

STICS ability to simulate long-term soil organic matter dynamics in crop-grassland rotations

Cadero A.¹, F. Ferchaud², N. Beaudoin², F. Chlebowska², B. Mary², F. Vertès³, Graux A.-I^{1*}

¹ PEGASE, Agrocampus Ouest, INRA, 35590 Saint-Gilles, France ; ² AgrolImpact, INRA, Site de Laon, 02000 Barenton-Bugny, France ; ³ SAS, Agrocampus Ouest, INRA, 35000 Rennes, France

* Corresponding author: anne-isabelle.graux@inra.fr

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Introduction

Grasslands ability to mitigate climate change by storing carbon in soils is well recognised but difficult to quantify as it depends on many environmental and agronomical factors. Modelling crop-grassland rotations can help quantifying the evolution of soil organic carbon (SOC) for a diversity of soils, climates, crops and managements, but it requires that models are sufficiently robust and accurate in their prediction of SOC. This study aimed to assess the STICS model ability to simulate long-term SOC dynamics in crop-grassland rotations. It is part of the French CarSolEl project.

Material and methods

STICS was tested against data from a 27-year experiment located at Kerbernez in western Brittany (France) and including nine crop-grassland rotations. Rotations A and B were silage maize monocrops. Rotations C, D and E were silage maize-Italian ryegrass rotations, with Italian ryegrass being established respectively for 6, 18 and 12 months between two-silage maize. Rotations I and J were respectively permanent and temporary perennial ryegrass grasslands established between two silage maize. Rotations Dd and Ed were only differing from respectively D and E by their rotation head. Crops were established on a 1m-depth loamy sand and slightly acidic soil, differing somewhat between rotations by the initial SOC stock (80-85 t C ha⁻¹ in 0-25 cm). Rotation A received only mineral N fertiliser. All other rotations also received bovine then pig liquid manure. Both Italian and perennial ryegrass were only cut. The experimental area was cut in half in 1992. We used a research version of the STICS model (release 2485) able to simulate rotations including grasses and other perennial crops (Autret *et al.*, 2019; Strullu *et al.*, 2020). The model was run continuously from 1978 to 2004. Available observed data were crop DM yields, crop N contents, SON and SOC stocks at different dates. STICS was evaluated using common indicators for validation of biophysical models. A score was attributed to each simulation unit using a method derived from Kersebaum *et al.* (2015) and based on the information source, the number of repetitions and the observed factors that the model does not account for (e.g. weeds). This first evaluation included a revised parametrisation of perennial ryegrass.

Results and discussion

STICS well predicted the evolution of SOC stocks in rotation A (Figure 1, Table 1). However, it overpredicted final SOC for rotation B and silage maize-Italian ryegrass rotations. This could be partly due to an overestimation of the humified carbon from pig slurry inputs. STICS prediction of SOC under temporary (rotation J) and permanent (rotation I) grasslands was acceptable with final SOC conversely slightly underpredicted. Silage maize yields were globally overpredicted. It is partly explained by the fact that the model did not account for the observed detrimental effect of *Solanum nigrum* presence on silage maize yields (results not shown). Model prediction agreement with observations of Italian and perennial ryegrass yields was either good (rotations D and Dd), fair or poor (other rotations)

(results not shown). STICS prediction of the N content in silage maize and harvested grass was respectively good and from fair to poor (results not shown).

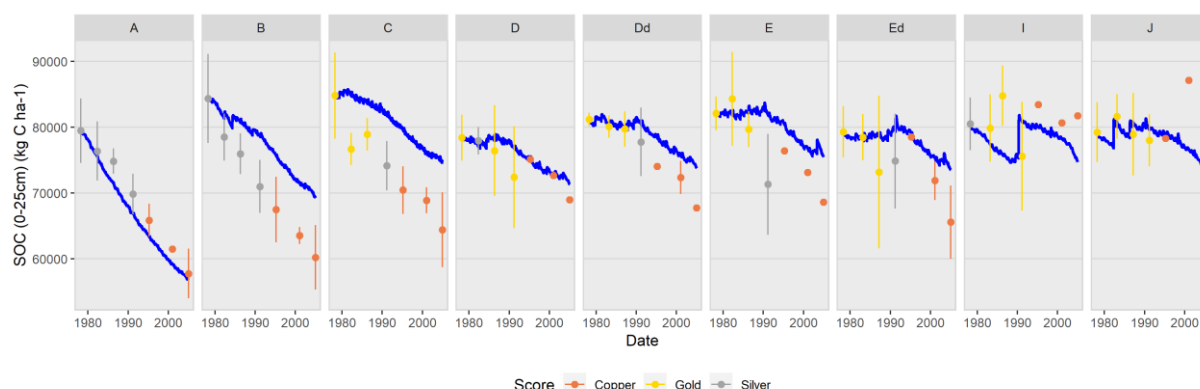


Figure 1. Comparison of simulated (blue lines) and observed (points) SOC dynamics over 27 years at Kerbernez site for nine crop-grassland rotations.

Table 1. Evaluation statistics (root mean square error (RMSE), relative RMSE (RRMSE), part of systematic error (pRMSEs), Nash-Sutcliffe model efficiency (EF) and Willmott index (d)) of STICS performance of predicted SOC

Rotation	RMSE (kg C ha ⁻¹)	RRMSE (%)	pRMSEs	EF	d
A	2147	3.2%	0.75	0.92	0.98
B	6598	8.5%	0.94	-0.69	0.79
C	7423	9.2%	0.89	-2.82	0.65
D	2076	2.7%	0.30	0.36	0.87
Dd	3255	4.1%	0.85	-0.64	0.81
E	5401	6.7%	0.50	-3.16	0.63
Ed	4286	5.5%	0.69	-3.04	0.68
I	5074	6.5%	0.79	-4.56	0.25
J	4783	6.1%	0.65	-2.80	0.18

Conclusions and perspectives

Further investigations are required to confirm these first results. STICS ability to simulate SOC dynamics in crop-grassland rotations will be assessed against data from two other long-term experimental sites of the INRA SOERE ACBB. If required, a calibration of the sensitive grassland root and shoot parameters will be done to improve the model prediction of SOC together with other soil and plant variables. Scoring each simulation unit will help selecting data to be used for model calibration and evaluation. The performances of STICS will also be compared with those of four other models.

References

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