UCD Earth Institute
UCD School of Biology and Environmental Science

# Simulation and validation of long-term changes in soil organic carbon under permanent grassland using the DNDC model

**M. I. Khalil[1,*], D. A. Fornara[2] and B. A. Osborne[1]**

[1] UCD School of Biology & Environmental Science and Climate-Resilient Agri-Environmental Systems (CRAES)-UCD Earth Institute, University College Dublin, Belfield, Dublin 4, Ireland. (*Corresponding author: ibrahim.khalil@ucd.ie)

[2] Agri-Food & Biosciences Institute (AFBI), Newforge Lane, Belfast, NI, United Kingdom.



## Introduction

- Activity data on SOC density/stocks are limited due to measurement errors and associated difficulties.
- Robust accounting of SOC is a global concern and essential for identifying whether an ecosystem is a source or sink and its GHG offsetting potential.
- Improved methodologies and models are vital to assess the:
  (i) long-term impact of management practices on SOC density (SOCρ) and its annual change (ΔSOCρ).
  (ii) sensitivity of model outputs to key soil variables and management practices.

## Materials & Methods

- A long-term (45 yr) grassland (silage) experiment was used.
- Soil is clay loam overlying Silurian shale-greywacke (Dystric Gleysol).
- The experiment has eight nutrient treatments:
  - Unfertilized control (N0)
  - NPK @ 200 kg N (as urea), 32 kg P, 160 kg K, $ha^{-1}$ $yr^{-1}$ (NU)
  - Pig slurry at low (PL=50), medium (PM=100) and high (PH=200), $m^3$ $ha^{-1}$ $yr^{-1}$
  - Cattle slurry at the same three rates (CL, CM and CH, resp.), $m^3$ $ha^{-1}$ $yr^{-1}$.
- Simulation of SOC content for 45 years was performed using the DeNitrification-DeComposition (DNDC95) model.
- Sensitivity of the model for SOCρ and ΔSOCρ to soil and management variables was analyzed.
- Statistical approaches were applied to evaluate significant differences (P<0.05) and to assess model efficiency.

## Results and Discussion

The measured SOCρ in control and urea-fertilized treatments (73-77 t C $ha^{-1}$) were significantly higher than simulated values (54-55) (Fig. 1a).

Simulated values were higher from cattle (88-99 vs. 66-116 t C $ha^{-1}$) than from pig slurry (75-78 vs. 55-69), increasing with application rate.

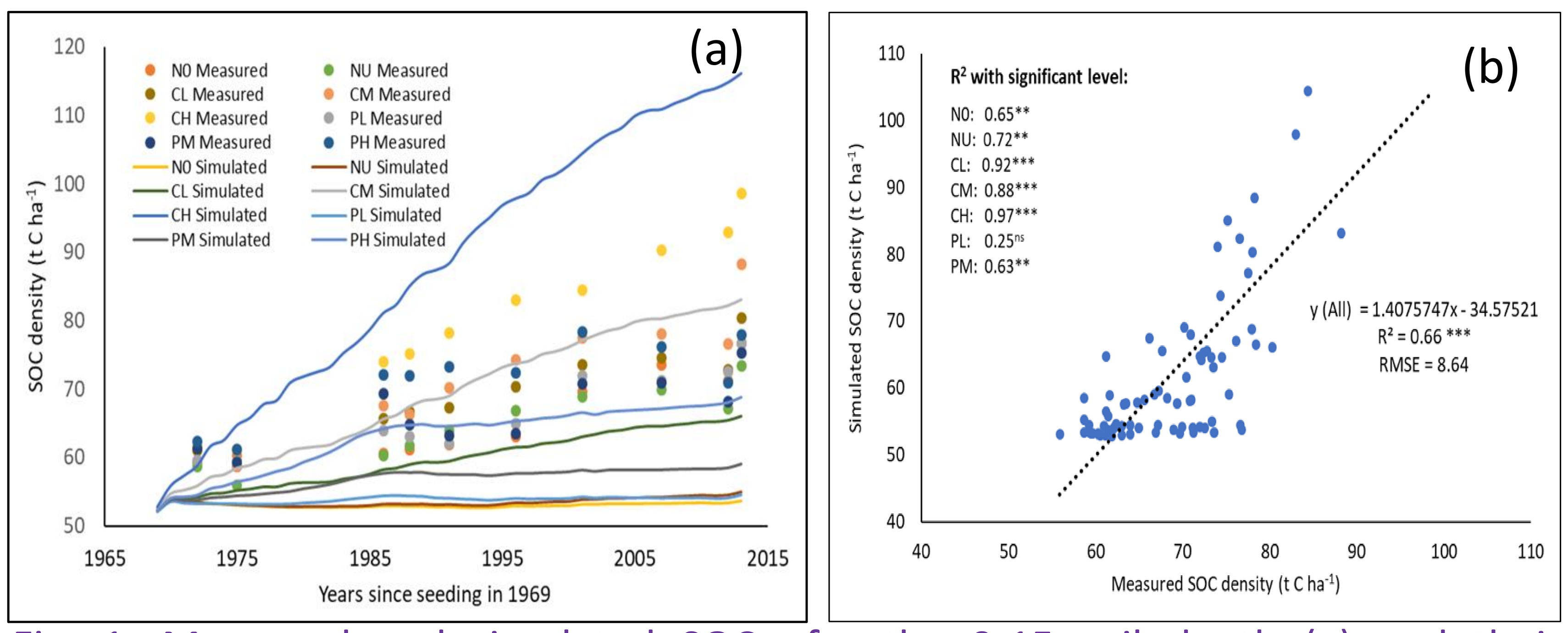


Fig. 1. Measured and simulated SOCρ for the 0-15 soil depth (a) and their relationship (b) under grass silage over 45 years. N0= Control; NU = Urea-N; CL = Cattle slurry @ low; CM = Cattle slurry @ medium; CH = Cattle slurry @ high; PL = Pig slurry @low; PM = Pig slurry @medium; PH = Pig slurry @high.

Regardless of treatment, SOC sequestration rates were 0.46 ± 0.06 (measured) and 0.37 ± 0.01 (simulated) t C $ha^{-1}$ $yr^{-1}$, respectively.

Simulated values correlated significantly well with measured ones, explained 66% of the variability (Fig. 1b).

Variations in the simulated SOCρ values could be explained by differences in applied C (62%), rainfall (15%) and air temperature (11%).

Values for SOCρ increased with increasing bulk density, SOC content and clay fraction, and the ΔSOCρ only with clay fraction and pH (Fig. 2).

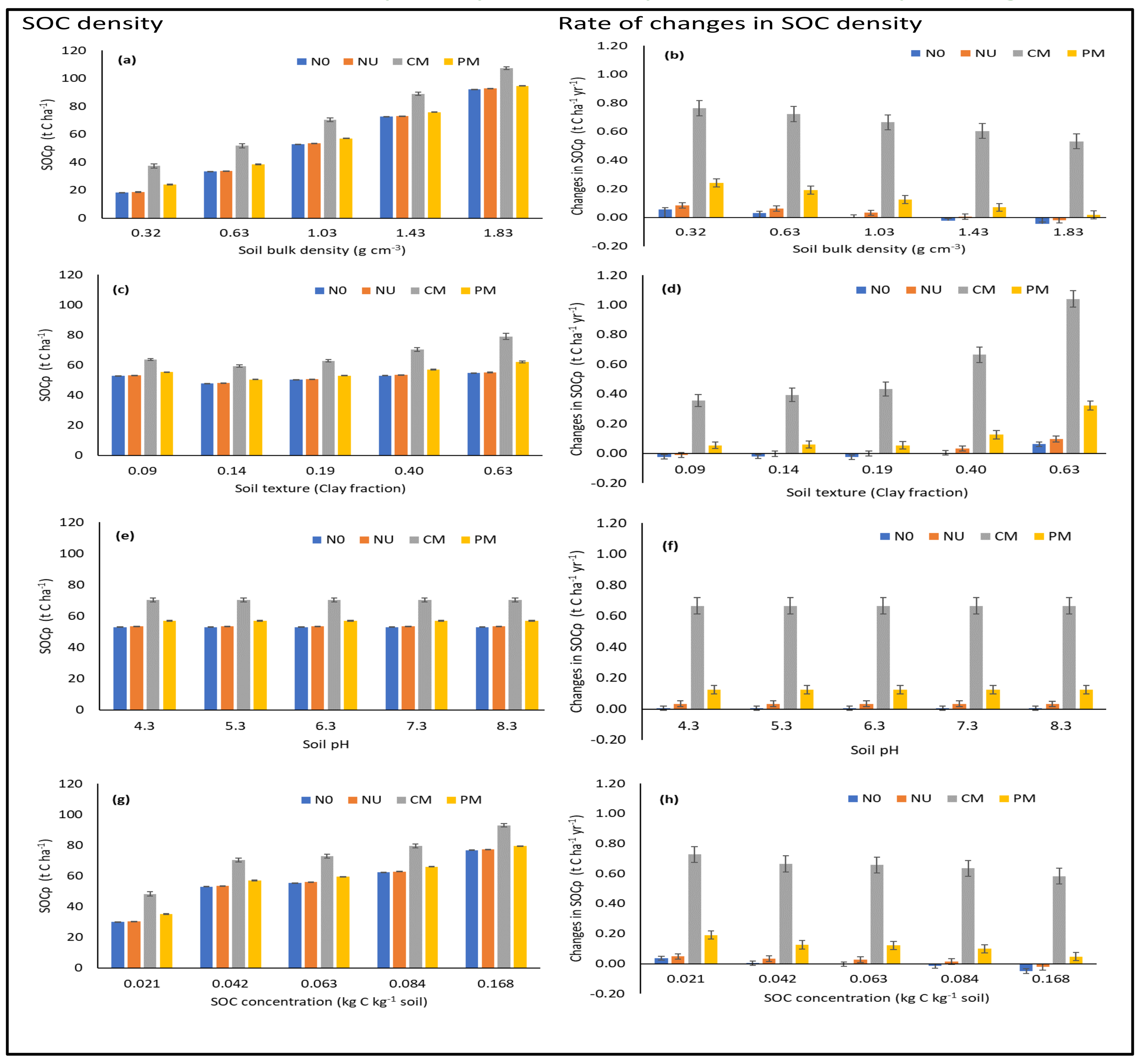
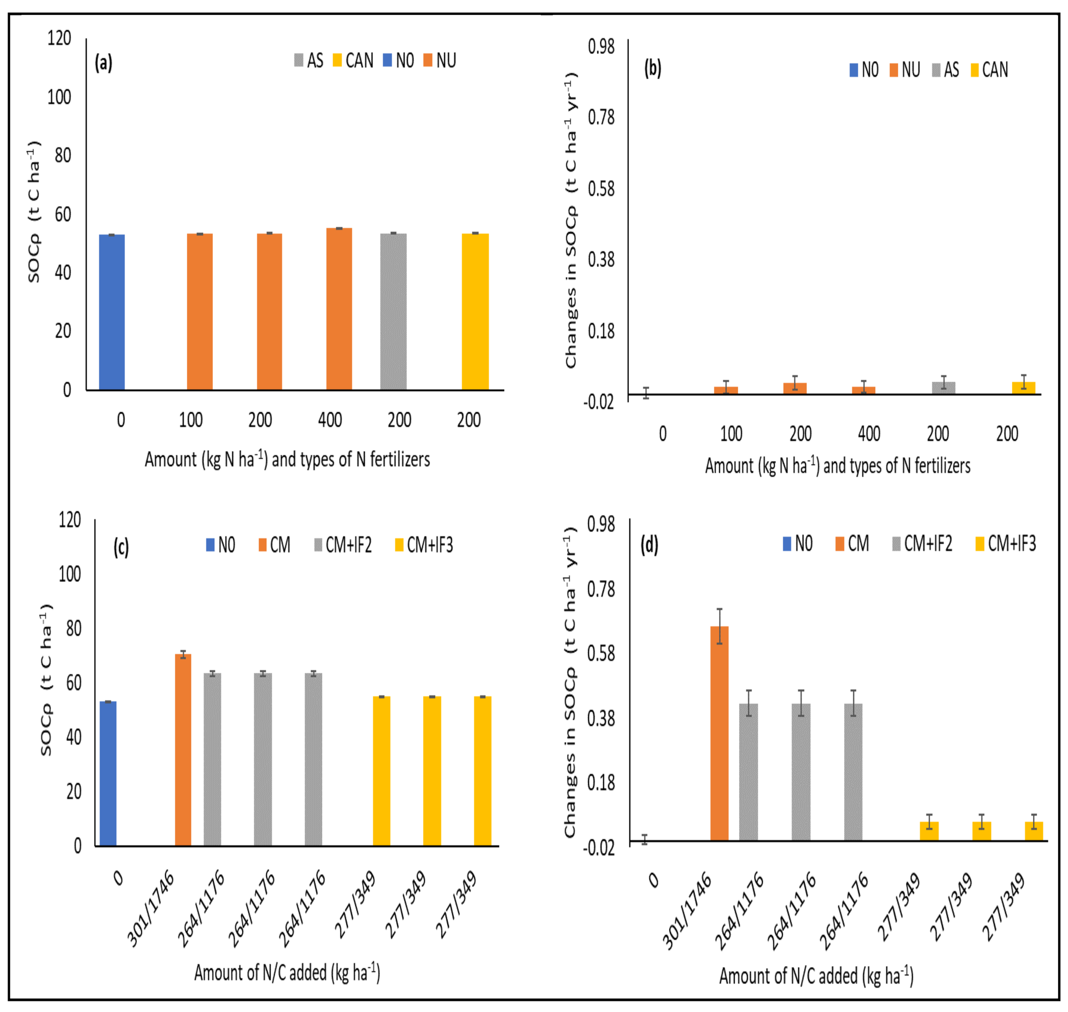


Fig. 2. Sensitivity analysis of soil properties on SOC density and its changes over 45 years in grassland silage receiving inorganic and organic fertilizers.

The model was less sensitive to urea-N rates or the N forms, and ΔSOCρ rose with increasing rates of N up to 200 kg N $ha^{-1}$ and dropped by 32% at the highest rate (Fig. 3).

The % increase of SOCρ for CM, CM+IF2 and CM+IF3 was 32.7, 19.6 and 3.4% compared to the control. The model response in predicting ΔSOCρ was similar to SOCρ.

Fig. 3. Sensitivity analysis of various inorganic (a, b) and organic fertilizers (c, d) on SOC density and its change over 45 years under grass silage. N0= Control; CM = Cattle slurry (medium rate); IF2 = the 2nd split of CM was replaced by Urea, Ammonium Sulphate and Calcium Ammonium Nitrate; IF3 = the 3rd split of CM was replaced by inorganic N fertilizers.



## Conclusions

- These findings show that a new SOC equilibrium was not reached in these grassland soils over 45 years.
- The DNDC95 model, although requiring more improvement, could respond well to the effect of soils, climate and management practices on SOCρ and its change over time.

Paper presented at the EGU General Assembly: Modeling agricultural systems under global change (BG2.52)" held from 7-12 April 2019 in Vienna, Austria.

## Acknowledgements

Department of Agriculture, Food and the Marine
afbi Agri-Food and Biosciences Institute