LIFE VitiCaSe

Viticulture for Soil Organic Carbon Sequestration

Carbon Farming IT Tool
User manual

Version 1.1

Summary

1. Introduction

The Carbon Farming IT Tool, developed within the framework of the LIFE VitiCaSe project, simulates the dynamics of organic carbon in soils using the Rothamsted Carbon Model—commonly known as Roth-C—originally developed by the Rothamsted Research Institute (Coleman & Jenkins, 1996).

The tool was designed to:

- Monitor changes in soil organic carbon over time;
- Understand the impact of different agronomic practices on carbon management;
- Reconstruct and assess the carbon balance in historical scenarios to support future decision-making.

To simulate soil carbon dynamics, the Roth-C model requires a range of climatic, agronomic, and soil physical data. Key inputs include monthly average temperatures, precipitation, and potential evaporation, as these influence both decomposition processes and soil moisture. It is also essential to specify whether the soil is covered by vegetation or left bare, as this affects moisture dynamics.

From an agronomic perspective, the model needs information on carbon inputs—specifically, the amount of crop residues and manure added to the soil each month. For each crop, the DPM/RPM ratio must also be specified to indicate how easily the organic matter decomposes.

In addition, the model requires several soil parameters: clay content, the reference depth for simulating processes, and the amount of inert organic matter (IOM). These data allow the model to estimate how carbon is distributed and evolves over time across the different organic matter pools in the soil.

2. Access to the tool

You can access the tool via the official LIFE VitiCaSe project website www.life-viticase.eu. Click the "Calculate soil carbon" button, which is located in the top banner to the right of the LIFE VitiCaSe logo, or access it through the menu.

Fig. 1: Desktop view of the VitiCaSe website

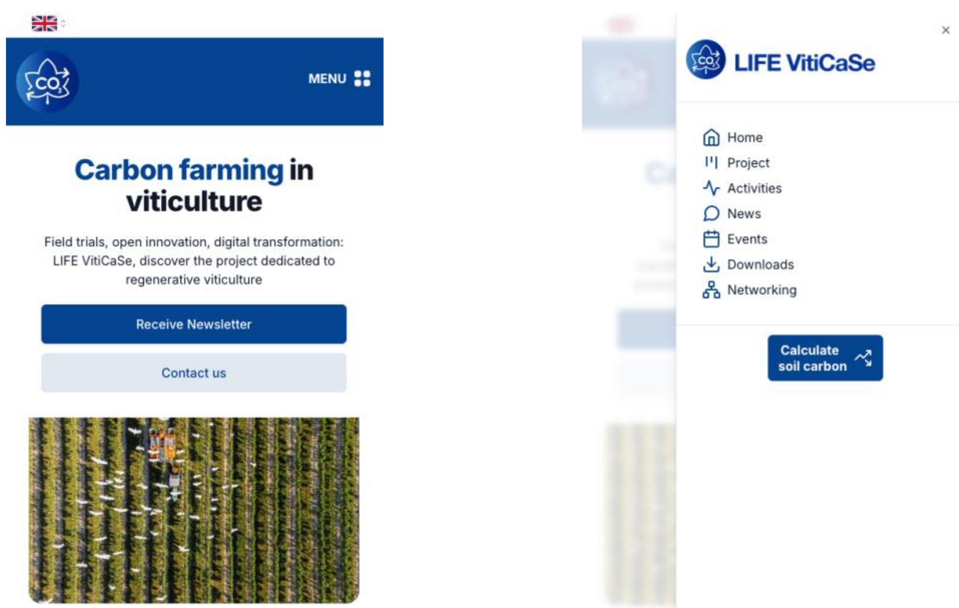


Fig. 2: Mobile view of the website — the access button appears after opening the menu

To use the online tool, you must be registered with the Image Line community. On the login screen, simply enter your community credentials.

If you are not yet registered, click “Here” and follow the guided registration process.

Fig.3: Login screen: use your Image Line community credentials to sign in.

3. Tool interface

The tool's interface is designed to be clear and user-friendly, and is organized into three main sections:

- **Information area**: this section provides a summary of the data required to run the simulation and includes a downloadable sample Excel file. The file must be completed with the simulation data and uploaded in the appropriate section;

- **Data entry**: here, you'll enter the key parameters for the simulation, including latitude and longitude (in decimal degrees), soil clay content (as a percentage), soil depth (in centimeters), and inert organic matter (IOM), expressed in tons of carbon per hectare;

- **Excel file upload and simulation start**: this section allows you to upload the completed Excel file and launch the simulation by clicking the "Calculate" button.

Fig.4: Data entry and Excel file upload section for calculation

4. Data entry

The Excel file to be uploaded must be organized in a monthly format, with one row for each month being simulated. It must include the following mandatory columns:

- **year:** the reference year (e.g. 2020);
- **month:** the reference month (1 for January, 12 for December);
- **modern carbon (%):** the percentage of modern radiocarbon in the atmosphere. Theoretical values provided in the manual may be used (see "Units of measurement and recommended values");
- **C_inp and C_inp2 (Carbon input**): input from the first and second crop respectively (expressed in tons of carbon per hectare
- **FYM (Farmyard manure**): the amount of carbon added through fertilization and organic amendments (expressed in tons of carbon per hectare);
- **PC (Plant Cover**): soil cover status. For each month, indicate whether the soil is covered by vegetation (PC = 1) or bare (PC = 0);
- **DPM_RPM and DPM_RPM2:** the ratio between rapidly decomposable (DPM) and resistant (RPM) plant material for each of the two crops (see "Units of measurement and recommended values").

Units of measurement and recommended values

- **Units of Measurement:**
    - Carbon (C_inp, FYM, IOM): tons of carbon per hectare (t C/ha)
    - Soil depth: centimeters (cm)
    - Latitude and longitude: decimal degrees (e.g., 44.29; 10.72)
    - Clay content: percentage (%)

- **C_Inp (Carbon input):**

This value represents the amount of carbon returned to the soil from plant dry matter. It should not be confused with the total biomass produced by the crop. If you know the annual crop biomass, you can estimate the C_input for the Roth-C model using the following formula:

$$C_{\text{input}} = B \cdot R \cdot C_f$$

Dove:
• B = total biomass produced (t of dry matter/ha),
• R = fraction of biomass that returns to the soil (e.g. crop residues, roots),
• C_f = carbon content of the dry matter (typically between 0.4 and 0.45).

📌 **Practical example:**

• Total biomass: 10 t/ha

• Residues returned to the soil (stubble + roots): 50% → R = 0,5

• Carbon content of the dry matter: 0,45

$$C_{\text{input}} = 10 \cdot 0{,}5 \cdot 0{,}45 = 2{,}25 \text{ t C/ha}$$

- **IOM (Inert Organic Matter):**

IOM refers to the fraction of soil organic matter that is chemically stable and does not participate in decomposition dynamics within the Roth-C model. In practical terms, this is organic carbon that is so resistant it is considered inactive over relevant time scales.

If direct field measurements of IOM are not available, it can be estimated from the SOC (Soil Organic Carbon) value using the empirical formula proposed by Falloon et al. (1998):

$$\text{IOM} = 0{,}049 \cdot \text{SOC}^{1{,}139}$$

Where:

• SOC is expressed in tons of carbon per hectare (t C/ha),

• IOM is also expressed int C/ha.

- **SOC (Soil Organic Carbon)**

If no direct measurement of SOC is available, it can be estimated from the percentage of soil organic matter (SOM) using the following formula:

$$\text{SOC} = \left(\frac{\text{SOM}}{100}\right) \cdot \text{BD} \cdot \text{P} \cdot 10^3$$

Where:

- **SOM** = organic matter content in the soil (%)
- **BD** = bulk density of the soil (t/m³)
- **D** = depth considered (in meters)
- The multiplier 10^3 converts the volume to an area of one hectare (10,000 m²)

📌 **Example:**

If SOM is 2%, bulk density is 1.3 t/m³, and depth is 20 cm (0.2 m):

$$SOC = (2/100) \cdot 1{,}3 \cdot 0{,}2 \cdot 10^3 = 52\ t\ C/ha$$

- **Recommended DPM/RPM values:**

Crop type	DPM/RPM Value
Herbaceous crop	1,44
Tree crops (vines)	0,35
Shrub crops	0,70

- **Modern Carbon:**

The Modern Carbon value represents the percentage of radiocarbon (C_{14}) present in the atmosphere in a given year, relative to a pre-industrial reference value (set at 100%). It is an isotopic indicator that reflects historical variations in atmospheric C_{14}, influenced for example by nuclear tests in the 1950s–60s.

In the Roth-C model, the Modern Carbon value is used to simulate the isotopic dynamics of soil carbon, i.e., to estimate the age of carbon in the various pools and to calculate the output parameter deltaC. This is especially useful for comparing model results with experimental data obtained from isotopic analyses of organic carbon collected in the field, thus improving the accuracy of model calibration.

If the goal is to make general estimates of carbon evolution, the model can function without C_{14} data, or using theoretical values calculated according to the radioactive decay equation.

$$N(t) = N_0 \cdot e^{-\lambda t}$$

Dove:

• N_0 ·= initial value

• t = years

• $\lambda = \frac{\ln(2)}{5730} \approx 0{,}000120968 \rightarrow$ *C_{14} decay constant.*

- **Recommended theoretical values of Modern Carbon:**

Year	Modern Carbon (%)
1980	128,3
1985	128,22
1990	128,14
1995	128,07
2000	127,99
2005	127,91
2010	127,84
2015	127,76
2020	127,68
2025	127,6

(You can use these theoretical values in the absence of field-measured data)

Example of Excel file compilation

year	month	modern carbon (%)	C_inp (t C/ha)	C_inp2 (t C/ha)	FYM (t C/ha)	PC	DPM_RPM	DPM_RPM2
2018	1	127,71	0	0	0	0	1,44	0,35
2018	2	127,71	0	0	0	1	1,44	0,35
2018	3	127,71	0	0	0	1	1,44	0,35
2018	4	127,71	0	0	0	1	1,44	0,35
2018	5	127,71	0	0	0	1	1,44	0,35
2018	6	127,71	0	0	0	0	1,44	0,35
2018	7	127,71	0	0	0	0	1,44	0,35
2018	8	127,71	3,9	1	0	0	1,44	0,35
2018	9	127,71	0	0	0	1	1,44	0,35
2018	10	127,71	0	0	0	1	1,44	0,35
2018	11	127,71	0	0	0	0	1,44	0,35
2018	12	127,71	0	0	0	0	1,44	0,35
2019	1	127,70	0	0	0	0	1,44	0,35
2019	2	127,70	0	0	0	1	1,44	0,35
2019	3	127,70	0	0	0	1	1,44	0,35
2019	4	127,70	0	0	0	1	1,44	0,35
2019	5	127,70	0	0	0	1	1,44	0,35
2019	6	127,70	0	0	0	0	1,44	0,35
2019	7	127,70	0	0	0	0	1,44	0,35
2019	8	127,70	2,4	1,1	0	0	1,44	0,35
2019	9	127,70	0	0	0	1	1,44	0,35
2019	10	127,70	0	0	0	1	1,44	0,35
2019	11	127,70	0	0	0	0	1,44	0,35
2019	12	127,70	0	0	0	0	1,44	0,35

In this simulation, data for 2 years (2018 and 2019) were entered referring to a hypothetical vineyard situation with cover crops or green manure. The C_input data were entered in the month of August; these represent the annual input of organic carbon from the two crops, expressed in t/ha. For crop 1 (cover crop or green manure), a DPM/RPM ratio of 1.44 is reported, typical of herbaceous crops, while for crop 2 a value of 0.35 is used, typical of woody crops such as grapevine. The PC parameter represents soil vegetation cover: in this case, it is assumed that in the summer (June–September) and winter months (November–January), the cover crop is removed and the soil is bare.

5. Model initialization (optional)

Before starting the simulation as described in Chapter 6, you have the option to perform an additional step to initialize the model with greater accuracy.

Although the model always performs an initialization by default—using the first 12 months of input data to calculate the initial equilibrium of the soil carbon pools based on historical climate data—the SOC (Soil Organic Carbon) value derived from this process may differ from the SOC measured in the field.

This additional initialization phase allows you to better align the model's initial equilibrium conditions with the actual SOC value measured in your soil.

To carry out the initialization, follow these steps:

Phase 1: Determining C_input

- Modify the Excel file by adding 12 months of data for a hypothetical "year 0" preceding your case study. Ideally, you should have a field-measured SOC value for this year (for example, 2017, if simulating a vineyard from the 2018–2019 seasons);
- In the C_inp column (only for the first crop, leaving the second crop C_inp column set to 0), enter a default value of 1 in a single month of your choice (e.g., August). This default value is used because the actual carbon inputs before the simulation period are unknown;
- Leave the FYM, PC, and DPM_RPM fields unchanged.

An example of how to complete the Excel file for initialization

year	month	modern carbon (%)	C_inp (t C/ha)	C_inp2 (t C/ha)	FYM (t C/ha)	PC	DPM_RPM	DPM_RPM2
2017	1	127,73	0	0	0	0	1,44	0,35
2017	2	127,73	0	0	0	1	1,44	0,35
2017	3	127,73	0	0	0	1	1,44	0,35
2017	4	127,73	0	0	0	1	1,44	0,35
2017	5	127,73	0	0	0	1	1,44	0,35
2017	6	127,73	0	0	0	0	1,44	0,35
2017	7	127,73	0	0	0	0	1,44	0,35
2017	8	127,73	1	0	0	0	1,44	0,35
2017	9	127,73	0	0	0	1	1,44	0,35
2017	10	127,73	0	0	0	1	1,44	0,35
2017	11	127,73	0	0	0	0	1,44	0,35
2017	12	127,73	0	0	0	0	1,44	0,35

2018	1	127,73	0	0	0	0	1,44	0,35
2018	2	127,71	0	0	0	1	1,44	0,35
2018	3	127,71	0	0	0	1	1,44	0,35
2018	4	127,71	0	0	0	1	1,44	0,35
2018	5	127,71	0	0	0	1	1,44	0,35
2018	6	127,71	0	0	0	0	1,44	0,35
2018	7	127,71	0	0	0	0	1,44	0,35
2018	8	127,71	3,9	1,6	0	0	1,44	0,35
2018	9	127,71	0	0	0	1	1,44	0,35
2018	10	127,71	0	0	0	1	1,44	0,35
2018	11	127,71	0	0	0	0	1,44	0,35
2018	12	127,71	0	0	0	0	1,44	0,35
2019	1	127,70	0	0	0	0	1,44	0,35
2019	2	127,70	0	0	0	1	1,44	0,35
2019	3	127,70	0	0	0	1	1,44	0,35
2019	4	127,70	0	0	0	1	1,44	0,35
2019	5	127,70	0	0	0	1	1,44	0,35
2019	6	127,70	0	0	0	0	1,44	0,35
2019	7	127,70	0	0	0	0	1,44	0,35
2019	8	127,70	2,4	1,8	0	0	1,44	0,35
2019	9	127,70	0	0	0	1	1,44	0,35
2019	10	127,70	0	0	0	1	1,44	0,35
2019	11	127,70	0	0	0	0	1,44	0,35
2019	12	127,70	0	0	0	0	1,44	0,35

- Run an initial simulation following the steps described in Chapter 6, using the modified Excel file. At the end of the process, the model will return the calculated values for the different carbon pools and SOC.

- Compare the SOC value calculated by the model for year 0 (referred to as *SOCeq*) with the field-measured SOC value (*SOCmeasured*).

You can then adjust the $\boldsymbol{C_{\text{input}}eq}$, to be inserted in the Excel file, value using the following formula:

$$C_{\text{input}}eq = ((SOCmeasured\text{-}IOM)/(SOCeq\ \text{-}IOM)) * C_{\text{input}}$$

Where:

- $C_{\text{input}}eq$ = is the value of the C_{input} we are looking for to determine the equilibrium

- *SOCeq* = SOC value at equilibrium after the initial run
- *IOM* = Inert Organic Matter value (t C/ha)
- *SOCmeasured* = SOC value measured in the field
- C_{input}= default value (1) initially used

Phase 2: Setting the initial equilibrium

Update the Excel file by replacing the default C_{input} value (1) with the corrected $C_{input}eq$ value calculated in the previous step (in the example reported, the calculated value is 2.3).

year	month	modern carbon (%)	C_inp (t C/ha)	C_inp2 (t C/ha)	FYM (t C/ha)	PC	DPM_RPM	DPM_RPM2
2017	1	127,73	0	0	0	0	1,44	0,35
2017	2	127,73	0	0	0	1	1,44	0,35
2017	3	127,73	0	0	0	1	1,44	0,35
2017	4	127,73	0	0	0	1	1,44	0,35
2017	5	127,73	0	0	0	1	1,44	0,35
2017	6	127,73	0	0	0	0	1,44	0,35
2017	7	127,73	0	0	0	0	1,44	0,35
2017	8	127,73	2,3	0	0	0	1,44	0,35
2017	9	127,73	0	0	0	1	1,44	0,35
2017	10	127,73	0	0	0	1	1,44	0,35
2017	11	127,73	0	0	0	0	1,44	0,35
2017	12	127,73	0	0	0	0	1,44	0,35
2018	1	127,73	0	0	0	0	1,44	0,35
2018	2	127,71	0	0	0	1	1,44	0,35
2018	3	127,71	0	0	0	1	1,44	0,35
2018	4	127,71	0	0	0	1	1,44	0,35
2018	5	127,71	0	0	0	1	1,44	0,35
2018	6	127,71	0	0	0	0	1,44	0,35
2018	7	127,71	0	0	0	0	1,44	0,35
2018	8	127,71	3,9	1,6	0	0	1,44	0,35
2018	9	127,71	0	0	0	1	1,44	0,35
2018	10	127,71	0	0	0	1	1,44	0,35
2018	11	127,71	0	0	0	0	1,44	0,35
2018	12	127,71	0	0	0	0	1,44	0,35
2019	1	127,70	0	0	0	0	1,44	0,35
2019	2	127,70	0	0	0	1	1,44	0,35
2019	3	127,70	0	0	0	1	1,44	0,35
2019	4	127,70	0	0	0	1	1,44	0,35

2019	5	127,70	0	0	0	1	1,44	0,35
2019	6	127,70	0	0	0	0	1,44	0,35
2019	7	127,70	0	0	0	0	1,44	0,35
2019	8	127,70	2,4	1,8	0	0	1,44	0,35
2019	9	127,70	0	0	0	1	1,44	0,35
2019	10	127,70	0	0	0	1	1,44	0,35
2019	11	127,70	0	0	0	0	1,44	0,35
2019	12	127,70	0	0	0	0	1,44	0,35

Without modifying any other data, run the simulation again following the instructions in Chapter 6.
The SOC value calculated by the model for year 0 (2017) should now match the SOC measured in the field.

By completing this initialization procedure, you can establish a more accurate distribution of soil organic carbon across its various pools at the start of the simulation, ensuring a better fit between the model and real-world field conditions.
This results in a more reliable simulation of carbon dynamics over the years of your study.

6. Starting the simulation

Once you have correctly completed the Excel file, you can proceed with the simulation:

- Verify that all fields in the interface are properly filled out and accurate;
- Upload the Excel file in the designated section;
- Click the "Calculate" button to launch the simulation.

The tool will automatically process the provided data.

Depending on the number of years entered in the Excel file, the calculation may take several minutes.

Initially, the model retrieves historical average weather data based on the specified geographic coordinates to estimate the starting soil carbon content. It then uses the monthly weather data provided in the Excel file to run the simulation over time.

Note: The model is currently configured to operate exclusively within Italian territory.

7. Processing of results

The simulation results are presented through two types of outputs:

- **Charts (Fig. 5)**: these illustrate the trends of climatic variables-temperature, rainfall, and evaporation-over the simulation period, along with the dynamics of the different soil carbon pools (DPM, RPM, BIO, HUM, IOM, and SOC).

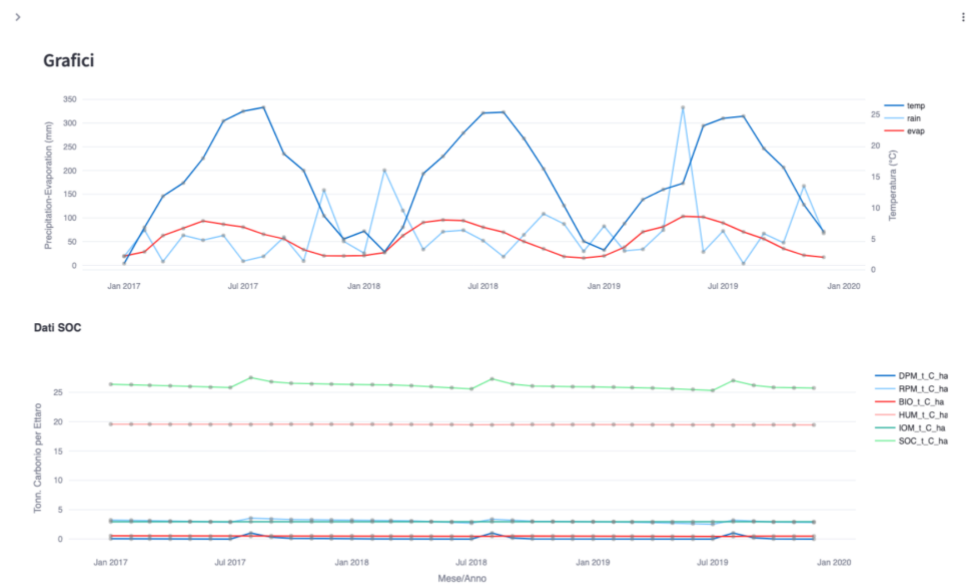
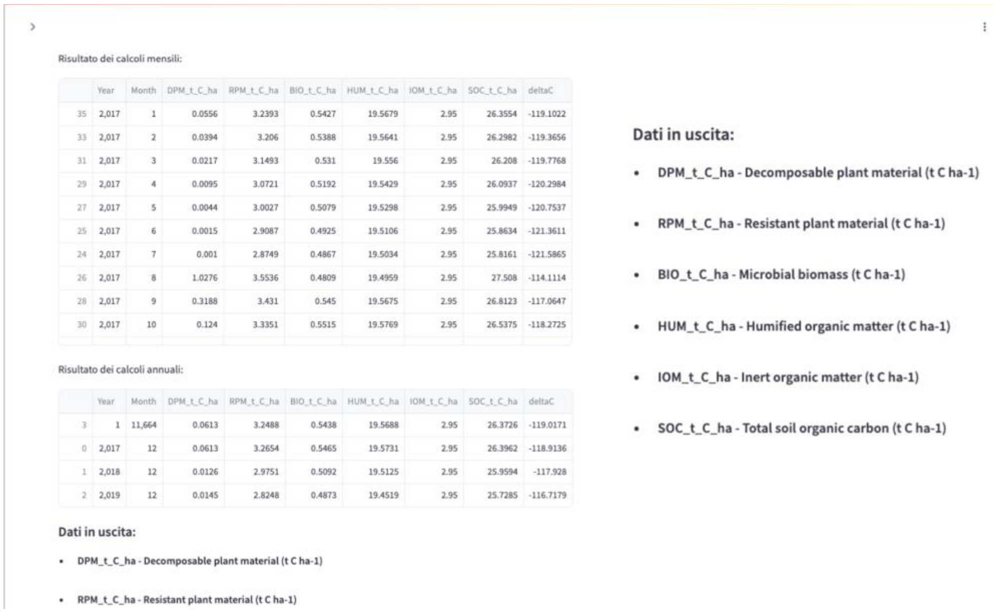


Fig. 5: Example of charts generated by the tool. The first chart displays the trend of weather data across the simulation years, while the second shows the monthly evolution of the various carbon pools.

- **Tables (Fig. 6):** these provide detailed numerical results on a monthly and annual basis, covering each organic matter compartment, the total soil organic carbon (SOC), and the deltaC values (radiocarbon indicator).



Risultato dei calcoli mensili:

	Year	Month	DPM_t_C_ha	RPM_t_C_ha	BIO_t_C_ha	HUM_t_C_ha	IOM_t_C_ha	SOC_t_C_ha	deltaC
35	2,017	1	0.0556	3.2393	0.5427	19.5679	2.95	26.3554	-119.1022
33	2,017	2	0.0394	3.206	0.5388	19.5641	2.95	26.2982	-119.3656
31	2,017	3	0.0217	3.1493	0.531	19.556	2.95	26.208	-119.7768
29	2,017	4	0.0095	3.0721	0.5192	19.5429	2.95	26.0937	-120.2984
27	2,017	5	0.0044	3.0027	0.5079	19.5298	2.95	25.9949	-120.7537
25	2,017	6	0.0015	2.9087	0.4925	19.5106	2.95	25.8634	-121.3611
24	2,017	7	0.001	2.8749	0.4867	19.5034	2.95	25.8161	-121.5865
26	2,017	8	1.0276	3.5536	0.4809	19.4959	2.95	27.508	-114.1114
28	2,017	9	0.3188	3.431	0.545	19.5675	2.95	26.8123	-117.0647
30	2,017	10	0.124	3.3351	0.5515	19.5769	2.95	26.5375	-118.2725

Risultato dei calcoli annuali:

	Year	Month	DPM_t_C_ha	RPM_t_C_ha	BIO_t_C_ha	HUM_t_C_ha	IOM_t_C_ha	SOC_t_C_ha	deltaC
3	1	11,664	0.0613	3.2488	0.5438	19.5688	2.95	26.3726	-119.0171
0	2,017	12	0.0613	3.2654	0.5465	19.5731	2.95	26.3962	-118.9136
1	2,018	12	0.0126	2.9751	0.5092	19.5125	2.95	25.9594	-117.928
2	2,019	12	0.0145	2.8248	0.4873	19.4519	2.95	25.7285	-116.7179

Dati in uscita:

- **DPM_t_C_ha - Decomposable plant material (t C ha-1)**
- **RPM_t_C_ha - Resistant plant material (t C ha-1)**

Dati in uscita:

- **DPM_t_C_ha - Decomposable plant material (t C ha-1)**
- **RPM_t_C_ha - Resistant plant material (t C ha-1)**
- **BIO_t_C_ha - Microbial biomass (t C ha-1)**
- **HUM_t_C_ha - Humified organic matter (t C ha-1)**
- **IOM_t_C_ha - Inert organic matter (t C ha-1)**
- **SOC_t_C_ha - Total soil organic carbon (t C ha-1)**

Fig.6: Example of tables generated by the tool. The tool produces a detailed table showing the values of each carbon pool month by month, along with a summary table presenting the annual results.

8. Interpretation of results

The Roth-C model provides, as a result of the simulation, the value of total soil organic carbon (SOC), broken down into different pools or fractions. Analyzing these components can help us better understand carbon dynamics in the soil.

- **DPM (Decomposable Plant Material):** the fraction of organic matter that decomposes quickly, such as leaves and fresh plant residues. It has a short lifespan in the soil and is rapidly transformed by microbial activity.
- **RPM (Resistant Plant Material):** the fraction of organic matter that decomposes more slowly, including tougher plant materials like stems and woody roots. It breaks down over a much longer timescale.
- **BIO (Microbial biomass):** the carbon contained within the living microbial community in the soil. This fraction is highly dynamic and varies according to environmental conditions, playing a key role in the decomposition of organic matter.
- **HUM (Humified Organic Matter):** the stabilized fraction of organic matter formed through the humification of DPM and RPM. It represents carbon that remains relatively stable in the soil over medium to long periods.
- **IOM (Inert Organic Matter):** the completely stable and inactive fraction of soil organic matter. It does not participate in decomposition processes and remains constant over time.
- **SOC (Soil Organic Carbon):** the sum of all organic carbon fractions in the soil (DPM + RPM + BIO + HUM + IOM). It reflects the total amount of organic carbon stored in the soil at any given time.
- **deltaC:** an indicator of the radiocarbon (C14) content within the organic matter pools, expressed in permille (‰). It measures how much the isotopic signature differs from the atmospheric reference value and is used to estimate the mean residence time of carbon in the soil. **Note:** If you used default values or entered 0, you can disregard this output.

9. Frequently Asked Questions (FAQ)

• **Can I simulate future scenarios with the tool?** Currently, the tool supports only simulations based on historical data. Future updates are expected to include functionality for long-term predictive simulations.

• **Is it mandatory to enter 12 months of initial data?** Yes, the first 12 months are required because the model uses this information—particularly C_input and Plant Cover values—to calculate the initial SOC based on historical weather data. For more information, refer to Chapter 5 (Model Initialization).

• **Do I need to perform the initialization phase, or can I skip it?** Although optional, the initialization phase is highly recommended to achieve SOC simulation results that closely reflect real-world values.

• **What if I don't know the SOC or SOM value of my soil?**

In this case, you can refer to published data or regional estimates of soil organic matter for your pedoclimatic context. The simulation will provide an estimated SOC at equilibrium, which can serve as a useful starting point or help evaluate the soil's carbon sequestration potential. Remember: the more accurate the initial SOC/IOM values, the more reliable the simulation results.

• **Can I edit the sample Excel file?** Yes, you can add additional rows if you wish to simulate across multiple years and adjust the values in each cell.

However, you must not alter the column headers, as this would prevent the model from recognizing the input data correctly.

• **How can I find the coordinates for my simulation area?** You can obtain geographic coordinates using any GIS software or online mapping tool. Be sure to use coordinates expressed in decimal degrees (e.g., 44.29; 10.72).

• **Can I input the total biomass produced by the crop as C_Input?** No, you must input the tons of organic carbon returned to the soil. You can calculate this value starting from the biomass data, as explained in Chapter 4.

• **How should I set the modern carbon value?** You can either use the theoretical values provided in the manual or enter experimental values obtained from field analyses, if available.

10. Contacts and credits

For support requests or information:

• **Email**: info@life-viticase.eu

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