Validation report

This report contains the validation results for the model applied by Climate Farmers to calculate changes to the carbon (C) stock in different environmental zones (Figure 1) due to changes in soil management. Validation can take three forms.

a. Reference to peer reviewed study. The model was considered to be fit for use in environmental zone/land use (EZ/LU) combinations in the cases in which the Roth C model had already been successfully applied in said EZ/LU. Specifically, this means cases in which the results from the validation have been published in peer reviewed scientific journals, and the authors have provided metrics of model fit indicating successful validation.

b. Validation using datasets published in peer-reviewed scientific journals. When validation of Roth C has not been carried out in the EZ/LU combination of interest or it has not been published in peer reviewed journals, data resulting from long term experimental fields from the EZ/LU will be used to carry out a validation following the steps outlined in section 2 of this report.

c. In the case that the environmental zone/land use combination has not been validated before, and no experimental data can be found to carry out a validation of our own, *other avenues will be explored*. These include the collection of management data from farms together with soil samples of at least 10 fields that represent the target EZ/LU. Validation will then be done using these data, following the steps outlined in section 2, with the exception that calibration will be done using carbon stock, bulk density and clay content values extracted from European maps (SoilGrids; Poggio *et al.* 2021)

Therefore, for each EZ/LU combination, an assessment was made such that first the literature was checked for existing validations (a) if this step was unsuccessful, databases and scientific literature were checked for data that would allow validation (b) and only if this step was unsuccessful was the last form of validation applied.

The validation report contains an overview of the validation status for different environmental zones and land use combinations (1), an introduction to RothC (2), and to the steps needed for model validation using pre-existing data (3). These sections are followed by a description of each validated environmental zone (4-7). Sections 4-7 contain an overview of the validation status for each land use within it. For each EZ/LU, we provide an explanation of the validation procedure followed, as well as the results.

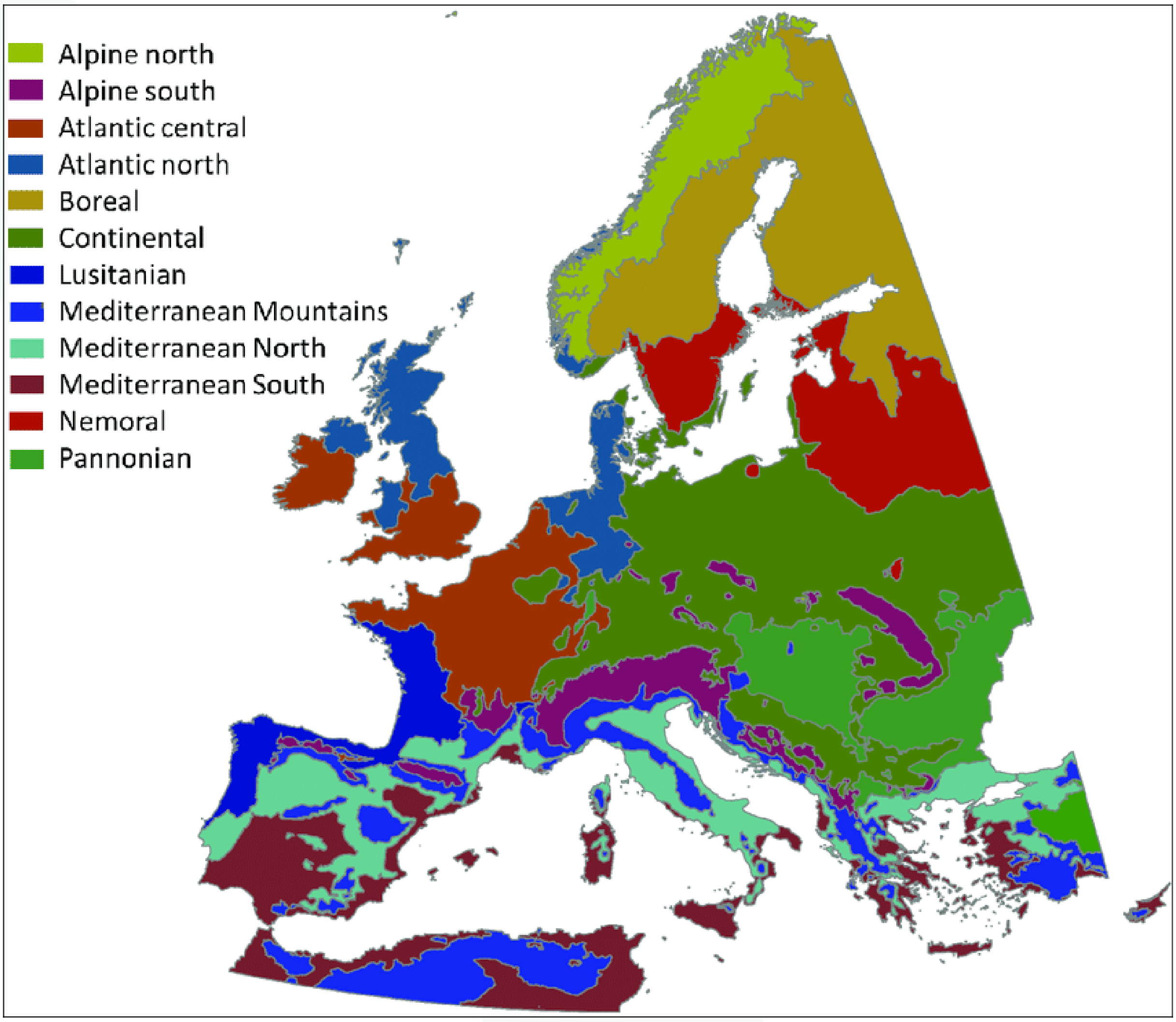

Figure 1. Environmental zones of Europe (Metzger *et al.*, 2005).

1. Overview of the validation status

Environmental zone	Land use	Practice	Status	Model version	Reference
Atlantic Central	Arable land	Organic vs inorganic fertilisation	Validated		Muhhamad *et al.* 2018 (Additional information I)
		Crop rotation	Validated		
		Bare fallow	Validated		
Continental	Arable land	Organic matter additions	Validated	RothC 26.3	Ludwig *et al.* 2007
	Grassland	Grazing	Validated	RothC 26.3	Jebari *et al.* 2021
		No grazing + mowing	Validated	RothC 26.3	Jebari *et al.* 2021
Mediterranean Mountains	Arable land	Organic matter additions	Validated	RothC 26.3	This report
Mediterranean North	Arable land	Residue removal	Validated	RothC 26.3	This report
		Residue incorporation	Validated	RothC 26.3	This report
		No cover crops	Validated	RothC 26.3	This report
		No tillage	Not validated	RothC 26.3	This report
		Cover crops	Validated in the case that legumes are included	RothC 26.3	This report
		Irrigation and various rotations	Validated	RothC10N	Farina *et al.*, 2017
	Grassland	Different cattle densities	Validated	RothC10N	Farina *et al.*, 2017
	Olive groves	Most common management	Validated	RothC10N	Farina *et al.*, 2017
	Vines	Most common management	Validated	RothC10N	Farina *et al.*, 2017
Mediterranean South	Arable crops	Rainfed crops	Validated	RothC10N	Farina *et al.*, 2013

Environmental zone	Land use	Practice	Status	Model version	Reference
Atlantic Central	Arable land	Organic vs inorganic fertilisation	Validated		Muhhamad *et al.* 2018 (Additional information I)
		Crop rotation	Validated		
		Bare fallow	Validated		
		Fallow treatments	Validated	RothC10N	Farina *et al.*, 2013
	Grasslands		Validated	RothC10N	Francaviglia *et al.*, 2013
	Olive groves	Tillage	Validated	RothC 26.3	This report
		Bare	Validated	RothC 26.3	This report
		Cover cropping + Mower	Validated	RothC 26.3	This report
		Cover cropping + Disk harrow	Validated	RothC 26.3	This report
		Cover cropping + Herbicide	Validated	RothC 26.3	This report
	Silvopasture	Tilled vineyards	Validated	RothC10N	Francaviglia *et al.*, 2013
		No till grassed vineyards	Validated	RothC10N	Francaviglia *et al.*, 2013
		Hay crops	Validated	RothC10N	Francaviglia *et al.*, 2013
		Grasslands	Validated	RothC10N	Francaviglia *et al.*, 2013
		Abandoned vineyards	Validated	RothC10N	Francaviglia *et al.*, 2013

2. Introduction to Roth C

RothC (Coleman *et al.*, 2014) is a model for the turnover of organic carbon in topsoils following effects of soil type, temperature, moisture content and plant cover on the turnover process, with a monthly time step (Coleman and Jenkinson, 1996). RothC models soil carbon cycling through five distinct pools of decomposable plant material (DPM), resistant plant material (RPM), microbial biomass (BIO), humified organic material (HUM), and inert organic matter (IOM); each of which has its own decomposition rate. At each iteration, SOC or decomposition of new plant residues (carbon inputs adjusted by DPM/RPM ratio) feed microbiota (BIO) and add to the more slowly decomposing organic matter (HUM). The degradation of each carbon pool is equated as the initial SOC stock for that compartment adjusted by clay content, rate modifying factors for temperature, moisture, and soil cover, and a pool-specific degradation rate.

The RothC model explains soil turnover with the following input data:

- Climate: air temperature, rainfall, and evaporation.
- Soil: soil depth, soil cover (bare or covered), clay content (%), initial SOC stock (SOC stock in the implementation of this model is translated from soil organic carbon sampling and bulk density).
- Carbon inputs: total amount of plant residues and/or farmyard manure.

The model does not distinguish between above ground residues such as litter and below ground biomass such as root exudates.

3. Model validation using experimental data

3.1 Experimental data selection

When experimental data is required for model validation, the data is gathered from peer-reviewed scientific literature. When selecting data for validation, the data must adhere to the following selection criteria:

- Data must originate from a field experiment in the target environmental zone.
- Soil carbon must have been measured at the beginning of the experiment and at least five years after the start of the introduced practices, or an appropriate control must be included in the experimental design.
- The experiment must introduce at least one practice implemented in the Roth C model, for example increase of C inputs through increased residues left in the field or the increase of manures or other organic inputs.
- The data, including the carbon inputs into the system were clearly stated in the literature.

Most data was extracted from the Catch C database (Lehtinen *et al.,* 2014). Whenever data comes from a different source, this will be clearly stated in the section explaining the experimental set-up.

3.2 Model calibration

In order to use RothC, the model must first be calibrated. Calibration of the model is necessary to provide the distribution of carbon between the five pools. Adequate calibration can increase model accuracy. Calibration is done via pedotransfer functions as presented by Weihermuller et al. (2013), and it is assumed that IOM could be calculated from SOC as per Falloon and Smith (2009). These functions estimate the amount of C allocated into each pool as a function of clay content (%) and soil organic carbon (t/ha) such that:

$$RPM = (0.1847 \times SOC + 0.1555) \times (clay + 1.2750)^{-0.1158}$$

$$HUM = (0.7148 \times SOC + 0.5069) \times (clay + 0.3421)^{0.0184}$$

$$BIO = (0.0140 \times SOC + 0.0075) \times (clay + 8.8473)^{0.0567}$$

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

3.3 Model predictions

Once calibration is done, the model uses information regarding local monthly weather, soil property information and information that reflects the total carbon input into the system as inputs for the prediction of carbon stocks. Some factors, like soil cover or the presence of tillage can affect the rate of decomposition of organic matter or the flow of carbon between the different pools, and are reflected as such in the model. Management can affect the total carbon input into the system as well as some of these factors.

Weather information is extracted from the ERA 5 reanalysis database (Hersbach et al. 2020). for the location of the study. When provided, soil property information is taken from the literature. If not, this information is extracted from the SoilGrids2.0 map (Poggio *et al.*, 2021). Changes to carbon inputs are most often directly extracted from the literature. If provided as biomass or manure application, carbon inputs were calculated according to scientific information regarding the carbon content of different crops and grasses, the turnover rate of grasses and tree materials, and the carbon present in manure or other organic materials.

Management practices are turned into input variables for the model. These input variables are then inserted into the model to predict soil carbon due to these changes in management. Management practices that can be included in the model change either

- the time that the soil stays bare (for example the inclusion of cover crops or the use of herbicides),
- the carbon input into the soil (for example changes in crop residue management or manure applications),
- changes to the tillage regime, or
- the irrigation regimes.

3.4 Model fit

To evaluate the model fit, we will calculate the following metrics:

Metric	Description	Reference	Cut-off
Root Mean Square Error - RMSE	It is the relative difference between the observed (O) and predicted (P) value (RMSE). The lowest possible value of RMSE is zero, indicating that there is no difference between simulated and observed data.	Smith and Smith, 2007	$\frac{RMSE}{SD} < 1$
Model efficiency	Values range from 1 to negative infinity. Best performance at EF = 1. Negative values indicate that the average values of all measured values is a better estimator than the model.	Smith and Smith, 2007	0-1
Spearman rank correlation coefficient	This is a non-parametric test, indicating the association between the two variables (in this case the observed and predicted data). Range is from - 1 (full negative correlation) to + 1 (full positive correlation). For models, the best value is 1 and worst is 0	Siegel and Castellan, 1988	>0.5

Following recommendations regarding model fit made by Singh *et al*. (2004) the relationship between RMSE and the standard deviation of the data will be evaluated. The RMSE-observations standard deviation ratio (RSR) will be calculated. This value represents the RMSE divided by the standard deviation of the data and it should be between 0 and 1 for a sufficient fit (i.e. Doblas-Rodrigo *et al.,* 2022). Moriasi *et al*., (2007), suggested that when evaluating model efficiency, values between 0.0 and 1 are acceptable levels of model performance, whereas values below 0.0 indicate unacceptable performance. For the Spearman rank correlation coefficient, a value above 0.5 will be considered sufficiently indicative of a linear relationship between observed and predicted values (Moriasi *et al*., 2007). It is important to note that one of these metrics performing well alone is not sufficient to indicate good model performance.

4. Atlantic Central

4.1 Arable crops

RothC (version 26.3) was validated for arable crops in the Atlantic central environmental zone by Muhammet *et al.* (2018). The authors used data originating from the Broadbalk fertiliser experimental fields in Rothamstead. This experiment was initiated in 1885 to compare the effects of inorganic fertiliser (N, P, K, Na and Mg at different rates) as compared to organic fertiliser (from farmyard manure to rape cake and castor bean meal). These treatments were compared to a non-fertilized control. In 1968 a bare fallow treatment was also introduced (Macdonald *et al*, 2015). The results from this validation were measured using RMSE, EF as well as the model bias. All metrics were indicative of a sufficient model fit for these treatments.

Farina *et al*. (2013) introduced a version of RothC more appropriate for semi-arid climatic zones (version RothC10_N; see 7. Mediterranean North for more details). This version was also successful in predicting carbon sequestration in two opposing treatments from the Broadbalk experimental site. The selected treatments included a bare fallow, one had received inorganic fertilisers since 1885, and the other farmyard manure. Similarly to the study above, the authors of this study calculated the model efficiency and RMSE, both of which showed a good model fit in arable systems in the Mediterranean central environmental zone.

5. Continental

5.1 Arable crops

RothC was validated for arable crops in the Continental environmental zone by Ludwig *et al.* (2007). The authors used data originating from a long term experiment in Germany in which different fertilisation regimes had been implemented. The treatments included two unfertilized treatments, two treatments implementing the use of farmyard manure, and two treatments providing both organic and inorganic fertilisers. One of each of the fertilisation treatments underwent a bare-fallow treatment from 1956 to 2003. The results from this validation were measured using RMSE, EF as well as the model bias and the coefficient of determination. All metrics were indicative of a sufficient model fit for these treatments.

5.2 Grassland

The performance of the RothC model has been evaluated by Jebari *et al.* (2021). The authors introduce modifications to the RothC model to improve its capacity to predict soil organic carbon storage in temperate grasslands. In doing so, they validated the original Roth C model in grasslands in the continental zone. These grasslands were managed differently, one was not grazed but mowed four times a year, while another was grazed for a number of months in the year. The efficiency for the original Roth C model was 0.78, indicative of a good model fit.

6. Mediterranean Mountains

The validation of arable fields in the environmental zone Mediterranean Mountain is presented below. Other land uses within this environmental zone are currently under study.

6.1 Arable crops

6.1.1 Addition of organic matter

[Monaco *et al.* 2008]

Monaco *et al.* (2008) evaluated the effect of additions of different organic materials to maize systems in the Mediterranean zone in an 11 year field experiment. Treatments included the addition of slurry, farmyard manure (FYM) or crop residues (table 6.1.1). The addition of these materials (in combination with urea) increased SOM content, particularly in the upper 15 cm of soil. FYM led to the highest increases in SOC, and plant residues the lowest, likely reflecting the decomposition of the materials.

Table 6.1.1. Treatment description from Monaco et al. 2008

Treatments	Code
Maize for silage, without any N fertiliser supply, utilised as the control treatment.	Ms0
Maize for silage; 200 kgN/(ha x y) urea before sowing, 100 kg N/haxy at ridging	Ms300
Maize for grain, fertilised as Ms300, with, on average, 12.6 t dry matter/ ha x y of straw.	Mg300
Maize for silage, 100 t/(ha x y) of cattle slurry before sowing and 100 kg N/ (ha x y) in the form of urea	MsFHigh
maize for silage, 40 Mg ha-1 y-1 of composted FYM before sowing and 100 kg ha-1 y-1 of urea-N at ridging	MsSHigh

Model predictions

The information obtained from the cited literature were used to calibrate the model and calculate the distribution of soil carbon in the carbon pools (Table 6.1.2).

Differences in Carbon stocks were calculated from the start of the experiment, rather than re-calibrating the model for each time step. Treatments with the addition of straw (Mg300) were predicted to have the largest C stock, while the control (Ms0) and the silage maize that received only urea (Ms300) were expected to have the lowest (Figure 6.1.1a).

Table 6.1.2. Resulting C compartmentalisation after initialisation with pedotransfer functions

Pool	Carbon (t/ha)
DMP	0.00
RPM	7.38
BIO	0.85
HUM	38.59
IOM	4.33
Total carbon - predicted	51.15
Total carbon - observed	51.16

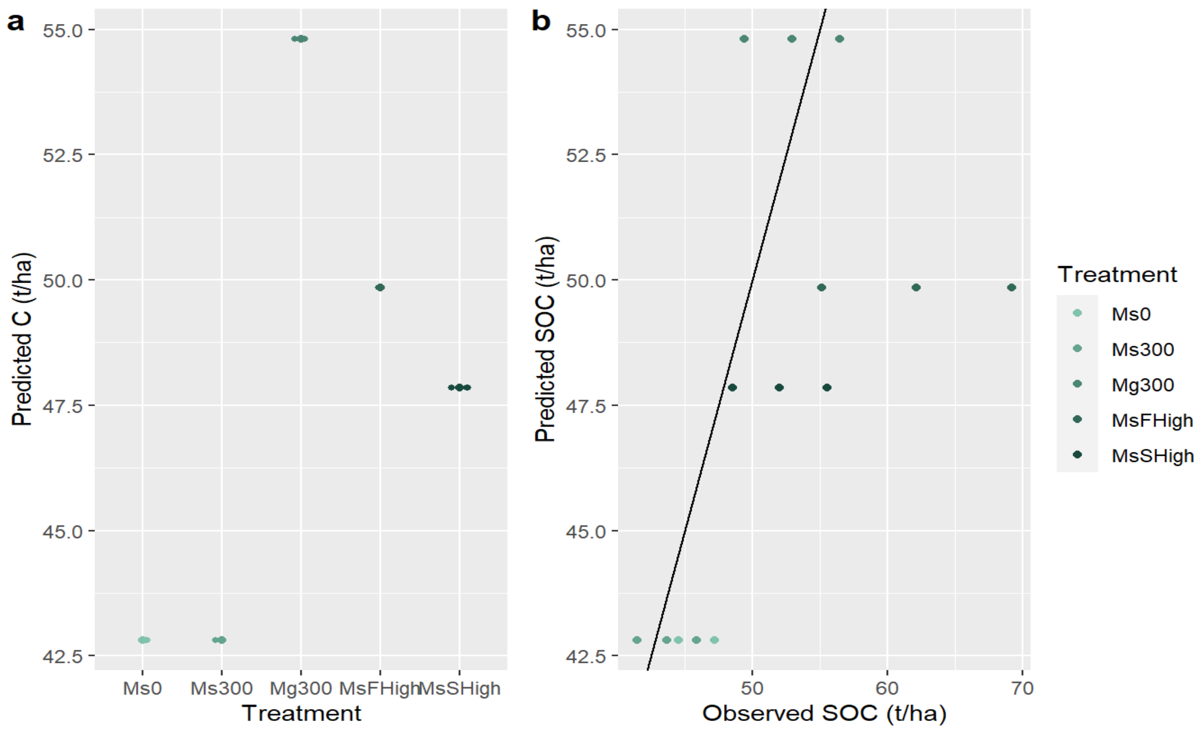

Figure 6.1.1. Soil Organic Carbon (t/ha) predicted by the Roth C model for an experimental site with differing management treatments and plotted against carbon stocks measured in the field (b). The diagonal line represents the one to one line.

Goodness of fit measures

The observed and predicted values were strongly correlated (rho = 0.79, p-value= 0), showing that the Roth C model as is can successfully calculate the trends of soil carbon change in arable fields in the mediterranean mountain environmental zone (Figure 6.1.1b). The RMSE divided by the standard deviation of the model was 0.92. The efficiency of the model was 0.1, indicating that using the model provides a better fit than using average of all observed values.

The model slightly underestimated the carbon stocks in treatments with farmyard manure and slurry (MsFHigh and MsSHigh), but the estimates for other treatments were very close to the 1:1 line (Figure 6.1.1). The underestimation could be related to an underestimation of the amount of carbon in farmyard manure and cattle slurry.

7. Mediterranean North

We provide below a validation of the Roth C model for arable crops under a diverse set of management practices. To this date, existing validations in the literature, or data obtained from grasslands, olive groves and silvopastoral systems in the Mediterranean North are unavailable. However, the farming systems assessed by Climate Farmers in the Mediterranean North are similar to those in the Mediterranean South in terms of management (being mainly montado and dehesa systems), and changes in the soil and climatic parameters are taken into account by the model. Therefore, we consider the validation for the Mediterranean South to be sufficient for the Mediterranean North until more data is gathered from this environmental zone.

7.1 Arable crops

7.1.1 Residue management

Lugato *et al.* (2006). Soil organic carbon (SOC) dynamics with and without residue incorporation in relation to different nitrogen fertilisation rates.

Lugato *et al.* (2006) explored the differences in soil carbon in a long term experiment in north-eastern Italy. The study began in 1966, and within it, the effects of residue incorporation (RI) and removal (RR) were studied in combination with different levels of mineral N fertilisation (0, 60, 120, 180 and 240 kg N/ha). Increasing nitrogen fertilisation led to higher yields, Higher yields of grains are associated with increased residues left in the field, and consequently more carbon input into the soil, in those treatments that received C inputs. The results of this study indicate a steady decrease in SOC content in the first 10 years of the experiment that then approached a steady state. Residue management had a significant effect on the rate of decrease in SOC, and mineral nitrogen interacted with residue incorporation, such that it led to the smallest decrease of SOC in plots with residue incorporation and high levels of N fertilisation. This interaction effect was not observed in the RR plots.

To reflect these results, and using data extracted from the associated literature, we assumed a linear increase in the total above ground C biomass in the RR system, and a constant difference between the average RI and the RR systems of 2.19t/ha, as reported by the paper. The increase in biomass due to increases in N fertilisation may not have been linear, and this could lead to slight differences between the modelled and observed values that we would not expect, had we known the actual yield values for each plot/year.

Model predictions

The information reported by Lugato *et al* (2006) and weather variables obtained from the ERA 5 reanalysis database were used to calibrate the model and obtain the distribution of carbon in different pools at the beginning of the experimental period (Table 6.1.1).

This pool distribution was used to initialise the model. Differences in Carbon stocks were calculated from 1966, rather than re-calibrating the model for each time step. The model predicted higher carbon stocks on sites with residue incorporation than those without (Figure 6.1.1a).

Table 6.1.1. Resulting C compartmentalisation after initialisation with pedotransfer functions

Carbon pool	Carbon (t/ha)
DMP	0.00
RPM	5.76
BIO	0.79
HUM	35.11
IOM	3.79
Total Carbon - Predicted	45.44
Total Carbon - observed	45.45

Goodness of fit measures

The observed and predicted values were strongly correlated (rho = 0.94, p-value= 0), showing that the Roth C model as is, can successfully calculate the trends of soil carbon change. The model, however,slightly underestimated the carbon stocks in residue removal treatments (RR) and overestimated them in residue incorporation (RI) treatments (Figure 7.1.1b).

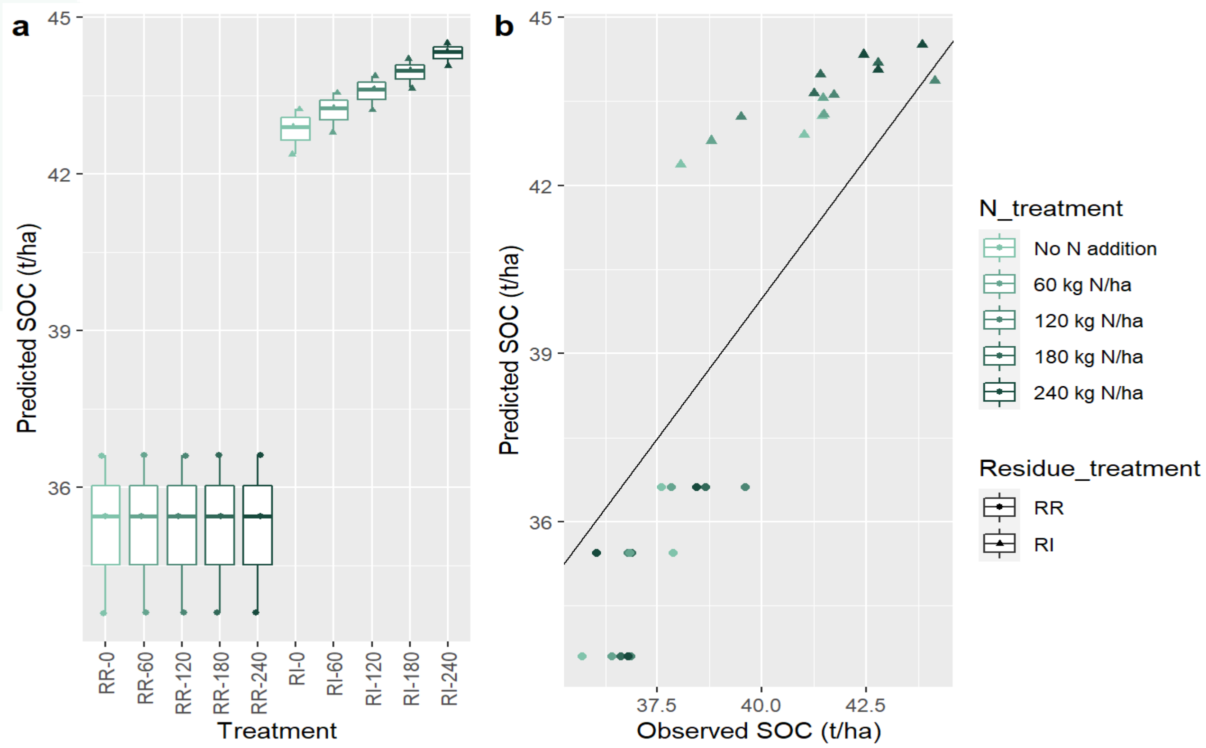

Figure 7.1.1. Soil organic Carbon (t/ha) predicted by the Roth C model plotted against two residue management treatments (Residue removal or residue incorporation; RR and RI respectively) and increasing inorganic nitrogen additions (N_levels) (a) and against the observed soil organic carbon at the end of the experiment (b). The diagonal line represents the one to one line.

The RMSE divided by the standard deviation of the observed data was 0.91, indicative of a sufficient, but not excellent model if. The efficiency of the model was 0.15, indicating that using the model provides a better fit than using average of all observed values.

7.1.2 Tillage, fertilisation and cover crops

Mazzoncini *et al.* 2011. Long-term effect of tillage, nitrogen fertilisation and cover crops on soil organic carbon and total nitrogen content

The authors in this study evaluated the effect of tillage, fertilisation rates and cover-crops on soil organic carbon. The experiment started in 1993. Soil samples were taken at the beginning of the study, and again in 2004. While the experiment included all afore-mentioned treatments in a full factorial design, the authors of this report could only access information on the average effect of each treatment separately.

Mazzoncini *et al* (2011) observed a strong correlation between the amount of C input into the system and the amount of C stored in the soil, and an interaction with the amount of nitrogen added into the soil.

Table 7.1.2. Resulting C compartmentalisation after initialisation with pedotransfer functions for different treatments

DMP	RPM	BIO	HUM	IOM	Tot C Obs	Tot C Pred	Treatment	Explanation of the treatment
0	6.29	0.79	35.39	3.87	46.35	46.34	CT	Conventional tillage
0	5.95	0.74	33.46	3.63	43.78	43.78	NT	No tillage
0	6.14	0.77	34.53	3.76	45.21	45.20	C	No cover crops
0	6.23	0.78	35.08	3.83	45.94	45.93	NL	Cover crop - not legume
0	6.03	0.75	33.95	3.69	44.43	44.42	LNL	Cover crop - Low nitrogen supply legume
0	6.06	0.76	34.13	3.71	44.67	44.66	HNL	Cover crop - High nitrogen supply legume

Model predictions

The initial carbon and clay contents of the soil, as reported by Mazzoncini *et al* (2011) were used to calibrate the model and calculate the distribution of carbon amongst the carbon pools modelled by Roth C (table 7.1.2).

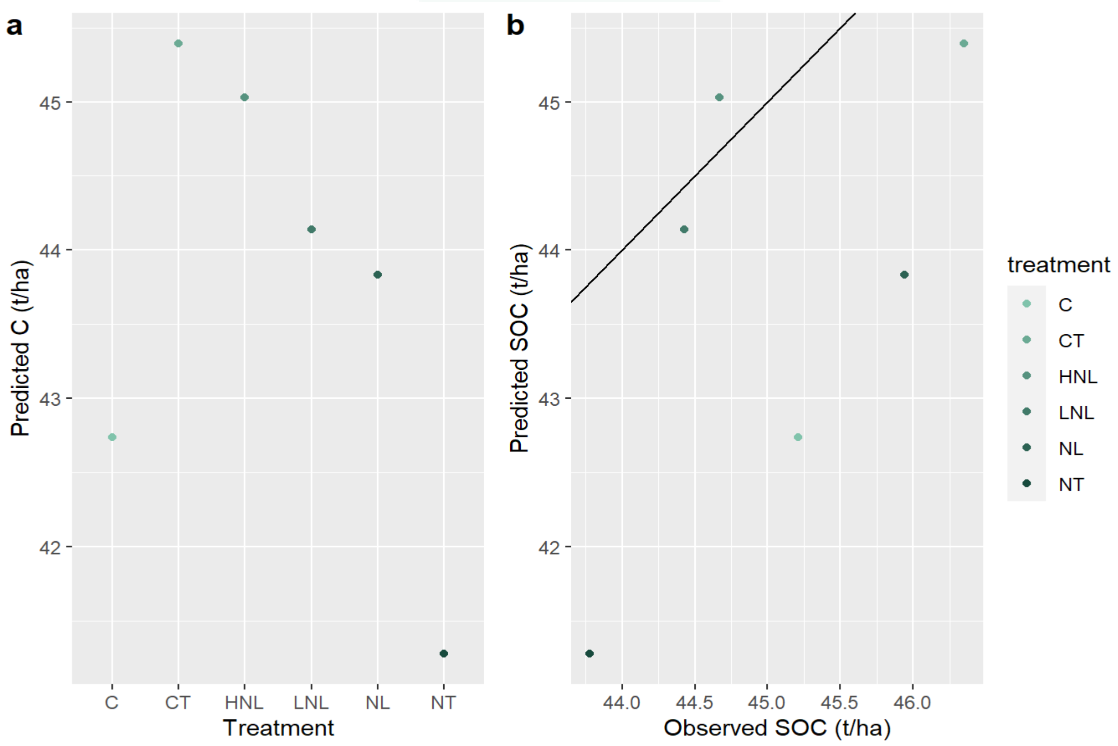

Figure 7.1.2. Soil organic carbon (t/ha) predicted by the Roth C model for differing cover cropping and tillage treatments (a) and plotted against the soil organic carbon measured in plots that had undergone those experimental treatments (b).

The pool distribution of each treatment was used to initialise the model. Differences in Carbon stocks were calculated from 1993, rather than re-calibrating the model for each time step. The model predicted higher carbon stocks on sites with residue incorporation than those without (Figure 7.1.2a).

Goodness of fit measures

The observed and predicted values were correlated (rho = 0.54, p-value= 0.3), although the correlation coefficient was not statistically significant. However, the model provided a near perfect estimate of soil organic carbon for the tilled system as well as the two cover cropping systems that included legumes (Figure 7.1.2b). The no tillage system, no cover crops and the cover cropping system without legumes were both expected to have less carbon than was measured (with a difference of less than 3 (t/ha)).

The RMSE divided by the standard deviation was 1.79 indicating a less than sufficient model fit. The efficiency of the model was -2.85, indicating that using the model does not, in this case, provide a better fit than using average of all observed values. The model seems poorly fit to estimating the carbon content of no tillage systems with no cover cropping, treatments with no cover crop and herbicide supply (and therefore very low C inputs), or treatments with cover crops that perform poorly due to low nitrogen supply in the Mediterranean North, since taking these treatments out improved the efficiency and RSR of the model (to 0.59 and 0.48 respectively). However, these values are calculated using only three points, and therefore are calculated with little statistical power.

6.1.3 Irrigation and crop rotations

To assess the effects of land use and land use changes on soil carbon stocks, Farina *et al.*, (2017) used a variation of the RothC for semi-arid areas (see section 8.1) to calculate the potential gains and losses of C in soils in the Mediterranean North area, specifically in the region of Foggia, Italy. They evaluated soil carbon stock changes in arable fields (irrigated and not irrigated) with different rotations, including a bare fallow. Additionally, they evaluated carbon stock changes in grasslands, olive groves and vineyards. When irrigation was assumed, it was included in the model as an increase in precipitation during the summer months. As is common practice in the Foggia region, it was assumed that applications of manure were negligible. Carbon inputs were calculated from information on yield, and equations that relate the harvest index to crop residue biomass, as well as root biomass. This effort was validated with an independent dataset. The average standardised error of the simulated data respect to the measured ones was −0.3 $Mg\ C\ ha^{-1}$, and the sRMSE was 1.01$Mg\ C\ ha^{-1}$ indicating a satisfactory model fit for all these land uses.

7.2 Grassland

See section 7.1.3

7.3 Olive groves

See section 7.1.3

7.4 Vines

See section 7.1.3

8. Mediterranean South

We present below the validation results for arable crops (4.1) and silvopastoral systems (4.3), which were obtained from scientific literature, as well as the results from the validation efforts for olive groves under different management techniques (4.2). We consider grasslands to be validated, as the results of 4.3 relate to grasslands with very low tree density, and the effects of the trees were not accounted for in the modelling.

8.1 Arable crops

Farina *et al.* (2013) validated a version of RothC adjusted for use in semi-arid areas (RothC10_N). In this version, calculation of the hydrological constants in the model is done through equations other than those in the original RothC model (Van Genuchten, 1980); the maximum total soil moisture deficit equals -1000 bars; and the maximum bare soil moisture deficit equals the maximum soil moisture deficit. This version of the model successfully estimated carbon storage in semiarid non-irrigated arable fields in the Mediterranean south, with a model efficiency of 0.56 in an experimental field in Cordoba including a wheat and wheat-fallow rotations. In all experiments in the semiarid climate, the observed versus predicted values were strongly correlated (rho = 0.94) and showed no bias. This implementation of the model is currently being applied to Climate Farmer projects in the Mediterranean South.

8.2 Olive groves

8.2.2 Tillage, cover crops and herbicides

Castro *et al.* 2008

The authors of this study set out to understand the effects of different soil management practices (between tree rows) on the carbon sequestration potential of olive groves in Mediterranean zones. Specifically, they looked at the effects of tillage (T), no tillage with bare soil (NC), cover crops with herbicides (CH), cover crops with mower (CM), cover crop with mower and a pass of a disk harrow (CMD). Soil parameters were measured 28 years after the beginning of the management practices. All cover crop systems led to increases in the carbon content in the upper layers of the soil. Lowest measured C was observed at the plot with no tillage and no cover crop.

Carbon inputs for the system were calculated from the information provided by Castro *et al.* (2008). The dry biomass measured at the inter rows was assumed to be the total carbon inputs in half of the field, since the interrows do not represent the full area of an olive grove. We therefore assume that we may be underestimating the carbon inputs in the no tillage and bare soil treatments, as the leaf litter is not being taken into account.

Model predictions

Carbon at the beginning of the experiment was not measured by Castro *et al.,* (2008). Therefore, using the coordinates provided by the study, we extracted the soil carbon stock in the top 30cm from the SoilGrids map (Poggio *et al.,* 2021). This value (32 tC/ha) was used as input in the pedotransfer sections (section 1) used to understand the distribution of carbon in the different carbon pools (Table 8.1.1).

Table 8.2.1. Resulting C compartmentalisation after initialisation with pedotransfer functions

Carbon pools	Carbon (t/ha)
DMP	0.00
RPM	4.26
BIO	0.55
HUM	24.71
IOM	2.54
Total carbon - predicted	32.06
Total carbon - observed	32.00

Differences in Carbon stocks were calculated from 1976, rather than re-calibrating the model for each time step. The model predicted higher carbon stocks on sites with cover crops than those without. The no tillage, bare soil treatment was predicted to have the lowest carbon stock (Figure 8.1.1a).

Goodness of fit measures

The observed and predicted values were strongly correlated (rho = 0.7, p-value= 0.23), showing that the Roth C model as is, can successfully calculate the trends of soil carbon change in olive groves located in the Mediterranean South (Figure 8.1.1b). The RMSE divided by the standard deviation was 0.67, indicating a sufficient model fit. The efficiency of the model was 0.47, indicating that using the model provides a better fit than using average of all observed values.

Overall, the model is fit to be used in Olive groves with differing management practices (see above) in the Mediterranean South.

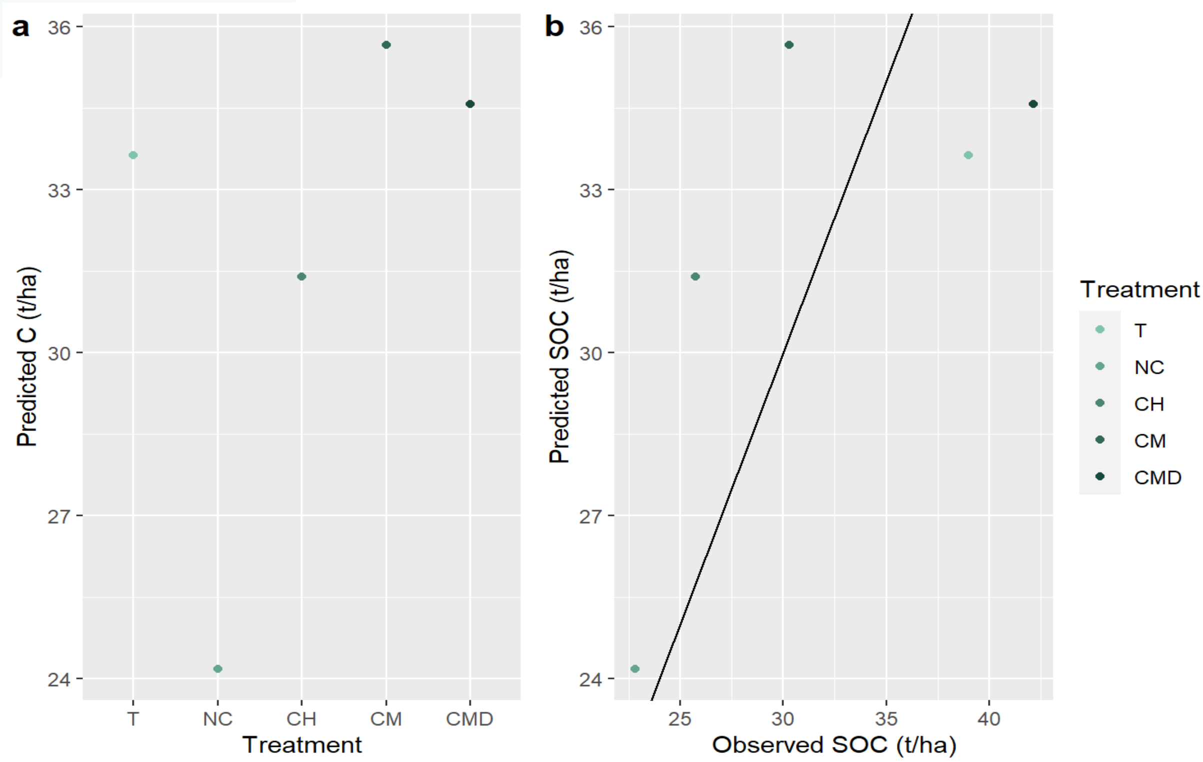

Figure 8.2.1. Soil organic carbon predicted under different management treatments (a) compared to the soil organic carbon measured in those experimental treatments (b). The diagonal line represents the one to one line.

8.3 Silvopasture

Francaviglia *et al.* (2013) applied the RothC model to a diversity of Silvopasture areas in the Mediterranean South, including Tilled vineyards, no-tilled grassed vineyards, hay crops and grasslands with sparse cork oaks and former vineyards (abandoned 30 years prior). Using the C content of nearby cork oak forests to initialise the model, the authors then created management files that reflect land use in these systems and run Roth C. Deviations between modelled and observed values were below 6% for all systems, indicating a successful validation.

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