25th International Congress on Modelling and Simulation, Darwin, NT, Australia, 9 to 14 July 2023
mssanz.org.au/modsim2023

Redesigning a nutrient model to enable faster model development

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Abstract: Farming systems modelling is a well-established science and an important tool for analysing complex farming systems problems. An ability to model the major components of a farming system lies at the core of this approach. As a result, accurate and effective modelling of important Soil Organic Matter (SOM) stocks and processes is important in many applications of Farming Systems Models. These include various SOM and mineral pools, flows of carbon and nutrients between these pools, and losses from these processes. The SoilNitrogen model within APSIM (Holzworth et al, 2018) provides such a capability.

Many researchers using the SoilNitrogen model have explored changes for improving model performance. Such efforts include i) changes in the number of soil pools, ii) flows between these pools, iii) functional forms used in calculating flows, and iv) parameters values used in these functions. However, implementation of such changes was not always straightforward because of the way models were implemented. Though there was some consideration of object-oriented approaches for abstracting the science of carbon and nutrient dynamics into instantiable models, the science was mostly captured using traditional procedural programming approaches in FORTRAN or C#. Though there was a clear conceptual model behind the specification of the model (e.g. pools, flows, algorithms), the use of traditional programming approaches did not reflect this way of thinking. Furthermore, it was difficult for researchers to understand or change model design.

We used an approach, already found to be widely successful within APSIM for crops (Brown et al, 2014), to capture the needs of researchers. Classes were developed for pools, flows and functions. Users can alter the number of pools, flows between pools, the functional forms used to calculate flows, and parameter values used in functions. All can be altered via the user interface or command-line tools, thus facilitating alternate model configurations or designs within simulations to compare model structures and parameterisations (ie model comparison). This new functionality is referred to as the APSIM Nutrient model.

We found that we could reproduce the behaviour of SoilNitrogen on wide range of test sets using a configuration duplicating the published model. Though this resulted in some minor changes in the ordering of calculations, there was no significant impact on predictions. Furthermore, this was achieved with a significant reduction in the number of lines of code, and increased transparency and flexibility. Some adverse impacts on execution time had to be resolved given the move from fast and efficient array processing in earlier implementations. There are some difficulties yet to be resolved at system boundaries where conceptual models varied between different parts of APSIM (e.g. between SOM and plant material or surface OM).

A current review of model science within the APSIM SoilNitrogen and Nutrient models is under way to highlight the need for changes in APSIM for modelling soil carbon and nitrogen cycling. The new design will provide a good platform for exploring alternative model configurations within the one code base.

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Keywords: *Plant modelling framework, APSIM, soil organic matter, functional programming*