Simulating crop and soil processes in crop sequences in southern NSW

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Abstract

The APSIM simulation model was tested against field data from a 12-year crop sequence study following a grass/legume pasture at Harden, and a three-year continuous wheat sequence at Condobolin. Soil water balance was well simulated in both experiments, however the model consistently under-predicted the amount of mineral N available to the crop at Harden. Simulation of soil mineral N was more realistic at Condobolin, where the climate was warmer and drier, and there was no recent pasture history. Biomass, yield and crop N uptake were usually well simulated at both sites when the soil mineral N and water were reset to actual values at sowing in each year. The soil mineral N balance was poorly simulated at the site with a recent pasture history and further investigation is required.

Key Words

Modelling, APSIM, wheat, water, soil nitrogen, rotation

Introduction

Decision support tools that predict the performance of farming systems can use models to simulate cropping sequences. The APSIM (Agricultural Production Systems Simulator) model (1) has the potential to simulate production for a range of crops grown in a sequence, although most APSIM testing in southern temperate regions of Australia has been performed on single crops in single seasons. Soil, plant and residue processes must be accurately simulated each year, in order to accurately simulate crop sequences over several years without resetting the model.

The aim of the present study was to determine if the APSIM models could be utilised to simulate performance of crop sequences in a temperate climate. The APSIM wheat, canola and chickpea modules were used to compare performance of the model with crop, soil water and soil nitrogen data collected from two crop sequence experiments conducted in southern NSW.

Methods

Harden experiment

A 12-year tillage experiment conducted near Harden, NSW (2, 3) was simulated. The soil was a red earth with total carbon in the surface of 1.3% and C:N ratio of 10. Paddock history was 5 years of perennial grass/lucerne/subterranean clover pasture prior to the commencement of the experiment in 1989 with an oat crop followed by wheat, lupin, wheat, canola, wheat, lupin, wheat, pea, wheat, canola and finally wheat in 2000. Growing season rainfall ranged from 179 to 539 mm (April to mid-November). The burn/cultivate treatment of the study was selected for simulation as the incidence of soil-borne disease was negligible. Stubble was burnt in late April of each year and plots were cultivated once with a scarifier prior to sowing. Fertiliser N was applied in 1993, 1994, 1996, 1998, 1999 and 2000 at rates of 97, 23, 22, 114, 130, and 110 kgN/ha, respectively. Measurements of profile soil water (gravimetric) and mineral nitrogen (NO_3 and NH_4; NO_3 dominated) were taken at sowing and maturity of crops in most years.

APSIM release 2.1 was utilised to simulate the crop sequence using the wheat (cv. Janz) and canola modules. Legume crops were simulated using the chickpea module (cv. Amethyst) to represent narrow-

leaf lupin and the pea crop, which was cut for hay in November. The Soilwat2 module was employed to simulate soil water. The model was specified to run continuously from 1989 to 2000. Soil water and mineral N profiles were reset to actual values using the sampling of the soil at sowing of the 1990 wheat crop. The model was run (a) without any further resetting, and (b) with resetting of soil water and mineral N profiles at sowing in each year when profile data were available. The simulation was set up to begin on 1/2/89 before the oat crop was sown in March. Pasture root biomass was set at 5 t/ha with a C:N ratio of 40. Surface residues were estimated to be 1 t/ha with a C:N ratio of 30. The 1989 oat crop was simulated as a wheat crop.

Condobolin experiment

Another simulation was based on a three-year continuous wheat sequence experiment conducted near Condobolin, NSW in 1991-1993 (4). The experiment followed a wheat, oats, wheat sequence from 1988 to 1990. The soil was a red brown earth with total carbon in the surface of 1.3% and C:N ratio of 13. In this drier environment, soil-borne diseases rarely cause yield loss and did not occur in this study. Growing season rainfall was 234, 341 and 324 mm respectively, during the three years. Treatments simulated were those receiving 25 kgN/ha at sowing in 1991 and 1993 and 10 kgN/ha at sowing in 1992. These treatments were selected as they provided the most comprehensive and continuous set of observed data for testing model performance. The cultivars sown and simulated were Rosella in the first two years (1991and 1992) and Dollarbird in 1993. The model was run (a) without any resetting after the 1991 sowing, and (b) with resetting of soil water and N profiles at sowing in 1992 and 1993.

For both sites, soil parameters for saturated water flow were set at 88 (*diffus_const*) and 35.4 (*diffus_slope*), consistent with soil texture. The run-off curve number was 72 and the soil evaporation parameter, *cona,* was set at 2.0 from April to September and at 3.5 for October to March, as this improved simulation of surface soil water content and is consistent with settings for *cona* used by others (5). Plant available water content of soil profiles to a depth of 1.6m were 169 and 145 mm, for Harden and Condobolin, respectively.

Climatic data were obtained from weather stations 2km (Harden) and <1km (Condobolin) distant. Mean annual temperatures were 14.7 and 17.5 ?C and the difference between the highest and lowest mean monthly temperatures were 16 and 16.5 ?C, respectively. The model simulations of above-ground biomass, yield, soil water and soil mineral N contents were compared with the observed data.

Results

Harden experiment

Simulation of water in the soil profile corresponded well with observed data (Fig. 1a). Soil mineral N however was poorly simulated by the model (Fig. 1b) being consistently underpredicted in all soil layers (data not shown). Resetting soil mineral N and water at sowing in each season provided more N to the crop, however even with annual resetting the simulated mineral N content of the profile was exhausted too rapidly during each crop.

Crop biomass, grain yield and above-ground N uptake were quite well simulated for wheat, canola and lupin crops when the model was reset at sowing for each crop (Fig. 2), despite inaccuracies in the simulation of soil mineral N.

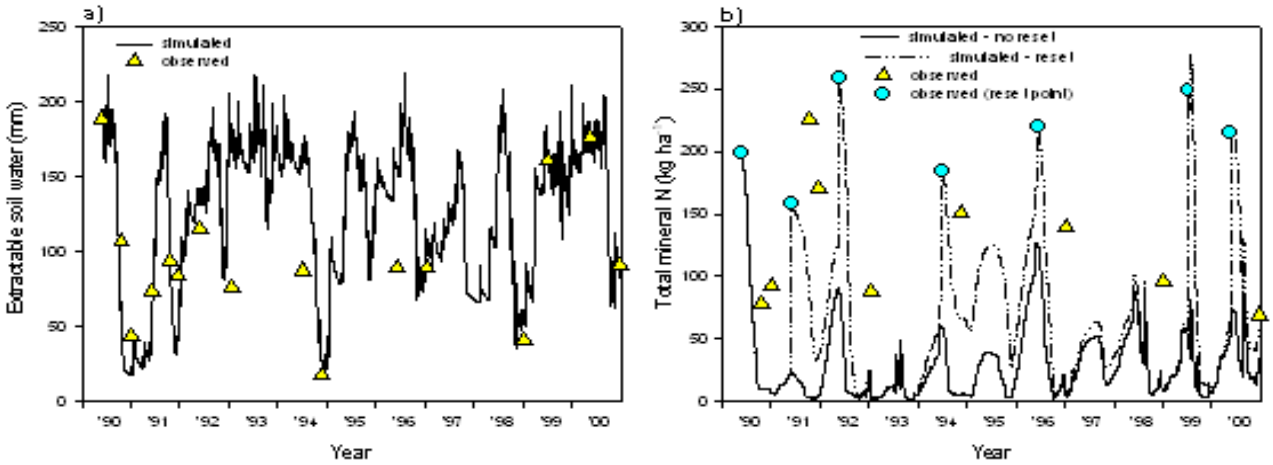

Figure 1. Simulated and observed a) plant extractable soil water, and b) mineral nitrogen in the soil profile (0-160cm) over a 12-year period at Harden. Simulated soil mineral nitrogen is shown for the run without resetting, and for the run which was reset to observed values at sowing each year.

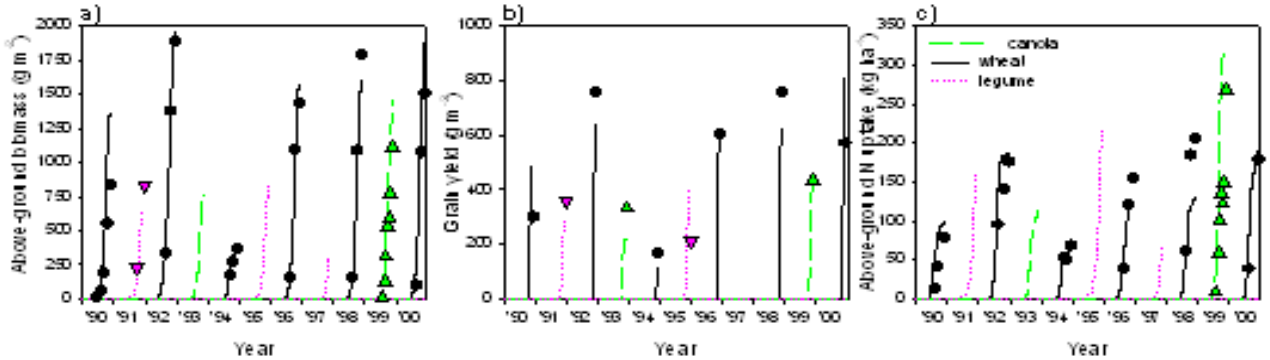

Figure 2. Simulated and observed data of above-ground biomass, grain yield, and N uptake of wheat, lupin, pea and canola during the 12-year crop sequence at Harden with soil water and mineral N reset to observed values at sowing each year.

Condobolin experiment

Soil water was accurately simulated for Condobolin (Fig. 3a). Simulations of soil mineral N were reasonably accurate at maturity of the 1991 and 1992 crops, but in 1993 the simulated soil mineral N was exhausted too rapidly from the profile (Fig. 3b). Summer/autumn mineralisation was underestimated by the model in 1992, but simulated reasonably well in 1993.

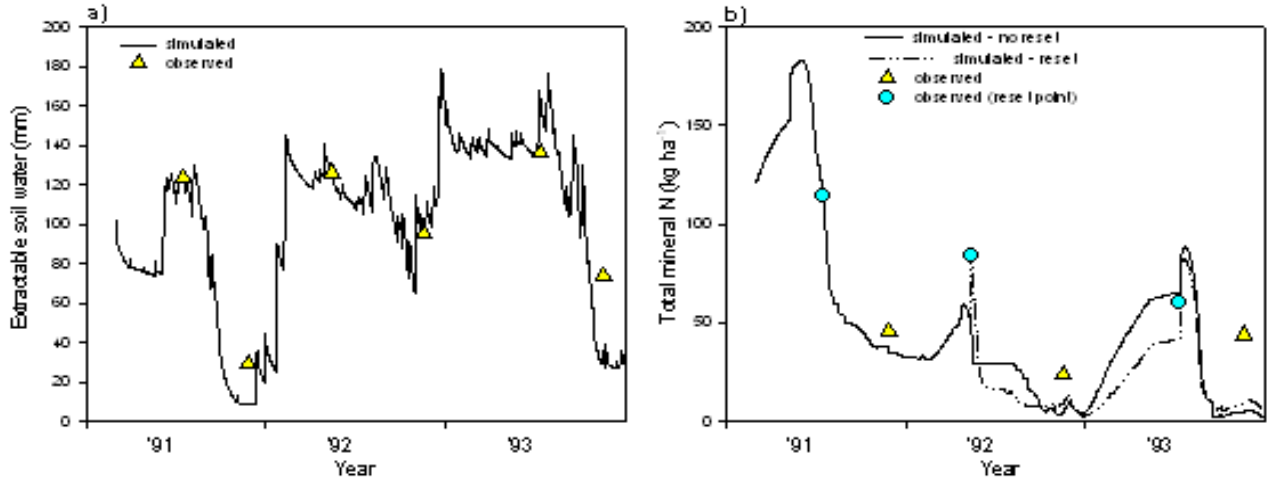

Figure 3. Simulated and observed a) plant extractable soil water, and b) mineral nitrogen in the soil profile (0-160cm) over a 3-year period at Condobolin. Simulated soil mineral nitrogen is shown for the run without resetting, and for the run which was reset to observed values at sowing each year.

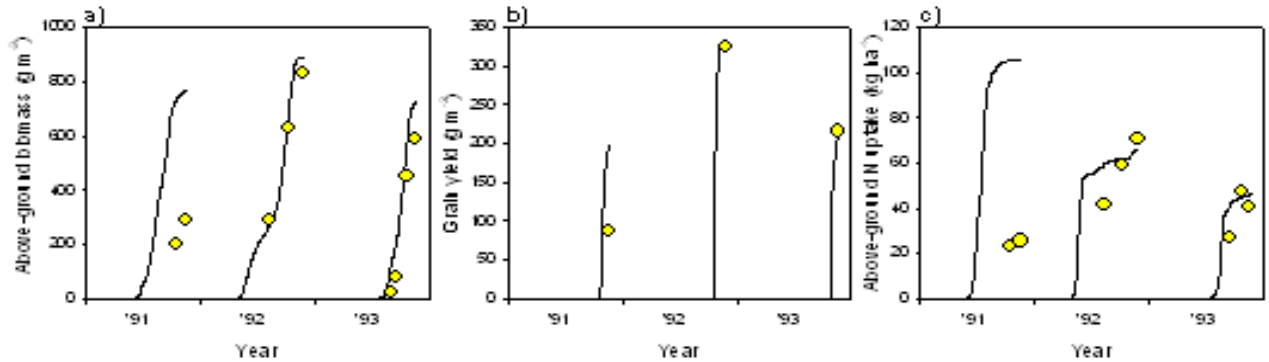

Figure 4. Simulated and observed data of above-ground biomass, grain yield, and N uptake of wheat, during the 3-year continuous wheat sequence at Condobolin with soil water and N reset to observed values at sowing each year.

In 1991, the crop hayed off and the model failed to capture the effects of environmental stresses, consequently simulated values of yield and biomass were at least twice the observed values (Figs

4a,b). However, biomass and yield of the 1992 and 1993 crops were accurately simulated. Concomitant with

biomass prediction, simulation of above-ground N uptake was extremely poor in 1991 but good in 1992 and 1993 (Fig. 4c).

Discussion

It appears that when measured data for soil water holding characteristics are available APSIM Soilwat2 module accurately simulates profile changes in soil water across lengthy crop sequences. Simulations of crop production by the three cropping modules, wheat, canola and chickpea were also reasonably robust.

Given the limitation of the inaccurate simulation of soil mineral N available to the crop biomass, yield and above-ground plant uptake of N were simulated surprisingly well.

Soil mineral N however was poorly simulated at the Harden site. At Condobolin, where there was no recent pasture history, soil mineral N was more closely simulated. N budgets including leaching and denitrification of N cannot account for differences between simulated and observed soil mineral N at Harden. Errors in soil mineral N simulation are also observed in the 'reset run' indicating that the underestimate is consistent across a range of years. Simulations of fallow plots at another site near Harden (data not shown) indicate that N mineralisation is underestimated by the APSIM model.

To initialise soil organic matter (SOM), two parameters can be adjusted. The *fbiom* parameter represents the more labile fraction of SOM, which mineralises faster than bulk SOM. The *finert* parameter represents the proportion of SOM that is unavailable for decomposition. Adjusting *fbiom* had little effect after the first year of simulation, while changes in *finert* produced a longer-term effect. A range of values for *finert* between 0.01 and 0.36 in the surface and increasing with depth were tested. These changes in soil parameterisation did not improve simulation of the soil N dynamics.

One possibility is that the N mineralisation routines incorporated in this model do not account for (a) high rates of mineralisation observed for several years after a pasture and/or (b) adaptation of soil microbes to the lower temperature regime experienced in this region.

To elucidate deficiencies in soil mineral N simulation for soils with a recent pasture history in the temperate environment, a study with frequent plant and soil measurements during a cropping cycle would enable closer examination of reasons for the departure of the model from measured values.

Conclusion

The APSIM simulation model can readily simulate soil water changes in medium-term crop sequences using basic soil water characteristics. However, the model did not accurately simulate soil mineral N content, particularly at the site with a recent pasture history. When soil mineral N was reset at sowing, APSIM produced good simulations of crop biomass and yield for wheat, lupin and canola crops.

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