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Trends and drivers of carbon stocks across rangelands over the decade 2010–2020

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Abstract: 50–75% of Australian land (between 3.75 and 5.625 Mkm^2) is defined as rangelands, which includes grasslands, shrublands, desert, and tundra (Russell-Smith et al., 2020). There is a growing interest in soil organic carbon (SOC) cycling in rangelands due to their extensive area, potential to produce high quality and volumes of forage for grazing (Safriel et al., 2005), and potential for carbon farming projects under the Australia Carbon Credit Units (ACCU) Scheme program. However, because of the diverse land cover, land use, and arid/ semiarid climate, there are complex interactions between natural and anthropogenic drivers controlling SOC dynamics in rangelands. Monitoring the SOC changes in rangelands using traditional measurement approaches is not economically and practically feasible. Therefore, SOC modelling plays an important role in estimating the changes and their drivers across rangelands, however, when modelling these environments, several technical challenges and uncertainties need to be overcome (Wang et al., 2018, Russell-Smith et al., 2020).

FullCAM is a process-based model that simulates and quantifies carbon fluxes across the land production systems. A key challenge in simulating rangeland areas is isolating key drivers of SOC fluxes, and assessing their uncertainty due to the high computational load required. From the carbon accounting perspective, it is important to understand how land management practices, climate, soil properties, and anthropogenic drivers affect SOC change in these ecosystems. Therefore, here we present a novel framework to estimate SOC stock and its drivers over the Australian rangelands for the period between 2010 and 2020. The work involved recalibrating key FullCAM parameters to match 166 best available field measurements while acknowledging their limitations. Then using recalibrated input data and simulation outputs, two surrogate models were trained using either a spatio-temporal Bayesian modelling approach or a random forest approach. We then extended the trained models across the rangeland regions to identify key drivers of soil organic carbon changes.

Overall, we found the variability in total SOC stock in rangelands in the decade 2010 to 2020 was not due to intense management practices, but instead related to changes in above-ground biomass. One of the advantages of using a spatiotemporal surrogate model to assess the past and current state of the national stocks is that the outputs included the confidence intervals, providing the first estimate of uncertainty. Our framework allows revisions and updates to the model to be benchmarked to estimate changes more precisely in SOC stocks and whether model improvements are addressing key sources of uncertainty. The framework can also be used to investigate drivers of SOC intra-annual variability and highlight areas under anthropogenic or climatic pressure, and if that changes over time.

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