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How and for how long should you "spin-up" soil C sub-pools in an APSIM simulation?

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Abstract: Modellers "spin-up" mechanistic agricultural models with the aim of achieving some level of model equilibrium/stability prior to the main simulation. While commonly applied in soil C-centric models such as ROTHC and CENTURY, spin-ups are used inconsistently in more dynamic cropping systems models like APSIM: spin-up durations in APSIM have been reported in published literature to range from four months to more than 100 years with little to no evidence supporting the decision around the spin-up duration. We propose a two-step approach to spinning-up the APSIM model: the first to reduce the model's sensitivity to uncertainty and potential incompatibilities in the initial soil C and nutrient pool parameterisation and the second to establish the pre-simulation conditions specified for the targeted cropping system/environment using a general or recorded site history.

Keywords: *Process-Based Model, Agriculture, Sensitivity Analysis*

1. BACKGROUND AND RATIONALE

In a review of the soil N model in APSIM, Verburg, Pasley et al. (2025) cited the initial parameterisation of the model's soil C pools as a major source of uncertainty in the model due their conceptual nature. For that reason, Cichota et al. (2021) proposed spin-ups as a potential way to parameterise soil C pool fractions. Building on the work of Probert et al. (1998), Luo et al. (2014; 2015), and Cichota et al. (2021), we explored the model's sensitivity to the initial parameterisation of soil C and N and how a spin-up can reduce model uncertainty.

Model soil C pool equilibrium steady-state (cited often as C pool sizes varying <1% annually) is a common indication in C-centric models that the model parameters are in-tune with each other following a spin-up. This target is not a realistic starting point for highly dynamic cropping system simulations like those generated by most APSIM model users. Such a simulation in a APSIM needs the model parameters to reflect the dynamic and non-equilibrium status of the soil, climate, and system resulting from a typical or recorded site environment and history.

2. METHODOLOGY

Using previously calibrated/validated simulations of four contrasting combinations of environments, soils and cropping systems as case studies, we investigated how model outputs were impacted by different initial parameterisation approaches, spin-up durations, and including the site's history. A Morris Sensitivity Analysis (Saltelli, 2002*)* was used to look at parameters found to be the most influential and uncertain by Luo et al. (2014; 2015) and Cichota et al. (2021). Initial parameterisation ranges were guided by recommendations from Probert et al. (1998) and Cichota et al. (2021). The BIOM C pool was selected as a good proxy for model dynamic stability following initial C pool parameterisation as it is the most active C pool (reflecting short-term trends in the model) and its size is defined as a fraction of the total C pool. Equilibrium was defined in this study as the point at which the year-to-year variability of the BIOM C pool's sensitivity (μ^*) to initial C pool parameterisation falls below a threshold of 10%. Simulations were initially run for 100 years to determine the duration of spin-up needed to reach model equilibrium. The importance of incorporating site history into model spin-ups was then demonstrated, highlighting the considerable difference in model outputs that result from simulations with and without a simulated site history (Figure 1).

3. RESULTS AND CONCLUSIONS

This study found that the duration of the first stage of the spin-up and the impact of including or not including a site history as the second stage of the spin-up varied depending on the targeted system, outputs, and environment. This proposed approach is meant to spark conversation about the best way to spin-up APSIM and similar cropping systems models. It primarily aims to highlight the importance of thoughtful reflection in the determination of spin-up approaches and of including site history as part of any spin-up approach.

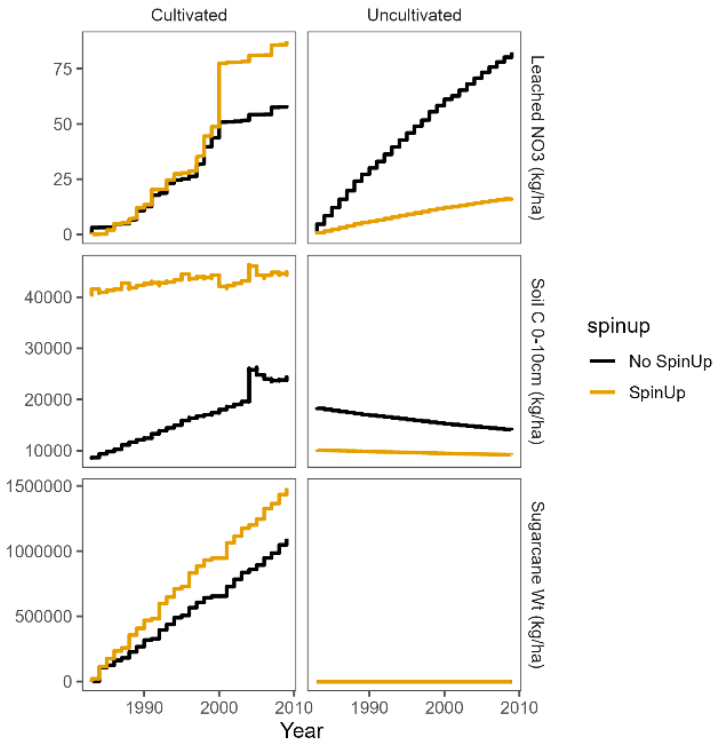

Figure 1 Outputs from the simulation of the Tully (tropical) case study site (Biggs et al., 2021) where sugar cane was grown for 80 years prior to the targeted experiment which started in 1983. The simulation was spun-up to minimise model uncertainty for 3 years prior to either (1) a spin-up of 80 years of site history followed by the targeted simulation (Spin-Up in yellow) or (2) the targeted simulation without any site history simulated (No Spin-Up in black). The targeted simulation looked at two treatments: cultivated and uncultivated, each with initial soil C values for 0-60 cm recorded on 25/08/1983.

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