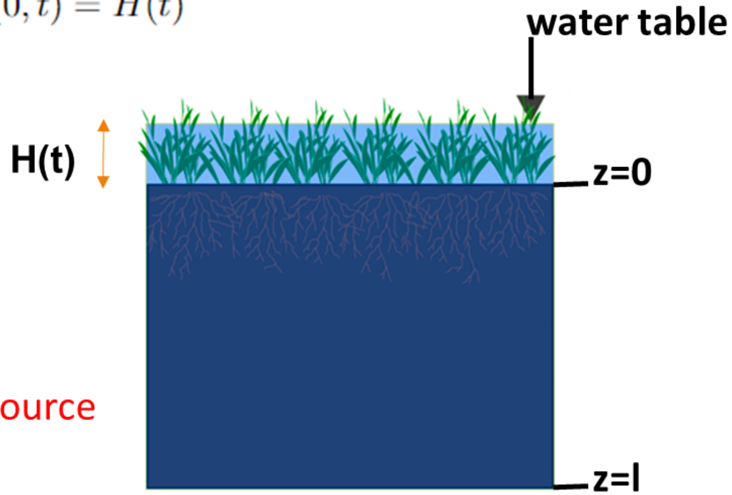
water level in an external source

$$h(l,t)=l-l_e(t)$$

Submerged soil:

prescribed value (Dirichlet condition)

$$h(0,t)=H(t)$$



Figures from: Asmuß, T., Bechtold, M., & Tiemeyer, B. (2019). On the potential of Sentinel-1 for high resolution monitoring of water table dynamics in grasslands on organic soils. *Remote Sensing*, *11*(14), 1659.

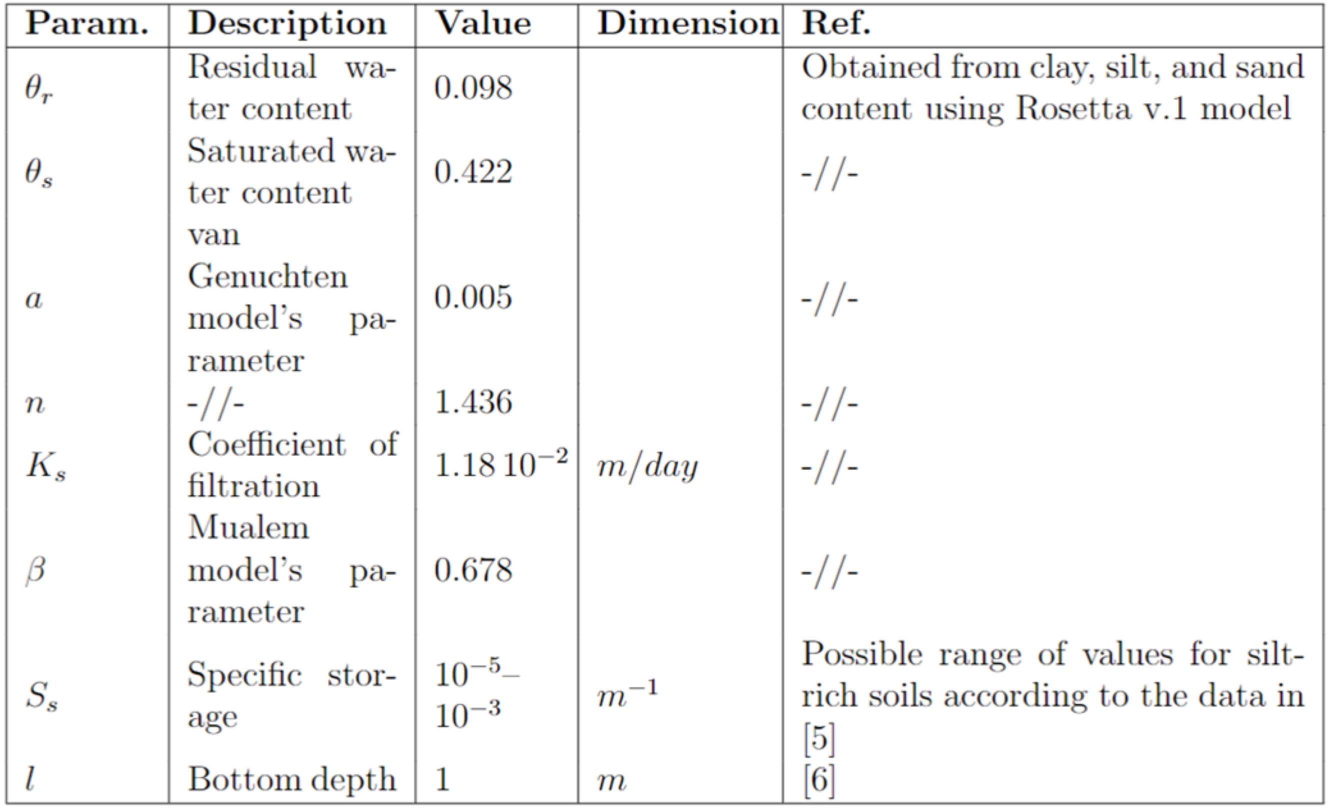
Scenario

The considered scenario was the growth of rice in the lands of Ebro Delta. Rice fields are flooded from the end of April to September-October. Flooding was modelled by linear change of water level Le(t) from the value below bottom depth in December-January to the level of 10 cm above soil surface in May-September

Monthly averaged precipitation and air temperature data was taken from the website https://en.climate-data.org/europe/spain/catalonia/amposta-56879/ for the city of Amposta, the nearest to the Ebro delta. Having only temperature data, evapotranspiration was calculated according to the Hargreaves-Saman formula

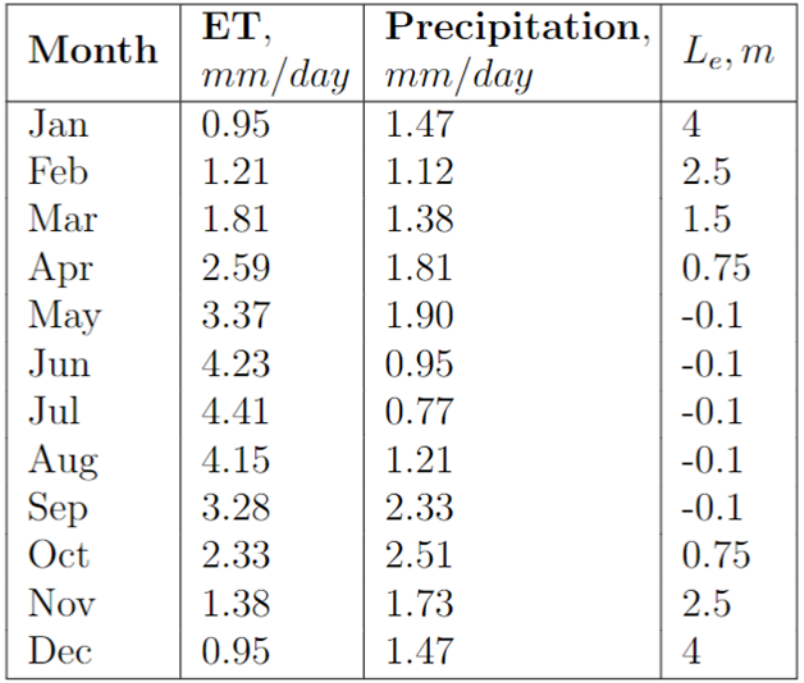
M. Belenguer-Manzanedo, C. Alcaraz, M. Martinez-Eixarch, A. Camacho, J. Morris, C. Ibanez, Modeling soil accretion and carbon accumulation in deltaic rice fields, Ecological Modelling 484 (2023) 110455

Parameters



Param.	Description	Value	Dimension	Ref.
θ_r	Residual water content	0.098		Obtained from clay, silt, and sand content using Rosetta v.1 model
θ_s	Saturated water content	0.422		-//-
a	van Genuchten model's parameter	0.005		-//-
n	-//-	1.436		-//-
K_s	Coefficient of filtration	$1.18\,10^{-2}$	m/day	-//-
β	Mualem model's parameter	0.678		-//-
S_s	Specific storage	10^{-5}–10^{-3}	m^{-1}	Possible range of values for silt-rich soils according to the data in [5]
l	Bottom depth	1	m	[6]

Table 1: The values of parameters for the Richards' - Richardson equation

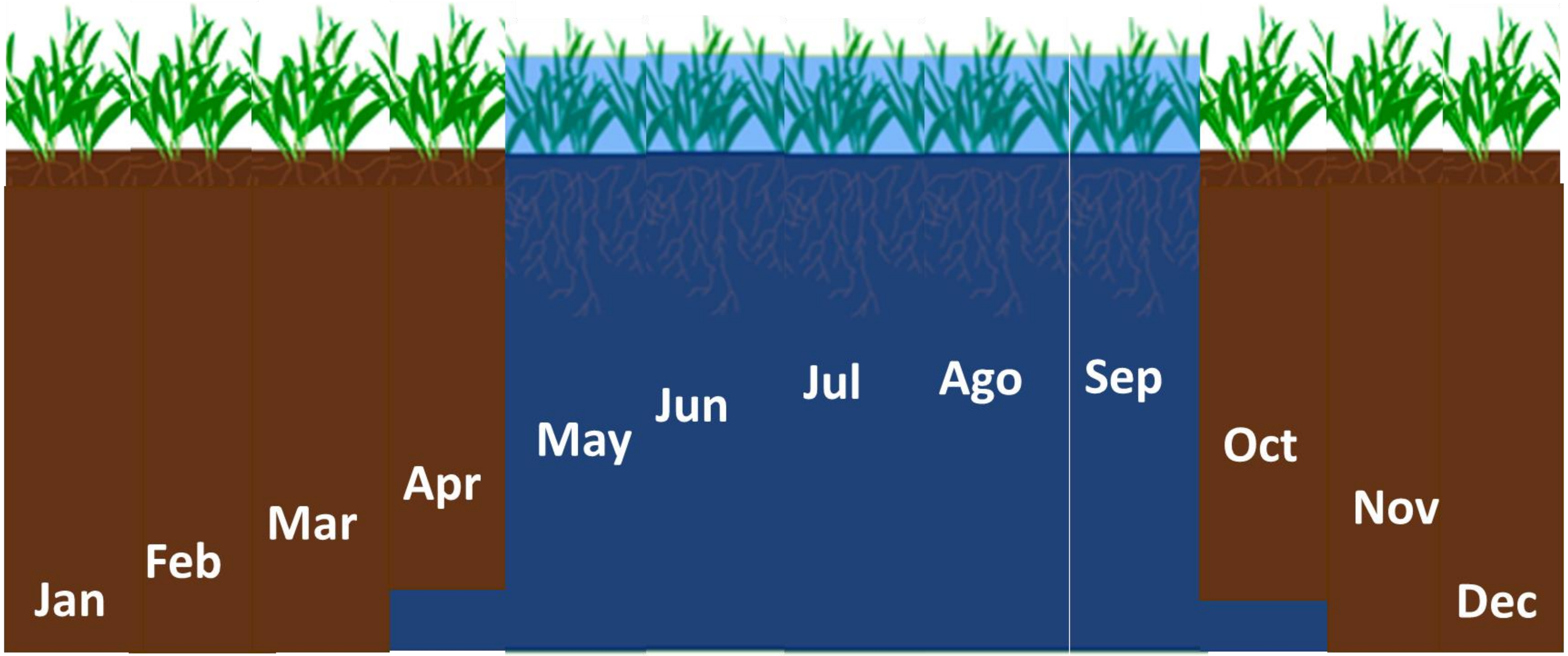


Month	ET, mm/day	Precipitation, mm/day	L_e, m
Jan	0.95	1.47	4
Feb	1.21	1.12	2.5
Mar	1.81	1.38	1.5
Apr	2.59	1.81	0.75
May	3.37	1.90	-0.1
Jun	4.23	0.95	-0.1
Jul	4.41	0.77	-0.1
Aug	4.15	1.21	-0.1
Sep	3.28	2.33	-0.1
Oct	2.33	2.51	0.75
Nov	1.38	1.73	2.5
Dec	0.95	1.47	4

Table 2: The values of parameters

Simulations

One-year simulation



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Diele, F., Luiso, I., Marangi, C. et al. Evaluating the impact of increasing temperatures on changes in Soil Organic Carbon stocks: sensitivity analysis and non-standard discrete approximation. Comput Geosci 26, 1345–1366 (2022), https://doi.org/ 10.1007/s10596-022-10165-3.

Diele, F., Marangi, C., Martiradonna, A. (2021). *Non-Standard Discrete RothC Models for Soil Carbon Dynamics*, Axioms, 10(2), 56.

https://github.com/CnrIacBaGit/NSRothC

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Thank you for your attention!

Any questions?

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- **Climate Change Impact on Biodiversity Patterns** | Lecce, Italy, 21-22 February 2024
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- **Biogeography** | Bologna, Italy, 4-5 April 2024
- **Biodiversity Observatory Automation** | Ljubljana, Slovenia, 11 April 2024
- **Habitat Mapping** | Aveiro, Portugal, 3 May 2024