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Modelling of soil nitrogen dynamics in a smart-irrigated maize field in Newry, Victoria

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Abstract: Accurate simulation of crop growth and soil nitrogen (N) dynamics is essential for supporting site-specific agricultural management and sustainable development. Process-based crop models such as the Agricultural Production Systems sIMulator (APSIM) have been widely used to predict crop yields, soil nutrient cycling, and water balance across diverse environments (Holzworth *et al*., 2014). This study employed APSIM Next Generation (APSIM-X) with the SoilWat module, specifically calibrated using field measurements to investigate nitrogen partitioning in a smart-irrigated field.

The model parameterization incorporated a comprehensive set of local soil parameters, including soil texture, pH, bulk density, hydraulic conductivity, and initial soil water content across five layers (0–5 cm, 5–15 cm, 15–30 cm, 30–45 cm, and 45–60 cm). Pre-growing season measurements of soil ammonium (NH_4^+), nitrate (NO_3^-), total nitrogen (TN), and total carbon (TC) provided detailed initial N and carbon (C) pools for each soil layer. Dynamic irrigation patterns were introduced through a smart-irrigation system using a center-pivot triggered by soil moisture sensors at 60% of field capacity. Other local agronomic practices, including site-specific fertilization and planting strategies, were fully integrated into the model to reflect actual farm management. The model development followed recommended APSIM maize parameterization workflows (Govindaraj *et al*., 2023) and soil parameterization workflows (Cichota et al., 2021).

The field campaign was conducted from early December 2024 to late April 2025. Throughout the growing season, time-series data of soil moisture at five different depths, rainfall and irrigation were collected at sub-daily time steps, while soil N concentrations (NH_4^+ and NO_3^-) at each depth, and biomass N and C content of maize (leaves, stems, and grains) were collected at two-week intervals. This sampling frequency covered key phenological stages, including vegetative growth, tasseling, grain filling, and maturity, ensuring sufficient temporal resolution to capture short-term N dynamics and maize growth responses. The parameterized and calibrated APSIM model can closely reproduce field-observed maize yields and capture the temporal patterns of soil N fluctuations during the growing season, effectively representing N uptake, leaching, and redistribution within the soil profile. Model performance was evaluated using multiple statistical indicators, including mean absolute error (MAE) and Nash-Sutcliffe efficiency (NSE). The entire growing season was stratified into irrigated and non-irrigated windows to evaluate how N dynamics respond to irrigation, using the same performance indicators. The model was able to reasonably capture field observations across the different water regimes. After model validation against field data, the model was subsequently used to simulate alternative irrigation and fertilization strategies, which produced plausible variations in N dynamics and crop responses, demonstrating the model's potential for informing management decisions.

This site-specific APSIM model provides a useful decision-support tool for N management in Newry. Future work may extend this model to multi-year simulations, multi-crop rotations, and integration with remote sensing to enhance spatial scalability and predictive capacity.

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