Simulation of tactical use of Phase Farming to reduce Deep Drainage

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Abstract

Including lucerne into the cereal rotation (phase farming) has been shown to be effective in drying out the soil profile and creating a buffer to limit deep drainage during the subsequent cropping phase. How quickly lucerne dries out the profile, and how quickly rewetting occurs under cereal crops depends on factors such as weather, soil type, and crop/pasture management. Simulations using the systems model APSIM (Agricultural Productions Systems Simulator, 2) have proven useful to analyse the effects of these factors in lucerne-wheat rotations. Here we illustrate how simulations using historical weather data can be used to evaluate measurements that could be used as an aid in determining when to change phase.

Key words

Phase farming, lucerne, soil water, deep drainage, dryland salinity, modelling.

Introduction

Dryland agriculture in southern Australia suffers in many places from rising water tables and associated salinity problems. This is thought to be due to increased deep drainage following the clearing of native vegetation and the introduction of annual crops and pastures, which use less water. The introduction of lucerne has been proposed as a possible solution to address the current hydrologic imbalance (1). When phased with crop rotations the deep-rooted lucerne can generate a dry soil buffer, which can substantially reduce deep drainage in the subsequent cropping phase, as has been shown in experimental studies (2,4). To extrapolate the site specific experimental results, the agricultural systems model APSIM has been used to simulate a wheat-lucerne rotation with fixed three-year phases (1). It was found that both the creation of the dry soil buffer under lucerne and the rewetting under subsequent cereal crops were influenced by weather, as well as soil type, rooting depth, and crop and pasture management. These simulations show that depending on seasonal conditions, the lucerne could be effective within 1 year or take as long as three to generate the buffer. Therefore there is a need to develop decision rules for phase changes. Here we present a further analysis using APSIM to explore the possibility of using simulations to identify parameters that could be used to help with tactical decision making.

MATERIALS AND METHODS

For the simulations presented, APSIMv1.6 was configured with the SWIMv2 water balance module, the Nwheat crop module, the Lucerne module, the SoilN2 soil nitrogen module, and the Residue2 surface residue module. The Manager module was used to simulate soil and crop management decisions. A grassy weed species, which germinated in summer following sufficient rainfall, was represented through a reconfiguration of the Nwheat module. The model and its parameterisation were tested against data from a detailed field study near Wagga Wagga, NSW, which was sown to wheat in 1993 and carried lucerne from 1994 to 1997 (2,5,6). The soil at the site is a red Kandosol and is reasonably well-drained.

The simulations of these experimental data were generally good. In particular the annual evapotranspiration totals, crop growth (wheat), fluctuations in soil water content, and timing and amount of drainage events were predicted satisfactorily. This gave confidence that the model was capable of simulating the water balance of the wheat-lucerne system.

Long-term scenarios were set up to reflect a wheat-lucerne phase farming system, with either fixed 3-year phases (fixed rotation) or conditional phase changes (tactical simulation). The simulations used historical weather data (SILO Patched Point Dataset) from the nearby Meteorological Office at Forest Hill (1957-1998). Wheat and lucerne sowing was conditional on rainfall within a sowing window between 1 May – 15 June or sown “dry” on 15 June. Crop and soil management were similar to that used for the 1993-1997 experiment. Wheat was fertilised at 137 kg N/ha/season (17 kgN/ha applied at sowing, the balance 62 days later) and crop residues were largely (95%) burned. Lucerne was managed as a fodder crop and cut frequently. At the end of the pasture phase it was removed on 15 December. In the simulations roots of wheat (var. Janz) were allowed to penetrate to a maximum depth of 1.2 m, whilst those of lucerne penetrated to a depth of 3 m, based on field experience at that site. For both the tactical and fixed-rotation simulations, the first five years were identical (fixed rotation) and were discarded in the analyses to allow the simulation to stabilise and minimise artificial initialisation effects.

Results and Discussion

During the fixed-rotation simulation there were six periods when there was drainage below 3 m: twice during a first lucerne year, twice during a third wheat crop, once during a second wheat crop, and once during a first wheat crop. Water storage in the 0-1.2 m layer was largely a function of rainfall, with fluctuations under lucerne just as large as under wheat. Hence this storage could not be used for predictive purposes. Analysis of water content fluctuations at 1.5 m showed that on all occasions increases in water content preceded the drainage events by sufficient time to allow a phase change. These results suggest that for this particular scenario, the water content at 1.5 m could serve as a trigger for phase changes. Once the soil at 1.5 m starts to wet, lucerne should be sown in the following autumn to avoid or at least limit deep drainage. Similarly, once this layer is dry lucerne could be removed and a crop sown the next autumn. Several other parameters were considered and found suitable provided they were accompanied by appropriate decision rules.

Tactical use of phase farming to control drainage at 3 m was explored by using the water content at 1.5 m as a trigger for phase changes. Whenever the soil at this depth had started to wet by the 1st of March, lucerne was sown instead of wheat, and when water extraction by lucerne had dried this soil layer to the lower limit, lucerne was removed (15 Dec) and wheat sown in the next autumn. The results of this simulation showed that one of the previous drainage periods could be avoided and that drainage could be significantly reduced during the other periods. During two of those periods drainage was reduced to less than 4 mm and during a third to less than 20 mm. Drainage during the remaining two periods (1974, 1989) was still significant, but inevitable given the excessive rainfall during the preceding months.

During the 36 year analysis period (from 1962) the tactical use of phase farming reduced drainage by 35-40% compared with the fixed rotation. This was, however, at the cost of the number of wheat crops grown, because the wheat phase was generally shortened. The lucerne phase was usually less than three seasons and sometimes the soil was sufficiently dried after just one season. In reality this may not be acceptable for economic and practical operational reasons. Although not possible with wheat, undersowing the lucerne would avoid this for some annual crops and have the additional advantage of an extra crop in each phase. This and other factors such as varying the length of fallow period, fertility, and economics need further analysis. The above scenarios do, however, illustrate the role simulation analysis can play in helping develop practical decision rules for phase changes.

Conclusions

The results presented here illustrate the potential role that simulations can play in helping to identify parameters on which phase farming decisions could be based. Results of the preliminary analyses suggest that economic and practical operational aspects will need to be considered in addition to the physical triggers considered here, but that significant reductions in drainage may be obtained. By careful selection of crops and use of undersowing options this may be achieved without decreasing the number of crops grown compared with a fixed rotation.

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