26th International Congress on Modelling and Simulation, Adelaide, SA, Australia, 30 Nov–4 Dec 2025
mssanz.org.au/modsim2025

Accounting for fire and grazing effects to improve soil organic modelling through emulator-based parameter recalibration

Sebastian U Ugbaje [a], **Dan Pagendam** [b], **Senani Karunaratne** [a]

[a] *CSIRO Agriculture and Food, Clunies Ross Street, Black Mountain, ACT 2601, Australia*
[b] *CSIRO Data 61, EcoSciences Precinct, 41 Boggo Road, Dutton Park, 4102, Queensland, Australia*
Email: Sebastian.ugbaje@csiro.au

Abstract: Natural and anthropogenic fires, along with grazing, are dominant features of Australian landscapes, shaping ecosystem functions such as carbon cycling that governed both carbon inflows and outflows. Therefore, proper representation of these events has always been very challenging in soil organic carbon (SOC) modelling, particularly when a long model initialization, creating uncertainties in baseline SOC estimates against which management effects are assessed.

We developed a framework to constrain the DayCent biogeochemical model using measured SOC fractions and by integrating fire and grazing regimes across 66 sites in a Hillston, New South Wales, Australia. SOC fractions were linked to model conceptual pools by tuning decomposition rates and parameters related to fire and grazing impacts on above ground biomass and SOC dynamics. We hypothesize that this approach improves alignment between model's conceptual pools and measured SOC fractions, particularly for the difficult-to-calibrate pyrogenic SOC pool (Dangal et al., 2022).

The model was applied across three periods: spin-up, historical land use, and current land use. Grazing events were included for all sites and periods, while fire events were applied in the spin-up phase for all sites and, additionally, in permanent pasture during the historical and current phases. Fire frequency was fixed at a 10-year cycle during the latter two phases but optimized during spin-up to enhance calibration.

To rigorously evaluate parameter importance, we performed a sensitivity analysis using the Sobol method (Soboĺ, 1993) on 14 fire- and grazing-related parameters, including fire frequency. Computational efficiency was achieved by training an emulator on 1,000 parameter samples. Subsequently, eight influential parameters, along with three decomposition rates, were then calibrated within a Bayesian hierarchical framework, allowing for an explicit representation of uncertainties.

The developed framework is scalable and has the potential to improve the representation of uncertainties in greenhouse gas inventories.

REFERENCES

Dangal, S.R.S., Schwalm, C., Cavigelli, M.A., Gollany, H.T., Jin, V.L., Sanderman, J., 2022. Improving Soil Carbon Estimates by Linking Conceptual Pools Against Measurable Carbon Fractions in the DAYCENT Model Version 4.5. J Adv Model Earth Sy 14(5).

Soboĺ, I.M., 1993. Sensitivity estimates for nonlinear mathematical models. Math. Model. Comput. Exp. 1, 407.

Keywords: *Soil organic pools; surrogate modelling, Bayesian framework*

© MSSANZ and The Authors, CC-BY