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

Projecting future changes in soil organic carbon across New South Wales using machine learning and climate projections

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Abstract: Soil Organic Carbon (SOC) plays a crucial role in supporting ecosystem services and climate resilience. However, SOC stocks are sensitive to climate variability and land-use changes, particularly in highly variable landscapes like New South Wales (NSW), Australia. This study aimed to predict the spatial distribution of SOC in 0-30cm under historical and future climate conditions using machine learning and downscaled climate scenarios from the NARCliM2.0 ensemble.

We developed a baseline SOC map for the historical period (1990–2009) at 100 m resolution using over 8,000 harmonised field observations and s suite of environmental covariates including terrain attributes, vegetation indices, soil type, and climate data. A quantile regression forest (QRF) model was trained and evaluated using 10-fold cross-validation, achieving an R^2 of 0.47 and RMSE of 2.5 g/kg for mean SOC prediction. Uncertainty was assessed using the 90% prediction interval from QRF outputs. Across most of the state, this interval ranged from 5 to 10 g/kg, with wider intervals observed in areas with fewer observations or greater climate variability.

Future SOC was projected under two contrasting shared socioeconomic pathways, SSP1–2.6 (low emissions) and SSP3–7.0 (high emissions), for two future periods: near future (2020–2039) and far future (2060–2069). Changes in SOC were expressed as percentage differences relative to the baseline.

Our results show a clear trend of SOC decline under both scenarios, with more pronounced losses under SSP3–7.0 by 2060–2069. In high-SOC regions of eastern and southern NSW, losses of 10–20% are predicted, while some areas in northwestern NSW show marginal increases in SOC (up to +5–10%). Under SSP1–2.6, SOC declines are generally less severe (<10%) and more spatially limited. Spatial patterns of change reflect interactions between baseline SOC, projected climate shifts, and environmental controls.

This study demonstrates a scalable and policy-relevant modelling framework that combines digital soil mapping, machine learning, and climate scenario analysis to support climate adaptation and soil management planning. The outputs offer valuable insight into the spatial variability of future SOC dynamics and provide a foundation for targeted interventions at regional and local scales.

Keywords: *Soil organic carbon, digital soil mapping, quantile regression forest, NARCLiM2.0*

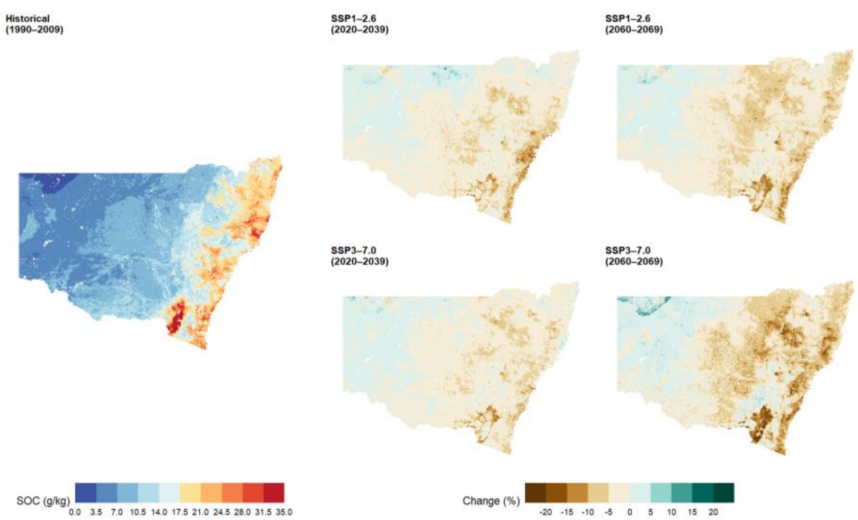

Figure 1 Historical and projected changes in SOC (0-30cm) under NARCLiM2.0

