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Soil C Impacts of Organic Amendments: Practical Models for Farmer Decision Support

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Rationale & aims

Soil carbon (SC) is an important consideration for farmers from a number of perspectives, ranging from crop productivity to climate change mitigation. However, SC can be challenging to measure. **Many SC models exist: how can these be used to support farmer decisions without making unrealistic data demands?**

Sub-field scale equilibrium and saturation dynamics of the SC pool introduce complexity. Environmental, management and time factors must be represented in models. **Decision support tools should provide the most useful information from the least data.**

The analysis presented here compares two model approaches (see *Methods*) for predicting the impact of organic C amendments on SC. **We run the SC models using different combinations of measured and estimated input data.**

We are interested in understanding:

- **Which data are most important for farmers to measure to understand SC changes?**
- **Does this vary by agro-ecological context?**
- **What is the information cost of reducing the data burden?**

Methods

Increasing data demand for users

IPCC T1 *with reference SCi* → IPCC T1 *with measured SCi* → RothC *with some estimated inputs* → RothC *with measured site data*

Experiment data used is from a systematic search by Foster et al.[1] on the SC impacts of adding organic amendments. Some comparisons include chemical fertilisers, some have zero inputs.

Site A	Site B	Site C	Site D
Moist	Dry	Dry	Moist
Warm temperate	Warm temperate	Warm temperate	Tropical

Models used were designed for different purposes, though both calculate change in SC over time:

- ***Empirical IPCC Tier 1 approach***[2]**.** Calculates a factor for 20 year change in SC stock (after a change in management) based on tillage practices and organic inputs. Can be applied using reference values for initial SC (SC_i): reference SCi values depend on soil type and climate zone.
- ***Process-based RothC model***[3]**.** Implemented through the SoilR package[4]. A five-pool model for SC which requires climate data, clay % and information about organic inputs. The pools are usually initialised to match SCi values, though can also be initialised using baseline organic C inputs.

Estimated data presented here is from the IPCC[2] and Harmonised World Soil Database (HWSD)[5,6]. The analysis is in progress and use of further estimated data is planned.

Findings

Figure 1: Estimated SC_i stocks are materially different from measured SC_i.

Figure 2: Even when using measured SC_i stocks, differences between measured and modelled SC_t can be significant. Models more often underestimate than overestimate SC storage increase.

Figure 3: Modelled sequestration rates are often significantly different from measured sequestration rates, though relative rates vary. Estimated input data has marginal impact on predicted sequestration rates. There is more difference between the models than within each model's input data scenarios.

These preliminary results indicate that estimating input data for a SC model does influence predicted SC_t stock, but has less of an impact on predicted sequestration rates. **This suggests that if a farmer is interested in sequestration rates, then the information cost of estimating data might be low.**

However, our results show model-predicted SC stocks and sequestration rates that are significantly different from measured data. This prompts us to ask: **how can we further improve model predictions for decision support without making unrealistic data demands?**

***Figure 1:* SC over time: measured & modelled** (four treatments, all models)

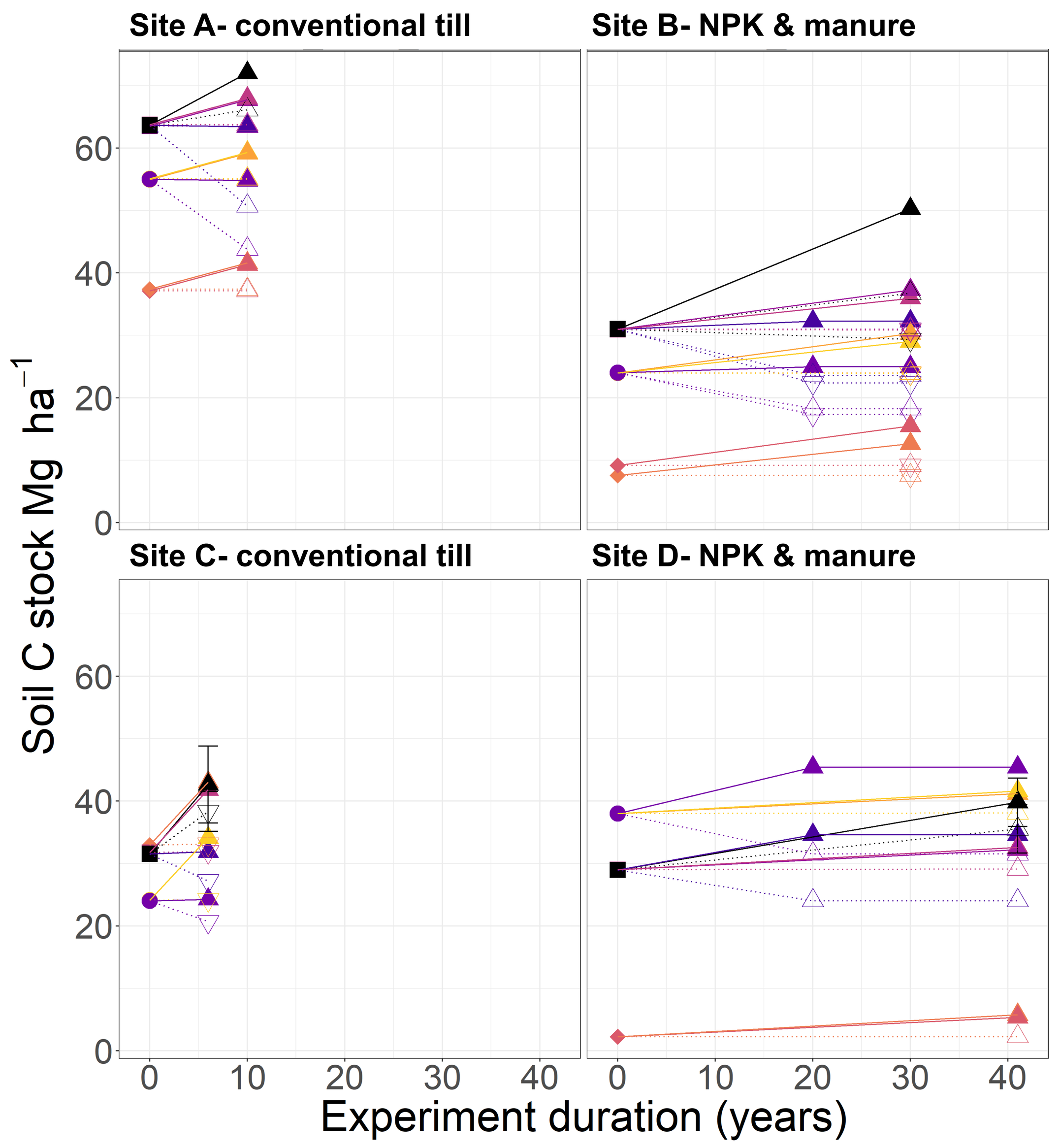


***Figure 2:* Difference between measured & modelled SC_t** (all treatments, models w. measured SC_i)

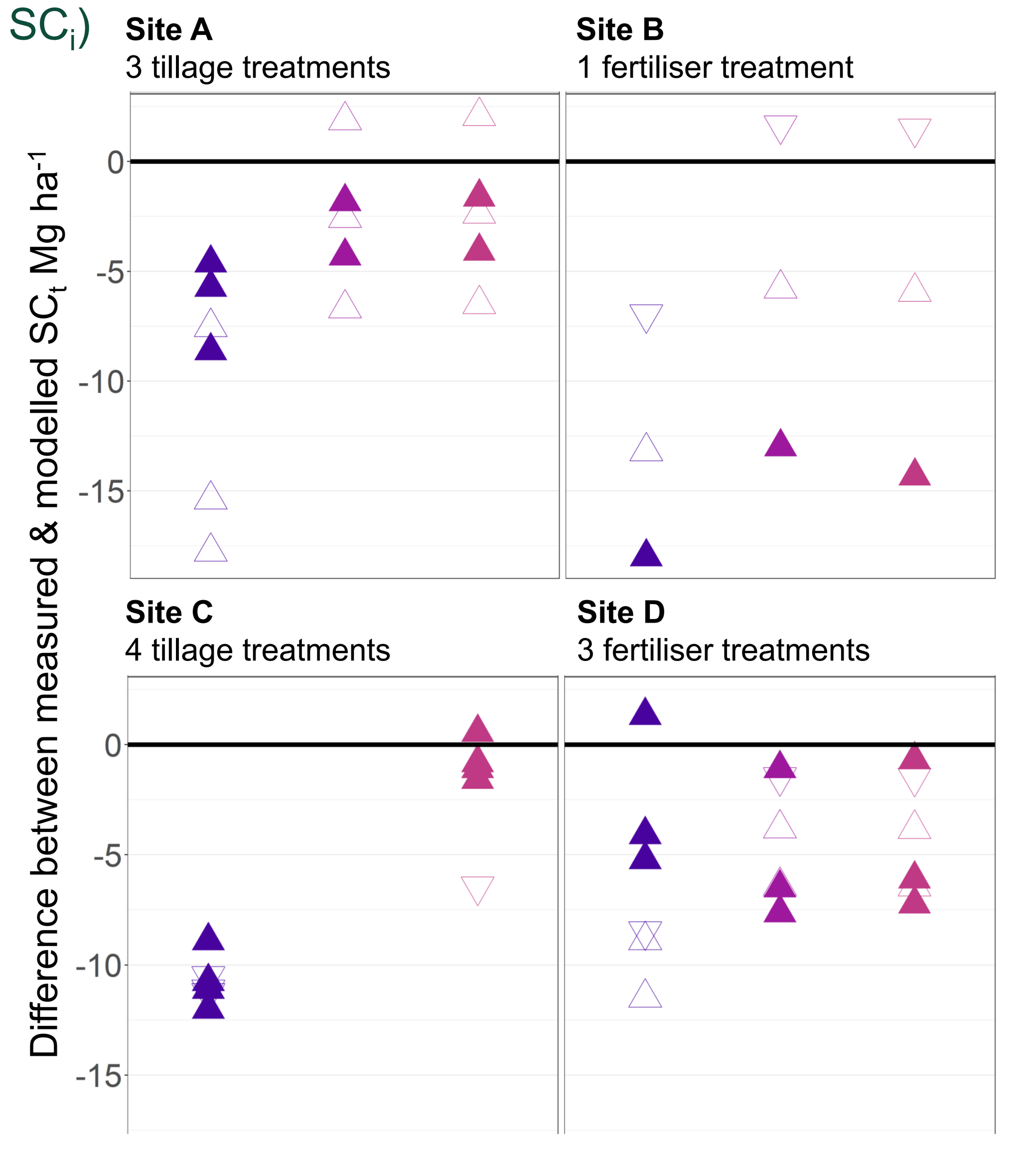
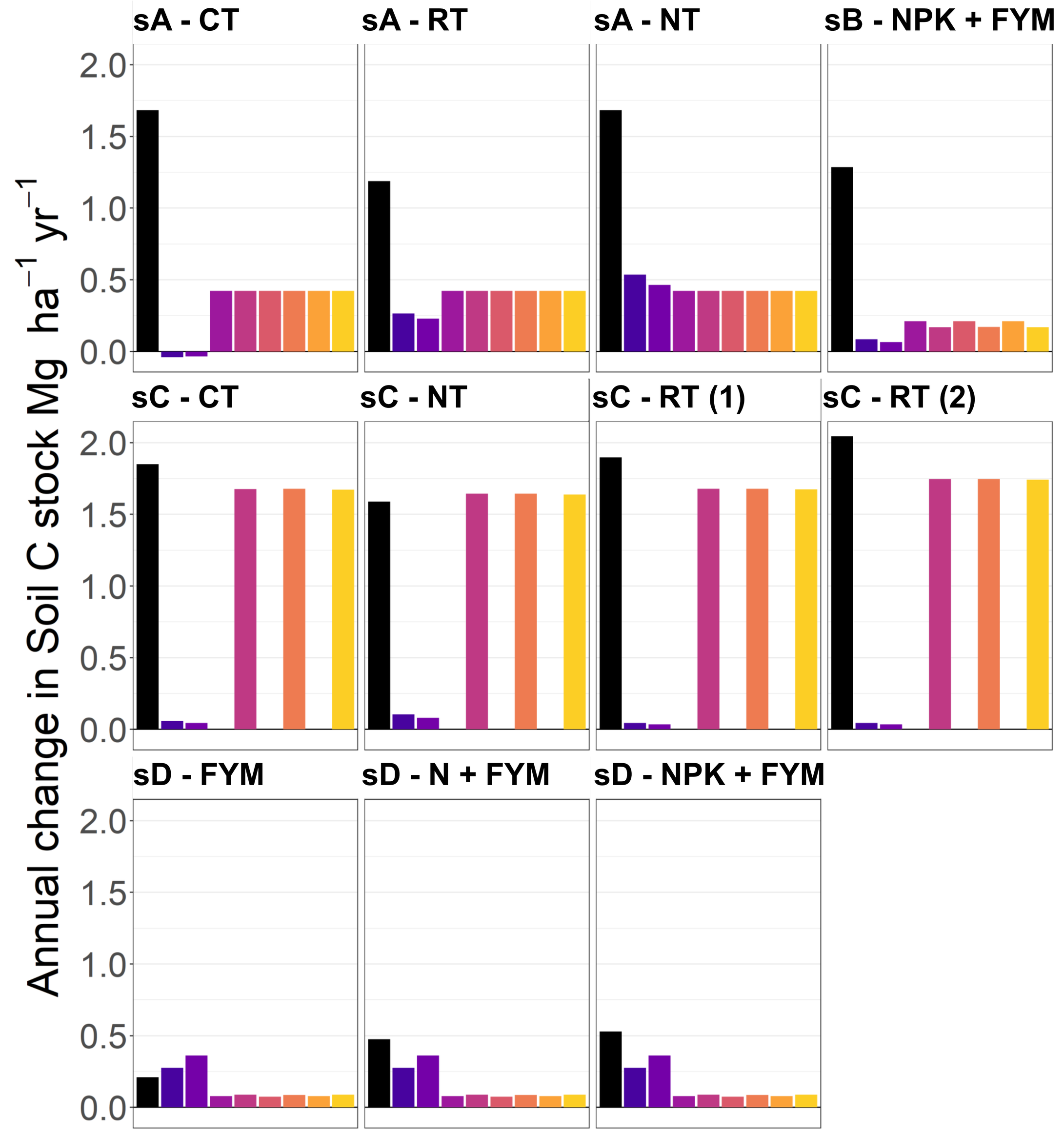


***Figure 3:* Annual rate of SC stock change: measured & modelled** (all treatments, all models)



Key & Acronyms

Soil C points

- ■ Measured SC_i
- ● IPCC reference SC_i
- ◆ SC_i from C inputs
- ▲ Organic amend (treatment)
- △ Chemical fertiliser (control)
- ▽ Zero input (control)

Model scenarios

● Measured study data		
● IPCC	Measured SC_i	
● IPCC	IPCC reference SC_i	
● RothC	Measured SC_i	HWSD clay
● RothC	Measured SC_i	Measured clay
● RothC	SC_i from C inputs	HWSD clay
● RothC	SC_i from C inputs	Measured clay
● RothC	IPCC reference SC_i	HWSD clay
● RothC	IPCC reference SC_i	Measured clay

Acronyms

SC	Soil Carbon
SC_i	Soil Carbon at start of experiment (time = 0)
SC_t	Soil Carbon at end of experiment
CT	Conventional tillage
NT	No tillage
RT	Reduced tillage
FYM	Farmyard Manure
N	Nitrogen
NPK	Nitrogen, Phosphorus and Potassium
HWSD	Harmonised World Soil Database

Next steps

To complete this analysis we may:

- Estimate more input data. For example climate data, as it is known that RothC is sensitive to temperature data.
- Assess more sites.
- Compare more models: possibly IPCC Tier 2 steady state.

Further statistical analysis of results will also be done. Future work may seek to parameterise approaches to improve model estimates; for example explicitly including tillage practices in RothC.

References 1. Foster, E. J.; Kelly, C.; Filley, T. (2020). "A global dataset of agricultural experiments quantifying organic amendment impact on soil carbon." Purdue University Research Repository. doi:10.4231/ABA8-6762 2. IPCC (2019). "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories". Calvo Buendia, E.; Tanabe, K.; Kranjc, A.; Baasansuren, J.; Fukuda, M.; Ngarize S.; Osako, A.; Pyrozhenko, Y.; Shermanau, P.; Federici, S. (eds). Published: IPCC, Switzerland. 3. Coleman, K.; Jenkinson, D. S. (1996). "RothC-26.3 A Model for the turnover of carbon in soil." In *Evaluation of soil organic matter models: using existing long-term datasets* (pp. 237-246). Springer Berlin Heidelberg. 4. Sierra, C. A.; Mueller, M.; Trumbore, S. E. (2012). "Models of soil organic matter decomposition: the SoilR package, version 1.0." Geoscientific Model Development, 5(4), 1045–1060. https://doi.org/10.5194/gmd-5-1045-2012. 5. Wieder, W. R.; Boehnert, J.; Bonan, G. B.; Langseth, M. (2014). "Regridded Harmonized World Soil Database v1.2." ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1247 6. Hufkens K. (2021). "The hwsdr package: an interface to ORNL DAAC HWSD API endpoints." https://bluegreen-labs.github.io/hwsdr/.