APSIM SOILWAT AND SOILN: VALIDATION AGAINST OBSERVED DATA FOR A CRACKING CLAY SOIL

M.E. Probert[1], J.P. Dimes[2], R.C. Dalal[3] and W.M. Strong[3]

[1]APSRU, 306 Carmody Road, St Lucia, Qld 4067
[2]APSRU, PO Box 102, Toowoomba, Qld 4350
[3]Queensland Wheat Research Institute, Toowoomba, Qld 4350

Summary. Changes in soil water and nitrate-N during the fallows of the continuous wheat treatments of the Warra Soil Fertility Restoration Experiment have been used as an example dataset to test the performance of APSIM modules for predicting the behaviour of water and nitrate-N in a cracking clay soil. Agreement between observed and predicted data is very good, both with respect to the amounts of water and nitrate-N in the profile and their distribution with depth. It is concluded that these modules are suited to describing the movement of water, the mineralisation of nitrogen and redistribution of nitrate in such soils.

INTRODUCTION

Modelling of farming systems offers exciting prospects for comparing alternative management strategies with respect to production, efficiency of resource utilisation and longer-term consequences for the resource. However, confidence in the use of models, and their outputs, rests on how credibly they represent the real world, and this must be judged from their ability to predict observed data.

APSIM (Agricultural Production Systems Simulator) is a flexible software system for simulating agricultural production systems (2). It has a modular structure so that high order processes are represented as discrete modules. For example, SOILWAT is a soil water balance module, SOILN describes the dynamics of soil carbon and nitrogen, and RESIDUE deals with the above ground crop residues.

Testing of model performance must ultimately deal with the whole system, but there are circumstances where it is desirable to isolate sub-systems so that certain aspects of model performance can be assessed without complications rising from other parts of the system. Here we address the question of how well the APSIM modules listed above simulate the behaviour of water and nitrogen in a cracking clay soil. By restricting the evaluation to fallow periods, issues related to water use and nitrogen uptake by the crop are avoided. The system is simplified so that only those processes involved in the recharge of soil water (runoff, evaporation, redistribution of water within the soil profile) and accumulation of mineral nitrogen (mineralisation, immobilisation due to crop residues, denitrification and leaching of nitrate) are operating.

MATERIALS AND METHODS

Data source

The data are from the Fertility Restoration Experiment at Warra (1). The soil is a vertisol which had been depleted in fertility through continuous grain cropping since 1935. For the present purpose only the continuous wheat plots, which compare conventional and zero tillage with three rates of applied nitrogen (0, 25 and 75 kg/ha as urea at planting), are considered. Wheat (variety Hartog) has been grown each year since 1987 except in 1991 when no planting opportunity occurred. All crop residues are retained.

Soil sampling has been carried out twice per year, prior to planting (in May) and after harvest (in October/November). Cores were sectioned in 10 cm increments to 30 cm, and then 30 cm increments to 1.5 m, and soil moisture and nitrate-N determined.

Simulation

The APSIM v1 modules SOILWAT, SOILN and RESIDUE were configured to simulate the experimental treatments during the period 1987-1994. The model ran continuously through this period using daily temperatures, radiation and rainfall measured at the site. Each year the soil water and nitrate-N were re-initialised with measured data from the post-harvest sampling and above ground residues and roots from the previous crop were added. Data are available for residue yields and their N content, but an assumption had to be made for roots; it has been assumed that 20% of total crop carbon was in roots with a C:N ratio of 40. Model performance was tested by comparing observed and predicted soil water and nitrate-N data at the next pre-plant sampling and, in the case of the missed crop in 1991, through the long fallow.

The conventional tillage treatments were cultivated up to four times during a normal fallow. The model assumes that each operation of the chisel implement used incorporates 15% of the above ground residues into the surface soil layer.

Specification of the soil properties for the model used the same layer structure as was followed for field sampling. The soil water characteristics (lower limit, drained upper limit and saturated volumetric water contents) were estimated from the driest and wettest moisture contents measured at the site during the experiment, though not necessarily for the continuous wheat plots. Soil organic carbon data are available at the beginning of the experiment. At initialisation of the model, the soil carbon has to be distributed between two soil organic matter pools. The BIOM pool, representing the more labile soil organic matter with a higher rate of decomposition, was assumed to be 2% (typical for cereal systems) of the total soil carbon in the surface soil declining to 1% in the deeper soil layers; the HUM pool represents the bulk of the soil organic matter. To reflect the reduced rate of decomposition of organic matter in the deeper soil layers, an increasing proportion of HUM is assumed to be inert and not susceptible to decomposition. Other model inputs (e.g. runoff curve number, evaporation coefficients) were chosen to be representative of the soil and environment. Model parameters defining the rates of decomposition of the soil organic matter pools and surface residues, and the transfer of carbon and nitrogen between pools were not changed from their standard values.

RESULTS AND DISCUSSION

The simulated time course for total soil water and nitrate-N in the profile is illustrated in Fig. 1 for the conventionally tilled, nil fertiliser treatment. It shows how the model was re-initialised with measured data after each crop and the observed data at the end of the fallows when comparisons can be made between the model predictions and observed data. The gaps in the plots are when the crop was growing; these periods are not relevant to the present discussion. The comparisons of observed vs predicted water and nitrate-N data, in terms of totals in the profile and contents in individual layers, for all six treatments (2 tillage methods x 3 fertiliser rates) are set out in Fig. 2.

In general, the model performed very well in predicting water and nitrate as shown by the proximity of the points to the 1:1 lines of Fig. 2 for both the totals and in the individual layers. Examination of depth profiles (data not shown) indicates that the model was able to capture not only the changes in total water and nitrate but also their distribution within the profile. The results, especially for the no fertiliser treatments, suggest that the variation in nitrate-N from mineralisation of the soil N and its interaction with crop residues is being satisfactorily captured by the model. During the long fallow of 1991-92 the model predicts a much greater accumulation of nitrate-N than in the normal short fallow, in close agreement with the observed data (Fig.1).

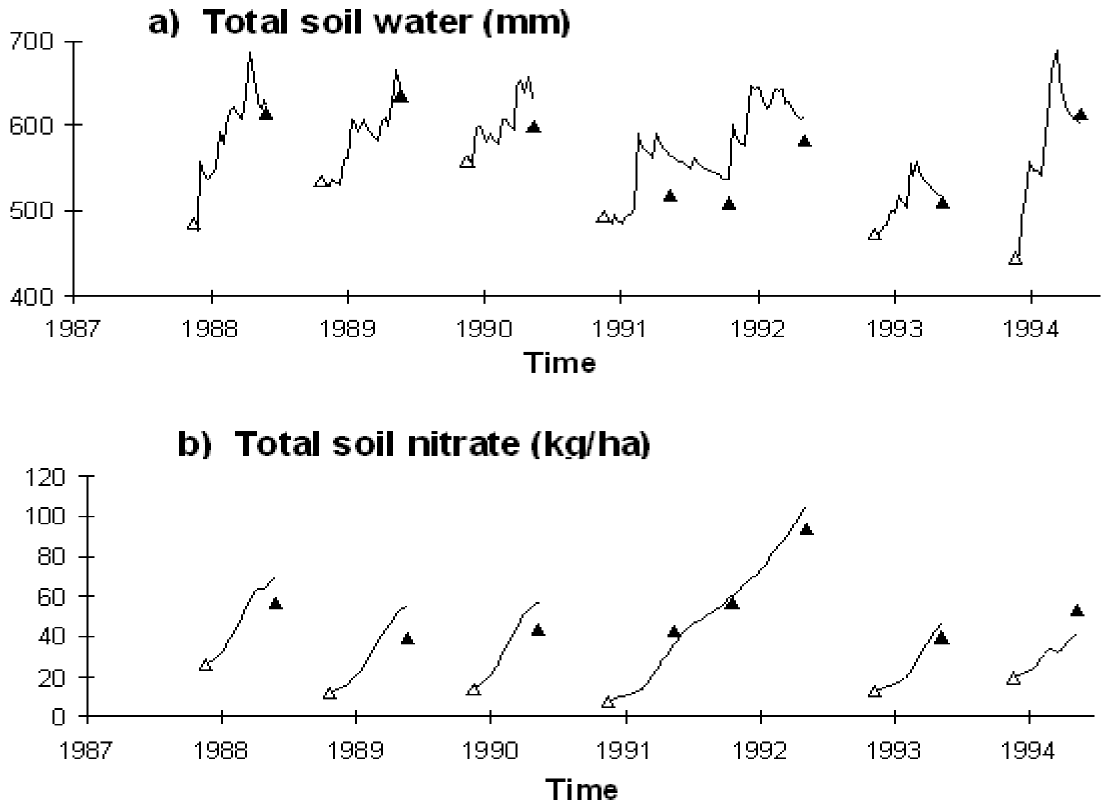

Figure 1. Simulated soil water and nitrate-N in the 0-150 cm profile for the conventional tillage treatment without fertiliser-N. Measured data shown as symbols, open symbols representing the post-harvest samplings that were used to re-initialise the model. During the 1991-92 long fallow, soils were sampled in May 1991, October 1991 and May 1992.

For soil water there was no difference in the goodness of fit for the two tillage treatments, showing that the manner in which the model varies runoff and evaporation in response to surface cover is in accord with the observations.

For nitrate-N the deviations between observed and predicted were greater for the highest rate of fertiliser application (Fig. 2). The effect is most noticeable in the nitrate-N concentrations where there are rather more outliers for the N75 rate of application. The root mean squared deviations (RMSD = $\mathrm{sqrt}\{\Sigma(\mathrm{obs}-\mathrm{pred})^2/n\}$) for total nitrate-N were 10.9, 11.0 and 24.5 kg/ha for the N0, N25 and N75 treatments, corresponding values for the nitrate-N concentrations in individual layers being 1.64, 1.59 and 2.79 mg/kg. At least part of this can be attributed to the difficulties of sampling the soils to representatively recover fertiliser N that had been applied as bands between alternate rows of wheat but was not taken up by the crop.

CONCLUSIONS

The simulation of these data from the Warra experiment show that the APSIM SOILWAT, SOILN and RESIDUE modules, which describe the dynamics of water and nitrogen, can do an adequate job in predicting the behaviour of water and nitrate-N in this cracking clay soil under two contrasting tillage managements. It provides confidence to progress to using such models for the simulation of more complex systems.

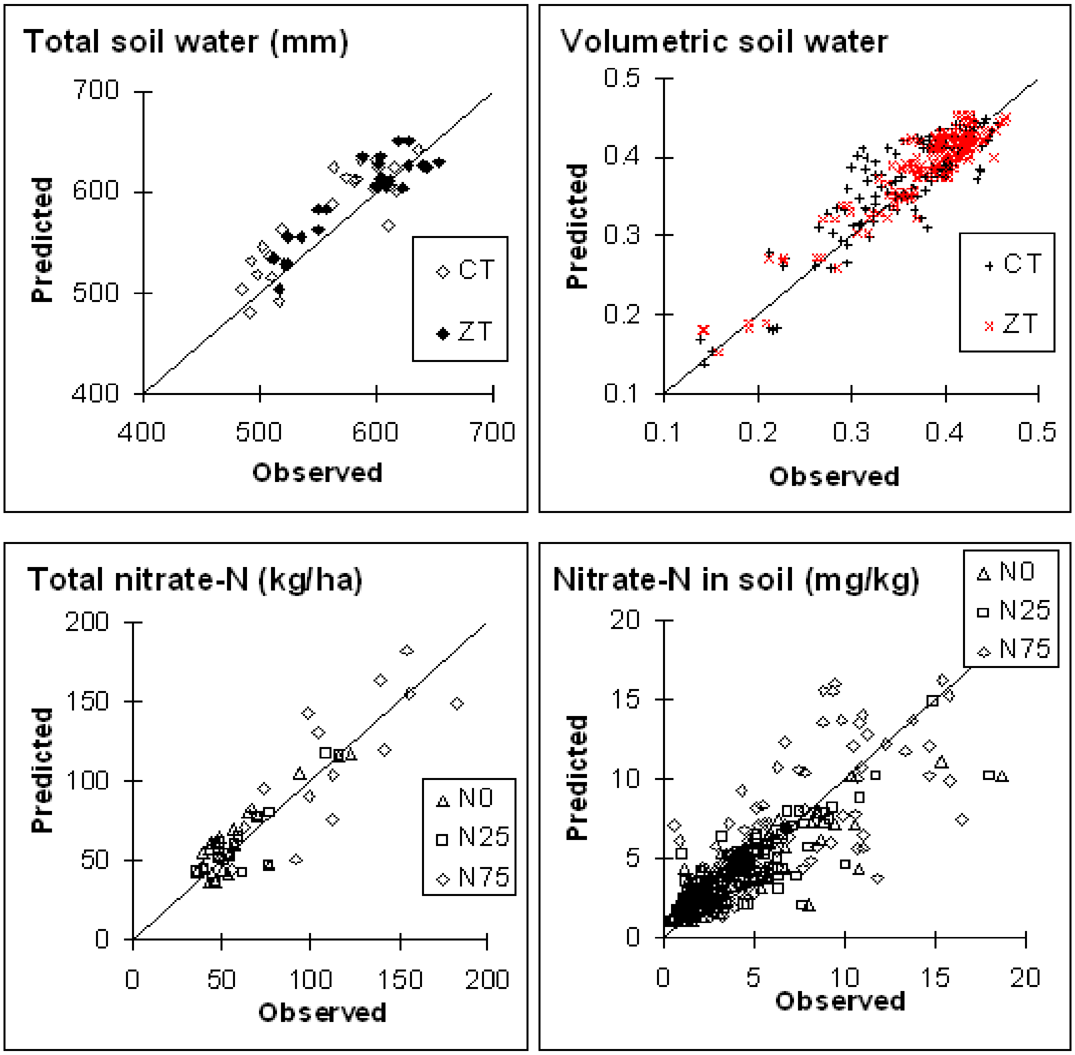

Figure 2. Comparison of observed and predicted soil water and nitrate-N in the 0-150 cm profile and in the individual soil layers for the six treatments. Root mean squared deviations between observed and predicted data are: total soil water in profile 25.9 mm; volumetric water content 0.027; total nitrate-N 16.7 kg/ha; nitrate-N concentration 2.08 mg/kg.

ACKNOWLEDGMENTS

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