KZR INiG System/8.2

Soil Models

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1. RothC Model (Rothamsted Carbon Model)

Model description

RothC is a model for the turnover of organic carbon in non-waterlogged topsoil that allows for the inclusion of the effects of soil type, temperature, moisture content and plant cover on the turnover process, with a monthly time step.

C sequestration in RothC is quantified solely based on soil processes, and as such it is not linked to a plant production model. The user defines carbon inputs to the soil. SOC is split into four active compartments and one inactive compartment which comprises the inert organic matter (IOM).

The structure of the model:

The four active compartments differ in the mean residence time of organic carbon in the soil and are defined as:

- Decomposable Plant Material (DPM);
- Resistant Plant Material (RPM);
- Microbial Biomass (BIO);
- Humified Organic Matter (HUM).

The structure of the model is shown in Figure 1.

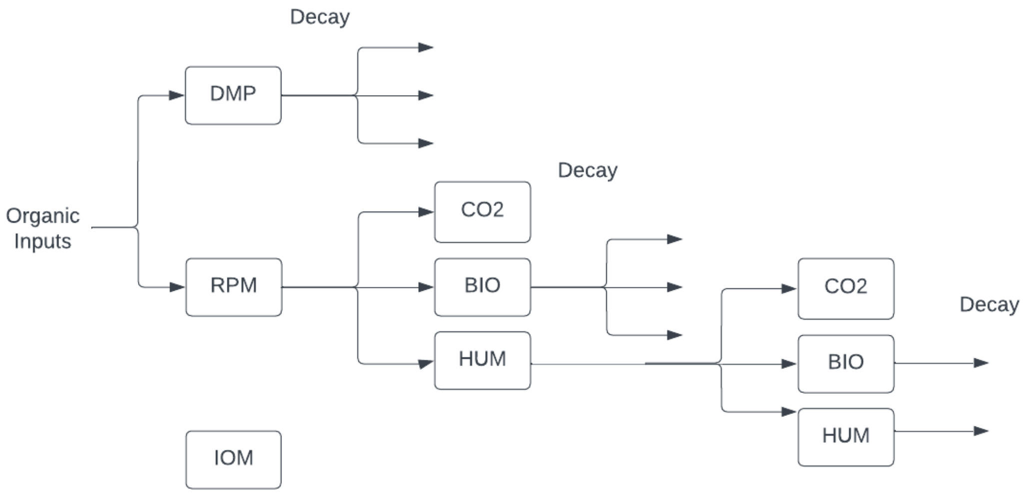

Figure 1. Structure of the RothC Model (RPM - Resistant Plant Material, DPM - Decomposable Plant Material, BIO - Microbial Biomass, HUM - Humified Organic Matter, IOM - Inert Organic Matter)

Calculations
The IOM compartment is resistant to decomposition and is calculated using the following equation:

$$\mathbf{IOM=0.049 \times SOC^{1.139}}$$

where:
SOC is soil organic carbon, (t C ha^{-1}),
IOM is inert organic matter, (t C ha^{-1}).

Incoming carbon inputs are split between DPM and RPM, depending on the DPM/RPM ratio of the particular incoming material. For most agricultural crops and improved grassland, the default DPM/RPM ratio is 1.44, i.e. 59% of the plant material is DPM and 41% is RPM. For unimproved grassland and scrub (including Savanna) a default ratio of 0.67 is used. For a deciduous or tropical woodland a default DPM/RPM ratio of 0.25 is used, i.e. 20% of the plant material is DPM and 80% is RPM. Both DPM and RPM decompose to form CO2, BIO and HUM. The proportion that goes to CO2 and to BIO + HUM is determined by the clay content of the soil. The BIO + HUM is then split into 46% BIO and 54% HUM. BIO and HUM both decompose to form more CO2, BIO and HUM. Each compartment decomposes by a first-order process with its own characteristic rate.

Decomposition of active compartment
If an active compartment contains Y t C ha^{-1}, this declines at the end of the month to:

$$\mathbf{Ye^{-abckt}\ t \cdot C\ ha^{-1}}$$

where:
a is the rate-modifying factor for temperature;
b is the rate-modifying factor for moisture;
c is the soil cover rate-modifying factor;
k is the decomposition rate constant for that compartment; and
t is 1/12, since k is based on an annual decomposition rate.

So $Y(1-e^{-abckt})$ is the amount of the material in a compartment that decomposes in a particular month.
RothC has also been adapted to simulate N and S dynamics, but nutrient and C dynamics are not interconnected in RothC. It was originally developed and parameterized to model the turnover of organic C in arable topsoil, and it was later extended to model turnover in grasslands, savannas and woodlands, and to operate in different soils and under different climates.

DATA requirements
The model requires climatic, soil and management data that are relatively easy to obtain or estimate. Each modeling unit (e.g. cell of a grid) requires the following minimum data;

Model input
Soil Data:
1. Total initial 0-30cm SOC stocks (t C ha^{-1})
2. Initial C stocks of the different pools (t C ha^{-1}): DPM, RPM, BIO, HUM, IOM
3. Clay content (%) at simulation depth.

Climate Data:
1. Monthly rainfall(mm)
2. Average monthly mean air temperature (ºC)
3. Monthly open pan evaporation (mm)/evapotranspiration (mm)

Land Use Management Data:
1. Monthly Soil cover (binary: bare vs. vegetated)
2. Irrigation (to be added to rainfall amounts)
3. Monthly Carbon inputs from plant residue (aboveground + roots + rhizodeposition), (t C ha^{-1})
4. Monthly Carbon inputs from organic fertilizers and grazing animals' excretion (t C ha^{-1})
5. DPM/RPM ratio, an estimate of the decomposability of the incoming plant material

Model output
The final *outputs* are SOC stocks of the five C pools of the *RothC model* (DPM, RPM, BIO, HUM and IOM), and the total SOC stock.
Careful harmonization of modeling procedures, datasets and input estimation methodologies is essential to obtain consistent SOC sequestration results across regions and countries.

Limitation
Roth C is mainly designed to simulate C dynamics.
RothC include empirical functions, so it is expected to perform best when operating in situations similar to those for which they were originally parameterized, which tend to be croplands and grasslands from the temperate zone.
There is relatively less available data of the performance of SOC models under tropical and arid conditions.
RothC may be limited in application to tropical and arid conditions, due to differences in soil fauna and their effects on SOC dynamics, the much faster turnover of slow and passive SOM, different temperature and moisture relationships with microbial activity, and differences in mineralogy in tropical soils, or water dynamics under arid environments.
Additionally, RothC does not accurately simulate SOC dynamics in waterlogged soils such as paddy rice.

2. CENTURY Model

Model description

A biogeochemistry ecosystem model used to assess the impact of climate, land use and management practice changes on C budget of the EU agricultural soils.
CENTURY is a process-based model designed to simulate Carbon (C), Nitrogen (N), Phosphorous (P) and Sulphur (S) dynamics in natural or cultivated systems, using a monthly time step. The model was originally developed in the late ’80s by Colorado State University and it is, currently, one of the most widely used soil biogeochemistry models.

In the JRC.D.3 model framework, CENTURY is running at a resolution of 1 km^2 in the agricultural soils of the EU, incorporating the most recently available pan-European datasets. The main purpose is to quantify the current soil organic carbon (SOC) stock and its change under different scenarios, although many ecosystem outputs (eg. soil respiration, plant productivity, etc.) can also be retrieved.

The structure of the model:

CENTURY is a typical soil organic carbon (SOC) compartment model based on first order decay: the soil organic matter sub-model includes three SOC pools (active, slow and passive), along with two fresh residue pools (structural and metabolic), each with a different turnover rate. Soil temperature and moisture, soil texture and cultivation practices have different effects on these rates. The model is also able to simulate the water balance, using a weekly time step, and a suite of simple plant growth models are included to simulate C, N, P and S dynamics of crops, grasses, and trees.

The CENTURY model is a general model of plant-soil nutrient cycling which has been used to simulate carbon and nutrient dynamics for different types of ecosystems including grasslands, agricultural lands, forests, and savannas. CENTURY is composed of a soil organic matter/decomposition submodel, a water budget model, a grassland/crop submodel, a forest production submodel, and management and events scheduling functions. It computes the flow of carbon, nitrogen, phosphorus, and sulfur through the model's compartments. The minimum configuration of elements is C and N for all the model compartments. The organic matter structure for C, N, P and S are identical, the inorganic components are computed for the specific inorganic compound.

Calculations

Soil organic C is distributed in the physical soil according to an exponential density distribution, expressed in a equation:

$$\mathbf{C(z) = Cb + (C0 - Cb) \cdot e^{-K \cdot z}}$$

where:

C(z) is C density ($g \cdot cm^{-3}$) at depth z (cm, z ³ 0), the maximum C density.

Cb is C density at bottom of profile ($g \cdot cm^{-3}$), the minimum C density. Profile depth = zmax.

C0 is C density at the surface ($g \cdot cm^{-3}$)

K is scale constant (cm^{-1})

DATA requirements

Model inputs

- spatial distribution of the agricultural land use categories (arable, pasture, rice, permanent crops)
- soil texture, pH, bulk density, layers definition and depth, hydraulic properties
- actual gridded climate
- climate projections
- crop area distribution at NUT2 level, livestock density at NUT2, NUT3 level
- crop distribution, fertilizer consumption, irrigation, livestock density
- soil erosion map

Model outputs

- soil organic carbon pools
- biomass pools (grain, root, straw, etc.)
- ecosystem variables (soil respiration, NPP, etc.)
- eroded C
- N fluxes including N_2O emissions

Limitation

CENTURY is able to simulate the effects of tillage on soil organic carbon but cannot predict the amount of soil carbon redistribution. Furthermore the model simulates only the top 20 cm and does not separate the humified portion of the litter from mineral soils. For this reason CENTURY does not describe the variation on soil organic matter among the soil horizons and the water content dynamics across the deep layers.

Sources:
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