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Nitrogen loss in sugarcane: uncertainty and sensitivity analysis of APSIM predictions

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Abstract: Managing nitrogen (N) in the Great Barrier Reef (GBR) catchment is a crucial environmental and agricultural challenge. N loss from sugarcane production, via runoff and leaching, degrades reef water quality, and nitrous oxide (N_2O) emissions add to agriculture's climate impact. Process-based models, particularly Agricultural Production Systems sIMulator (APSIM), have been extensively used to study sugarcane growth, N cycling, and loss for over 25 years. APSIM outputs underpinned the development of the industry's 6 Easy Steps (6ES) N rate guidelines, as well as the Paddock-to-Reef program, which evaluates the effectiveness of improved management practices across the GBR catchment and informs policy.

Although APSIM is a valuable research tool, its application for regional modelling across the GBR catchment faces limitations due to uncertainties in model parameters and input data. For example, Takeda et al. (2024) reported large variability in denitrification-related parameters when calibrated at different sites within the GBR catchment, leading to substantial differences in simulated denitrification and N_2O emissions, as well as N leaching and the subsequent overall N budget in sugarcane. Such findings highlight the need to better understand and quantify the uncertainty in N loss simulation when APSIM is applied regionally across the GBR catchment with limited calibration.

This research addresses that gap by conducting a spatially explicit uncertainty analysis of APSIM predictions of N leaching, denitrification, and N_2O emissions across three sugarcane growing regions (Tully, Herbert, and Burdekin). The uncertainty analysis draws on ranges of possible APSIM parameter values obtained from literature, field and incubation studies, and past model calibrations, which are then used in Monte Carlo simulations to obtain uncertainty in model predictions. Second, a global sensitivity analysis using the FAST method is used to apportion the uncertainty in predictions to individual model parameters related to denitrification and nitrification. The uncertainty associated with soil hydraulic properties is also taken into account in both parts of the analysis.

This spatially explicit uncertainty and sensitivity analysis revealed that predicted N losses, along with their associated uncertainty, vary substantially among the three regions. The importance of individual parameters for predicting N loss also varies between regions. Moreover, parametrization choices can significantly alter the partitioning of N loss between leaching and denitrification. Building on these findings, future research can target the main sources of uncertainty at the regional level to improve model predictions. More broadly, this work contributes to advancing the use of process-based models and strengthening their credibility in regional applications.

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