A VALIDATION OF APSIM NITROGEN BALANCE PREDICTIONS UNDER INTENSIVE CROPPING

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Abstract

Agricultural systems models can be used to address the growing need to understand the impact that management decisions have on nutrient cycling and leaching. In this paper we report a test of the Agricultural Production Systems sIMulator (APSIM) by comparing simulated nitrogen dynamics with data from a field experiment.

Results indicate that APSIM successfully simulated the nitrogen balance of the field experiment. However, questions are raised about APSIM’s estimates of nitrogen mineralisation, and the movement of mineral nitrogen through the soil profile. Possible causes for the differences between the simulated outputs and measured values are discussed, and suggestions proposed for possible modifications to APSIM.

Introduction

There is a growing need within New Zealand for agricultural systems models to address the implications of management decisions on nutrient cycling and leaching. Tools to predict the effects of land management on groundwater quality are needed by both farmers and policy makers. While there are models that can estimate nutrient losses from single crops there are few that can give meaningful outputs for cropping rotations.

APSIM is a systems model which, through a suite of modules, enables the simulation of systems that cover a range of plant, animal, soil, climate and management interactions. APSIM can be set up to simulate a rotation of different crops with complex management rules. While there has been extensive testing and calibration of the plant and soil modules of APSIM in Australian conditions (Probert et al. 1998a; Probert et al. 1998b; Keating et al. 2003; Thorburn et al. 2010), they have not been extensively tested in New Zealand conditions.

In this paper we report a test of APSIM to simulate nitrogen (N) dynamics by comparing with data from a three-year field experiment, designed to measure the effects of irrigation and fertiliser on year-round N losses.

Methods

Data were collected from a field trial with a factorial combination of N fertiliser rates and irrigation managements in a randomised block design. The experiment was established at Lincoln, Canterbury in spring 2004 on a well-drained, intensively cropped soil, with four replicates of the crop rotation; potatoes – winter fallow – spring peas – winter fallow – potatoes. Each main plot was split into two different irrigation rates (optimum (W1) and either increased frequency or increased amount (W2)), and these sub-plots were split again into three different N fertiliser rates (nil (N0), optimum (N1) and excess (N2)). Irrigation was applied by drippers and fertiliser was applied as calcium ammonium nitrate.

Measurements of soil mineral N, crop N, soil water content and leachate N concentration were made at regular intervals throughout the trial. Soil samples were taken at 0.2 m intervals from the soil surface to 1.5 m and analysed for mineral N. Crop dry matter yields and N uptake were calculated at harvest. Soil water was measured using a neutron probe, with tubes installed to a depth of 1.5 m; the 0 to 0.2 m depth was measured using time domain reflectometry (TDR). Leachate was collected from ceramic cup solution samplers installed at a depth of 0.6 m in the first potato crop and 1.5 m in the fallow, pea and second potato crop. Nitrogen leaching was calculated using the soil solution nitrate concentration measured from samples collected in the ceramic cups and the drainage calculated by APSIM through the use of a water balance model. This procedure aimed at reducing uncertainty around drainage estimates.

The observed data were compared with simulations developed in APSIM 7.2. APSIM allowed the integration of several crop models with an underlying soil module which simulates soil water movement and nutrient supply. The crop modules used were ‘potato’ and ‘fieldpea’. The soil water module SoilWat was used. The soil description (e.g. soil texture) and initial values were provided from data collected at the start of the experiment.

Results and discussion

The amount of N taken up by the crop at harvest was accurately simulated by APSIM (Figure 1). Predicted values for the potato crop are marginally below measured values, while predicted values for the pea crop are above measured values. The under-prediction for potatoes may be due to N losses through senescence and/or disease in the field experiment, while the over-prediction for the pea crop may be due to uncertainty in the amount of N fixation by the crop. However, predictions of N removal by the crops are within acceptable ranges of those observed in the field experiment.

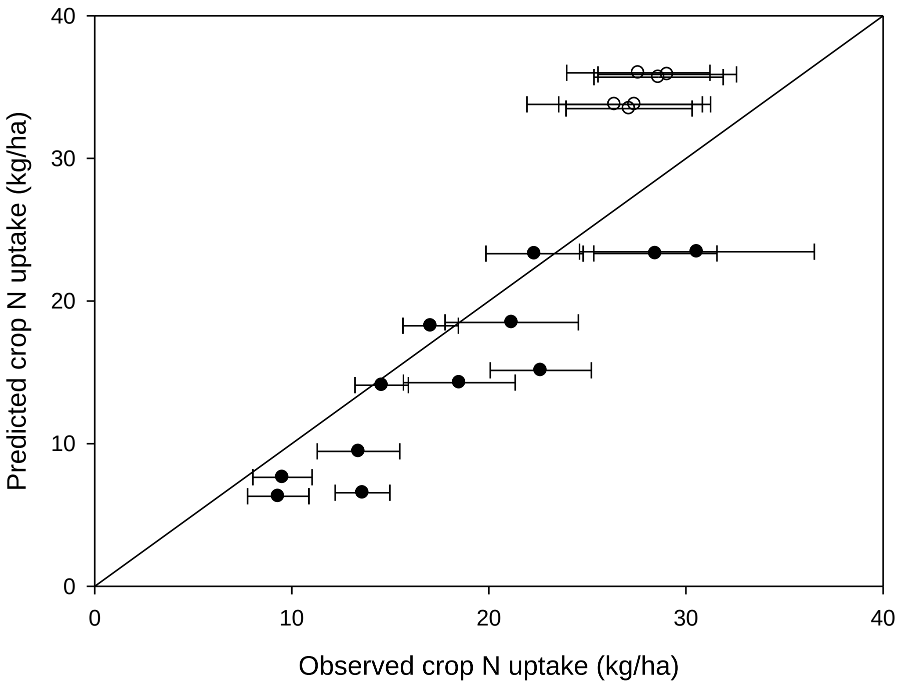

Figure 1. Observed against predicted crop nitrogen uptake by potatoes (●) and peas (○), with associated standard deviation, for different treatments and 1:1 reference line.

The primary source of N loss from the system was nitrate leaching. Predictions of annual leaching in the first year exceed the observed, but were lower than the observed in the final year (Figure 2). Given that the starting values for soil N were measured and APSIM predicts a reasonable approximation of N uptake by the crop, it suggests that APSIM over-predicts the leaching loss of N from the system. Estimates of leaching, both experimentally and in APSIM, are a product of drainage and the soil solution nitrate concentration. While there were no direct measurements of drainage in the field experiment with which to test APSIM against, intensive measurements of soil water content were taken.

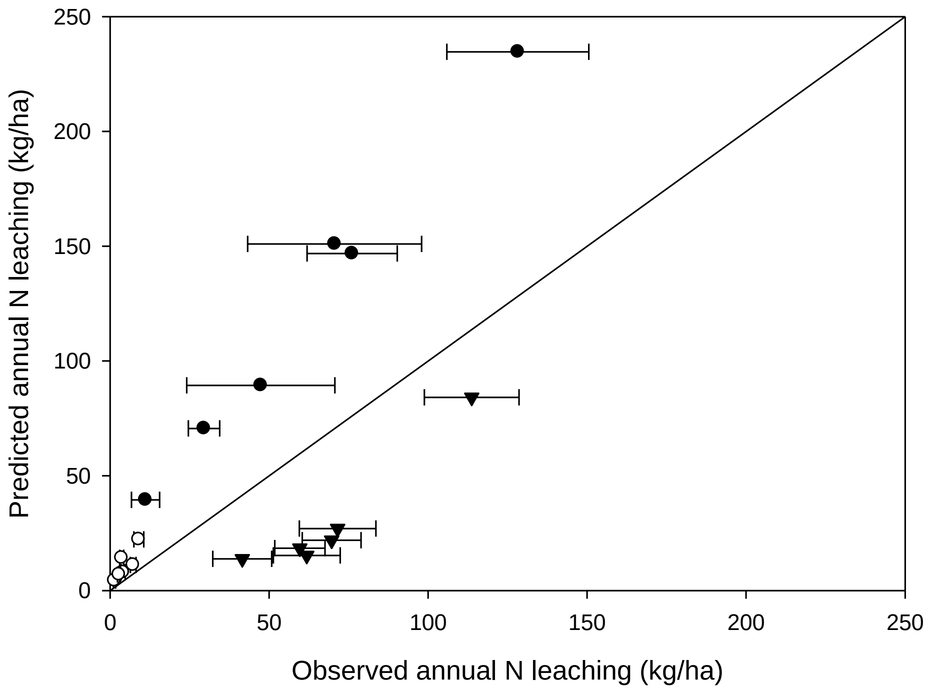

Figure 2. Observed against predicted annual nitrogen leaching in year 1 (●), year 2 (○) and year 3 (▼), with associated standard deviation, for different treatments and 1:1 reference line.

Figure 3 shows the changes in volumetric water content through time for each layer within the soil profile to a depth of 1.5 m for the W1 treatment. APSIM gave a good prediction of soil water content in all layers except in the top layer when under potato crops. This discrepancy may be due to changes in the soil bulk density as a result of the ridges and furrows created for the crop. Nevertheless, through all of the soil layers, APSIM simulations track the observed data through time, and respond accordingly to the increases and decreases in soil water content with the wetting and drying of soil. Given that there is confidence in the irrigation and rainfall data used by APSIM describing the water inputs to the system and the soil water content is well approximated by APSIM simulations, it can be inferred that drainage from the system is simulated appropriately. This therefore suggests that the overestimation of annual leaching in the APSIM simulations is likely to be due to an overestimation of soil solution nitrate concentration. Essentially, a greater amount of nitrate in the soil water is moved down through and out of the soil profile, by soil water, in the APSIM simulations than in the observed data.

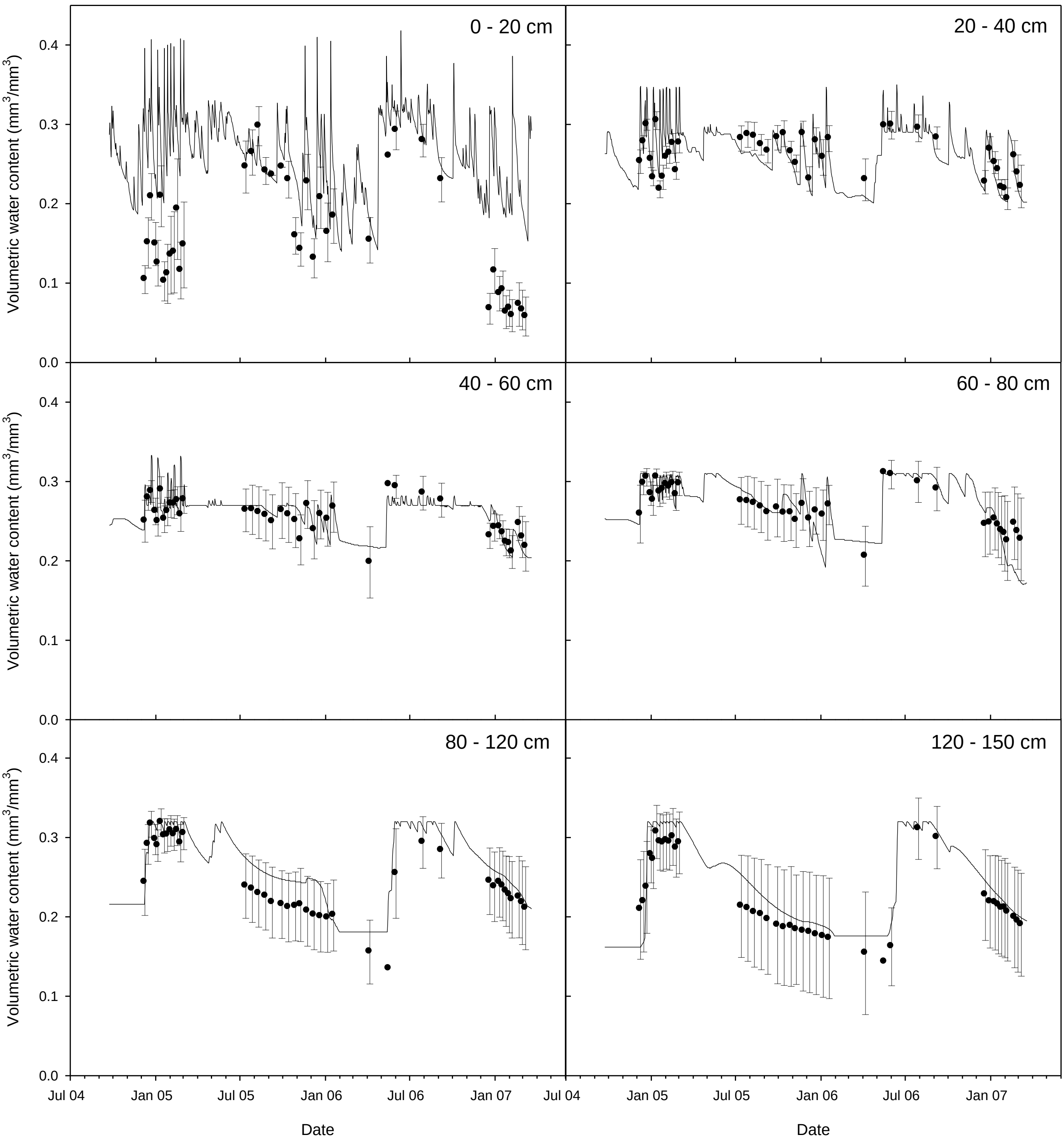

Figure 3. Observed (●), with associated standard deviation, and predicted (-) volumetric soil water content through time in soil layers of increasing depth for the W1 treatment.

Within APSIM's SoilWat module the saturated and unsaturated flows of soil water are used to calculate the redistribution of solutes throughout the soil using a 'mixing' algorithm (APSIM Undated). Efficiency factors adjust the effectiveness of mixing for either saturated or unsaturated flows. This means that solute movement is calculated as the product of the water flow, the solute concentration in that water and the efficiency with which they mix. It is assumed in APSIM 7.2 that incoming water and solute, from both saturated and unsaturated flow, are fully mixed with that already present in any layer to obtain concentrations for solutes that are applied to the water leaving the layer. They therefore have efficiency factors of 1.0. If this assumption is relaxed, so that when there is saturated flow there is not complete mixing, less solution nitrate will be moved down through and out of the soil profile. For this modelling study an efficiency factor of 0.7 gave the best fit of predicted annual nitrate leaching values to those observed for the first and second year of the experiment (Figure 4) also shows that there is a very poor fit in the third and final year of the trial.

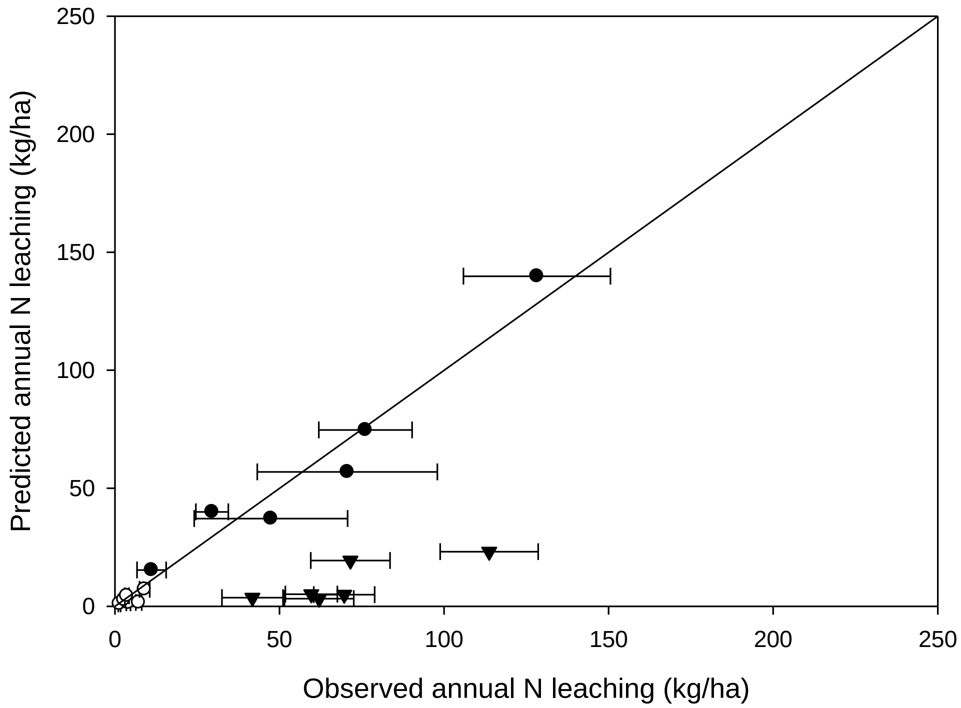

Figure 4. Observed against predicted annual nitrogen leaching in year 1 (●), year 2 (○) and year 3 (▼), with associated standard deviation, for different treatments and 1:1 reference line.

The significant under-prediction of annual N leaching in year 3 of the trial may result from the under-prediction of soil mineral N content. Figure 5 shows total soil mineral N to 0.6 m through time for the W1 N0 treatment. Measured values show that during the first potato crop there is a decline in mineral N and then a subsequent increase. The same is also observed in the predicted values, yet the increase is not so great. Since this treatment does not have any mineral N applied, any significant increase in mineral N comes from mineralisation. The same pattern is also observed in the W2 N0 treatment, as shown in Figure 6 This therefore suggests that through the first winter fallow and in later periods in the experimental sequence APSIM is under-predicting N mineralisation.

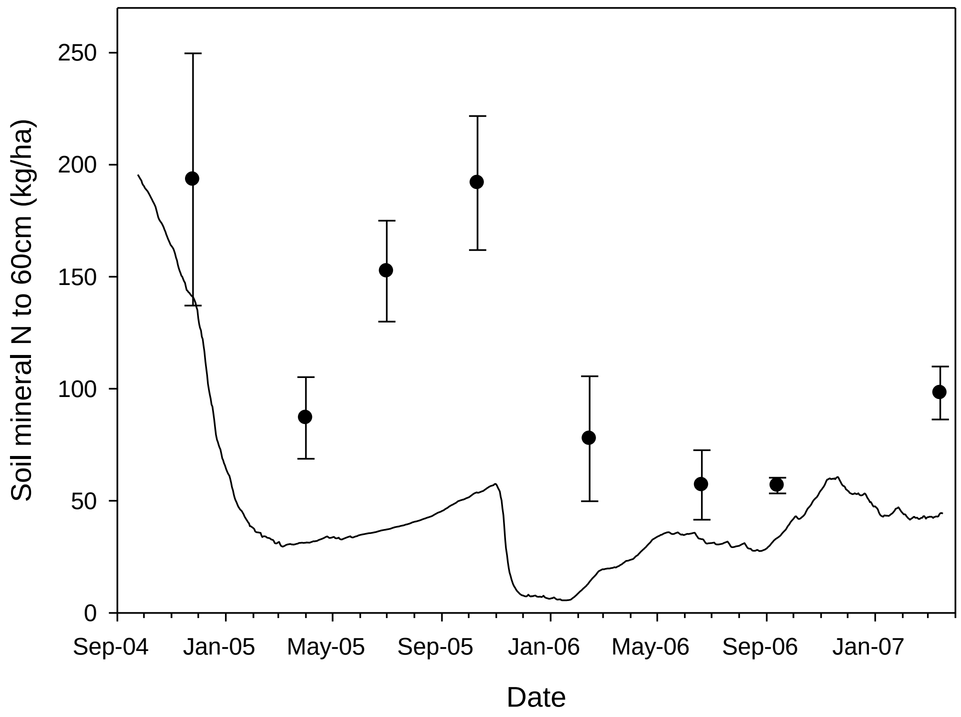

Figure 5. Observed (●), with associated standard deviation, and predicted (-) soil mineral nitrogen to 60 cm through time for the W1 N0 treatment.

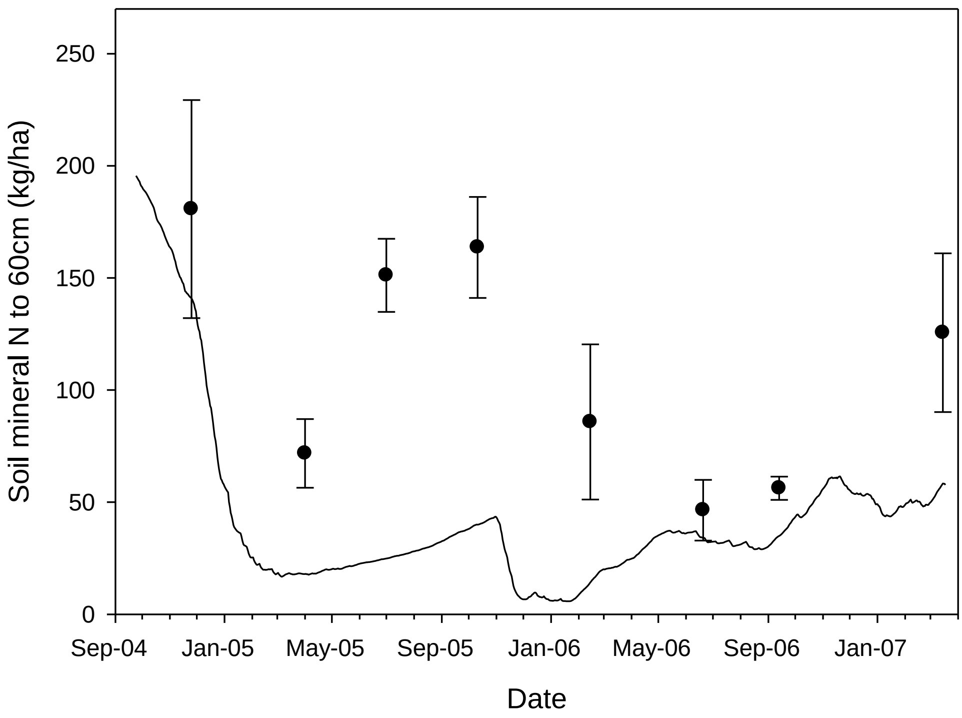

Figure 6. Observed (●), with associated standard deviation, and predicted (-) soil mineral nitrogen to 60 cm through time for the W2 N0 treatment.

Conclusions

APSIM was successful at simulating the N balance of this crop rotation. However, analysis showed that APSIM over-estimates the leaching of mineral N through the soil profile, and when adjustments are made, estimates of leaching are much improved. Further questions are also raised about N mineralisation within APSIM, especially within the winter fallow period, and further work is required to adapt APSIM to New Zealand conditions.

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