Parameters Optimization of RothC Model for Simulating Soil Organic Carbon Dynamics: A Case Study of Rice Straw and Soybean Residue Inputs

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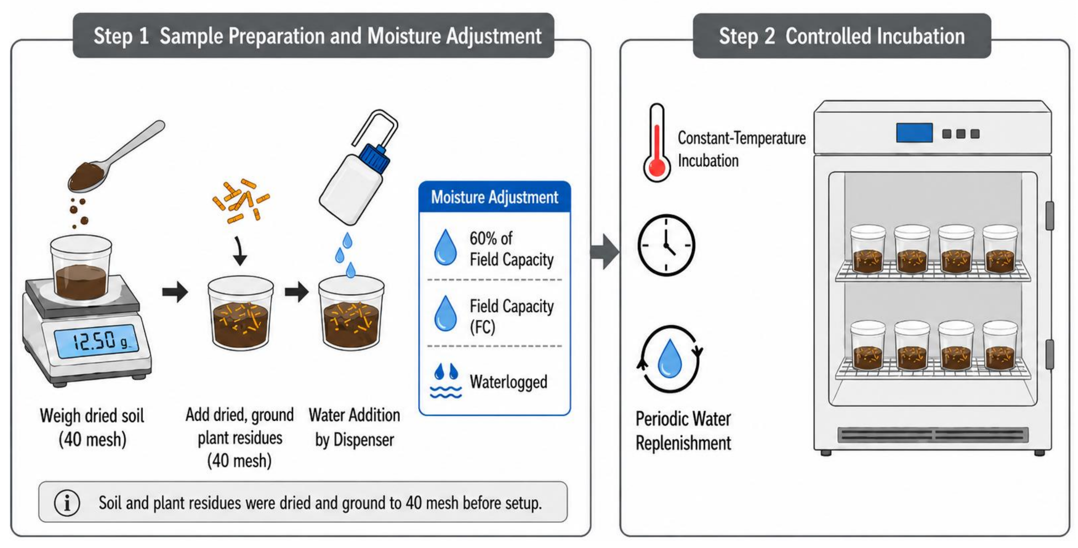
Introduction

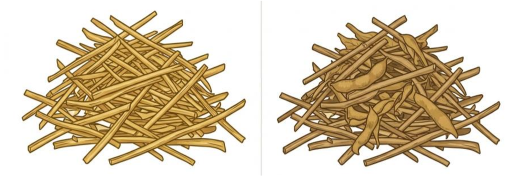
Accurate prediction of Soil Organic Carbon (SOC) dynamics is essential for enhancing soil carbon sequestration and mitigating climate change. The Rothamsted Carbon (RothC) model is a globally recognized tool for simulating SOC turnover; however, its application in Taiwan faces critical challenges due to the subtropical/tropical climate and agricultural systems dominated by intensive rice-upland rotations. To bridge this gap, this study utilizes long-term soil incubation experiments under controlled temperature and moisture regimes to systematically evaluate and optimize the model's parameters, specifically focusing on the initial partition of plant residues (DPM/RPM ratio) and the decomposition response under high organic inputs.

Experimental Design & Material

Soil Incubation Experimental Design

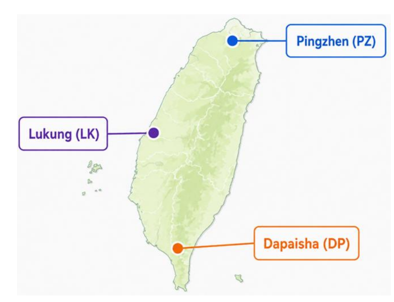


Plant Residues & Input Rate



Input rate: 1%, 2%, and 5% (w/w)

Distribution of experimental soil series



RothC Calibration Workflow

1. Incubation dataset
Observed SOC time series
3 soils x residues x moisture
15/25/35˚C: 0.5–6 months
25˚C only: 9–18 months

2. Native RothC run
Initial SOC, clay content, plant C input and default RothC settings

3. Bias diagnosis
Observed vs. simulated SOC
1:1 plot and residuals by soil, water, temperature, residue

4. Calibration targets
Identify parameters causing systematic bias before model validation

5A. Residue quality calibration
Estimate DPM/RPM ratio using 1% and 2% plant-residue input to avoid high-input distortion

5B. High-input correction
Estimate γ factor with 5% input to account for non-linear decomposition response

6. Validation & final model
Apply calibrated parameters to validation data and evaluate R^2, RMSE, bias, slope, intercept

Purpose: transform incubation SOC observations into site- and residue-specific RothC parameters for more accurate SOC simulation.

Native RothC run

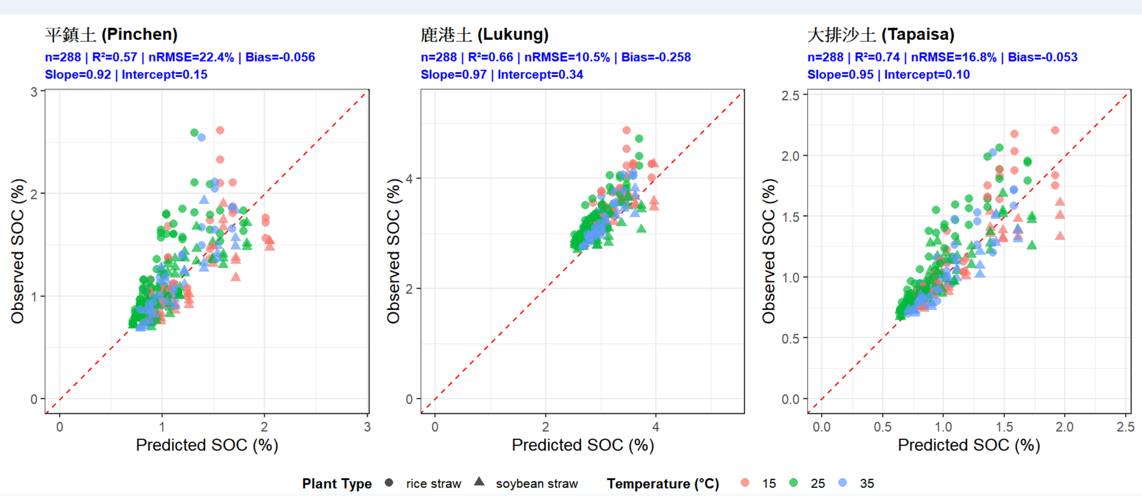


Figure 1. Comparison of observed and RothC-predicted soil organic carbon (SOC) percentages for Pingzhen (PZ), Lukung (LK), and Dapaisha (DP) soils under different incubation temperatures (15˚C, 25˚C, 35˚C) and residue treatments (rice straw, soybean straw). The dashed red line represents the 1:1 line.

Bias diagnosis

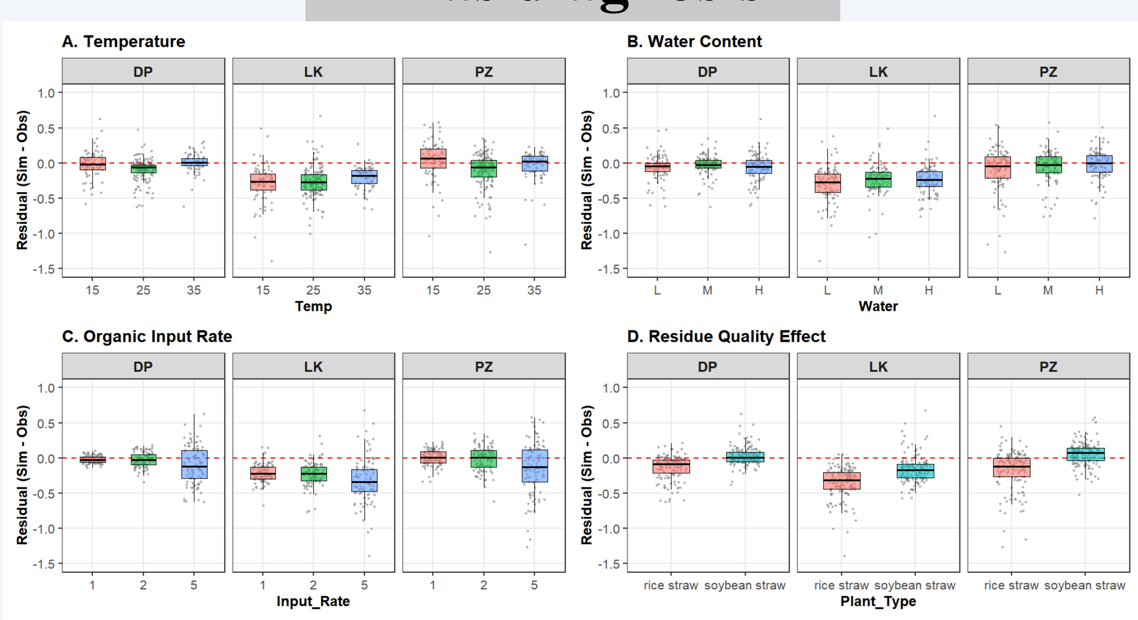


Figure 2. Residual analysis (Simulated minus Observed SOC) of the RothC model across three soil types (DP, LK, and PZ) as affected by different experimental factors: (A) incubation temperature, (B) soil water content, (C) organic input rate, and (D) residue quality. The dashed red line represents zero residual, indicating perfect model prediction.

Validation & final model

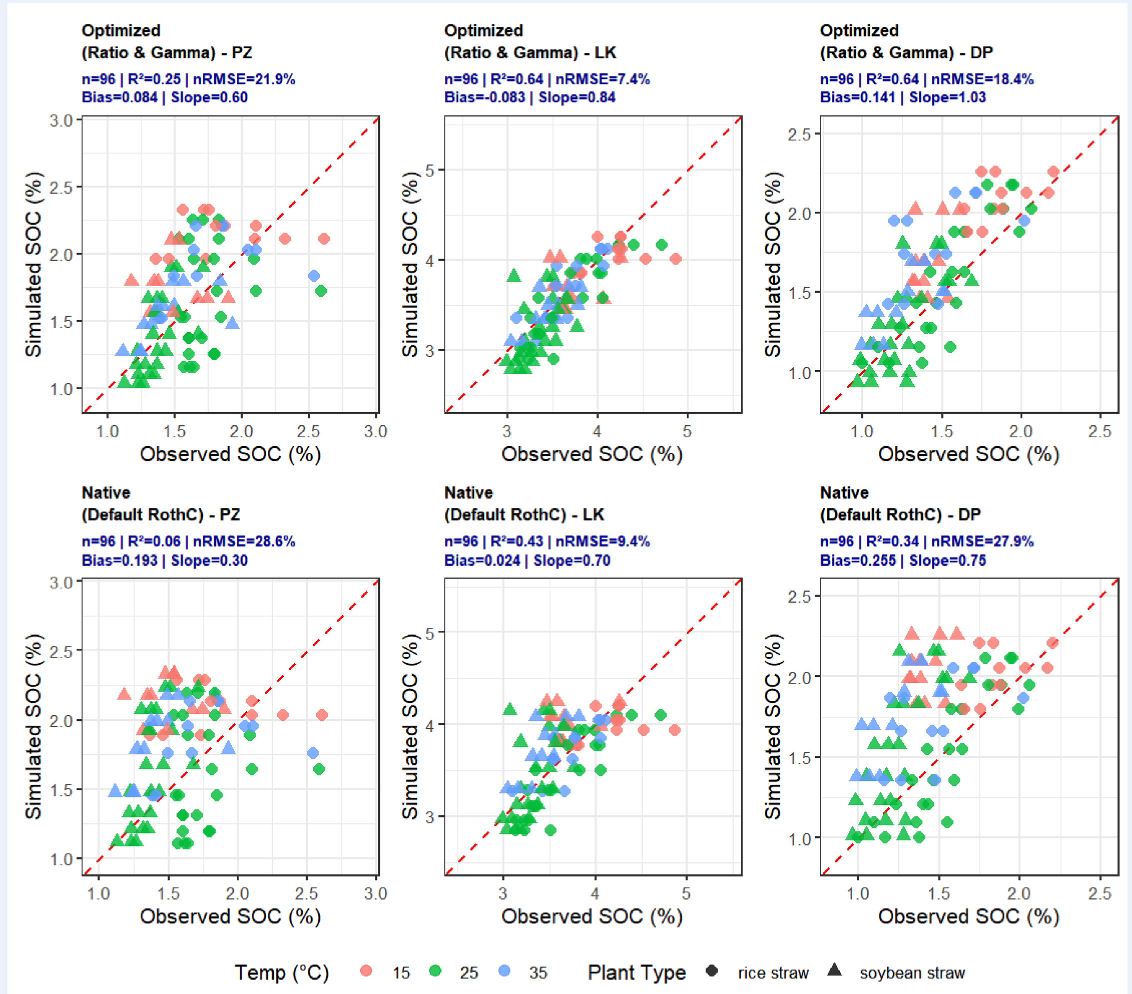


Figure 3. Comparison of observed and simulated SOC using optimized and native RothC parameters.
Scatter plots present the combined validation results for PZ, LK, and DP soils across all residue incorporation levels (1%, 2%, and 5%) and available temperature treatments, including 15, 25, and 35˚C.
Top row (Optimized): γ = 0.936 for the 5% residue input condition; rice/soybean DPM/RPM ratios = 0.17 / 1.16.
Bottom row (Native): γ = 1.0; DPM/RPM ratio = 1.44. The red dashed line represents the 1:1 line. Parameter optimization improved R^2 and regression slopes and reduced nRMSE and bias across all soils, with the best model performance observed in LK soil (R^2 = 0.64, nRMSE = 7.4%).

Calibration targets

DPM/RPM Ratio: The default ratio (1.44) tended to overestimate the apparent initial decomposition rate of local crop residues in Taiwanese soils. Optimizing this ratio is therefore important for capturing residue-specific decomposition characteristics.

High-Input Correction Factor (γ): Under high residue loading (5% input rate), SOC dynamics deviated from standard decomposition kinetics. A global scaling factor (γ) was introduced to adjust the overall decomposition response under high-input scenarios.

Residue quality calibration

Calibration Phase	Target Parameter	Crop / Input Condition	Native Value	Calibrated Value
Phase 1: Residue Quality	DPM/RPM Ratio	Rice Straw	1.44	**0.170**
		Soybean Straw	1.44	**1.164**
Phase 2: High-Input Correction	Global Scaling Factor (γ)	High Residue Input (5%)	1.00	**0.936**

Conclusion

This study calibrated the RothC model for Taiwanese agricultural soils by optimizing crop residue quality and high-input decomposition kinetics. Calibrating the DPM/RPM ratio from the default 1.44 to 0.17 for rice straw and 1.16 for soybean straw improved the representation of residue-specific decomposition characteristics, while introducing a global scaling factor (γ = 0.936) stabilized simulations under high (5%) organic loading. Simultaneous optimization of both parameters improved predictive accuracy by increasing R^2 and slopes while reducing model errors across all tested soil series, with the best performance observed in Lukung (LK) soil (R^2 = 0.64, nRMSE = 7.4%).