Deep drainage under cropping in Western Australia

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Abstract

High rates of deep drainage (water loss below the root-zone) in Western Australia are contributing to groundwater recharge and secondary salinity. However, quantifying potential deep drainage through measurements is hampered by the high degree of complexity of crop-soil systems as a result of spatial and temporal variability. Simulation models can provide the appropriate means to extrapolate across time and space and supply a new insight into such systems. The Agricultural Production Systems Simulator (APSIM) had been extensively tested with field measurements, including measurements of deep drainage, before it was used to analyse deep drainage under wheat crops in the Mediterranean climate of the central Western Australian wheat-belt. The analyses revealed the extent of the excess water problem that currently threatens the sustainability of the wheat-based farming systems in Western Australia. The simulation results showed that increasing crop production had a minor impact on deep drainage within a growing season. However, increased production reduced the amount of soil water stored at crop maturity, which has an impact on next season's drainage. Simulation scenarios for a catchment indicated that about 50% of the catchment area with the most drainage-prone soil types are required to be re-vegetated with perennials to reduce long-term average drainage rates by 60%. Even more drainage reduction is required to be sustainable and avoid a water table rise.

Keywords

leakage, dryland salinity, wheat

Introduction

In south Western Australia, the impact of dryland salinity is large, with 1.8M ha of previously productive agricultural land already saline, with three times this area at future risk (1). Associated negative impacts include degradation of current agricultural production, ecosystem biodiversity and town infrastructure (2,3).

Dryland salinity in south Western Australia is a result of a perturbation in the hydrological cycle due to replacement of perennial with annual vegetation. The deep-rooted native perennial vegetation has been replaced with shallow-rooted annual crops and pastures over 80% of the agricultural region (2). From a compilation of case studies, the relationship between deep drainage and rainfall for both native and agricultural land use was presented by Hatton and George (4). A difference of one to three orders of magnitude was evident between the land uses, at annual rainfalls of 1200 and 400 mm, respectively (4,5). These higher rates of deep drainage under the current farming system are causing groundwater tables to rise resulting in widespread salinisation (2). Management of this excess water is one of many important issues required to address dryland salinity. This paper outlines management scenarios on a point and spatial scale to reduce deep drainage using a simulation modelling approach.

Methods

The Agricultural Production Systems Simulator (APSIM) (6) for wheat (APSIM-Nwheat, version 1.55s) was used in simulation experiments to analyse the impact of wheat management (7,8) and a perennial crop (9) on reducing deep drainage. G. Pracilio (personal communication) extended the application of APSIM-Nwheat spatially to the Elashgin Creek catchment in the central eastern wheat-belt of Western Australia, which is mostly under crops (70%) with the remainder under pasture. Spatial revegetation strategies were analysed with the model in combination with a Geographic Information System. Due to the flat terrain of the catchment with an average slope of 2%, horizontal water flow was ignored. Deep drainage was spatially distributed across the catchment by probabilities of soil type.

APSIM-Nwheat is a crop simulation model, consisting of modules that incorporate aspects of soil water, N, crop residues, crop growth and development and their interactions within a wheat/soil system that is driven by daily weather data. The soil water module simulates the various vertical water movements in a layered soil system using a multi-layer cascading approach. Drainage (or deep drainage) is defined a water loss below the potential maximum root depth. Documented model source code in hypertext format can be viewed at www.apsim-help.tag.csiro.au. To test the performance of the model to reproduce deep drainage rates under different crop management, measured soil characteristics, initial soil water conditions and local weather records were used to simulate deep drainage under early- and late-sown wheat crops over three years at Beverley, Western Australia. Simulation results were compared with measured deep drainage reported by Eastham and Gregory (10).

Results and discussion

High rates of deep drainage under wheat crops in the Mediterranean climatic region of Western Australia (7) are contributing to groundwater recharge and secondary salinity. In contrast to most expectations, the large potential increases in current wheat biomass that can be achieved through improved management in Western Australia were not matched by substantial reductions of within-season deep drainage, when the results from a simulation model linked with long-term historical weather records were used (8). The small effect on drainage control associated with increased biomass had been traced to the effect of rainfall distribution, with major occurrences of both rainfall and drainage during winter (June - August) coinciding with the lowest potential atmospheric demand for evapotranspiration, in combination with low water-holding capacity soils. Nitrogen-induced increases in crop transpiration corresponded with reduced soil evaporation, which increased water-use efficiency and occurred mostly after the main drainage period but had little effect on deep drainage within a season (8). This agrees with field measurements by Zhang *et al.* (11) and Gregory *et al.* (12) who showed increases in biomass production following increased N applications had little impact on evapotranspiration. These findings were further supported in an experiment by Gregory *et al.* (13) in which a well-established crop lost only 15 mm more water over the growing season through evapotranspiration than a bare soil. Gregory and Eastham (14) found large differences in biomass production between early- and late-sown wheat crops, but no significant differences in deep drainage (10). The measured deep drainage reported by Eastham and Gregory was closely reproduced with the APSIM-Nwheat model as shown in Figure 1.

Despite little opportunity of drainage control within a season, improved management can reduce some of the water left behind after crop harvest (8), which in turn can increase the water storage capacity or dryness of the soil for next season’s rainfall with a further decrease in deep drainage potential.

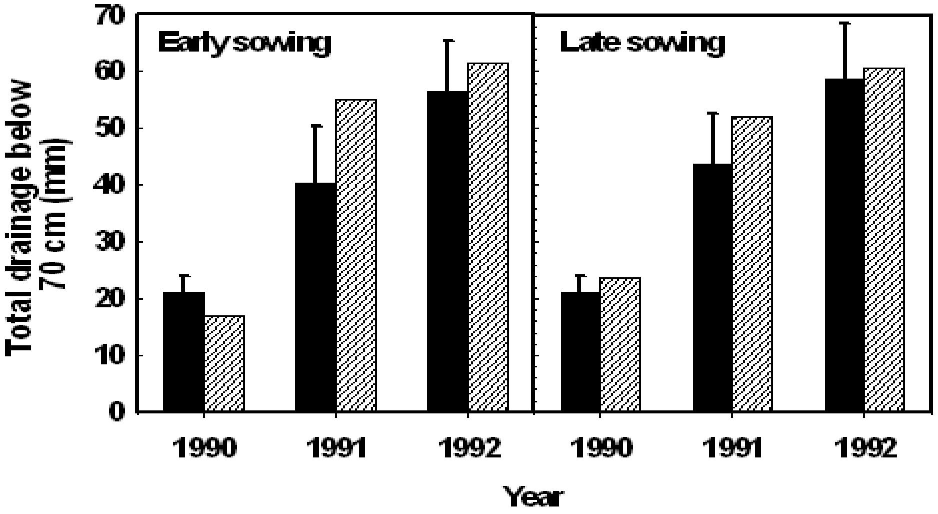

Figure 1. Measured (■) and simulated (▨) deep drainage water losses below the potential maximum root zone in a shallow duplex soil (70 cm) for early- and late-sown wheat crops over three years at Beverley, Western Australia. Measured data after Eastham and Gregory (10). Error bars indicate LSD(P=0.05).

Indeed, Dolling and Asseng (9) have shown the water storage capacity of the soil at the beginning of the season is an important factor in determining the drainage potential of a location. For example, doubling a water storage capacity of 25 mm would reduce the average drainage rate by 25% at a high rainfall location, and halve the drainage rate at a low rainfall location. As a consequence, the inclusion of perennials such as lucerne into rotations was suggested to increase the water storage capacity through deeper and out-of-season water uptake to control drainage in cropping systems (9).

G. Pracilio (personal communication) extended the application of APSIM-Nwheat spatially to the Elashgin Creek catchment in the central eastern wheat-belt of Western Australia. A simulation experiment using historical weather records estimated the long-term average drainage to be 18 mm/year in this catchment, which represents 5% of average annual rainfall. Local and regional management scenarios, in which paddocks or large regions, respectively, were revegetated with perennials, were simulated. For simplicity in this analysis, zero drainage was assumed under perennial vegetation. Acid loamy sand and sandy duplex were identified as the two soil types with the highest drainage rates under crops in this catchment. When areas greater than 100 ha containing acid loamy sands were revegetated with perennials, the average catchment drainage rate was predicted to be reduced to 12 mm/year (Table 1).

Table 1. Simulated average deep drainage below the potential wheat root zone for the Elashgin Creek catchment in the central eastern wheat-belt of Western Australia (after G. Pracilio, personal communication).

Revegetated areas	Average deep drainage of catchment (mm/year)	Area with perennial vegetation (%)[A]
None	18	0
ALS[B] >100ha ALS + SD[D]	12[C]	22

	7[C]	48

[A] Percentage of the catchment with perennial revegetation
[B] Probable areas of acid loamy sand (ALS)
[C] Zero (mm) deep drainage is assumed in management areas with perennial plants, with average deep drainage in the remaining areas.
[D] Probable areas of sandy duplex (SD) soil

When areas containing acid loamy sands and sandy duplex soils, representing 48% of the catchment, were revegetated with perennials, the average catchment drainage rate was predicted to be reduced to 7 mm/year (G. Pracilio, personal communication). However, such a rate is still too high to minimise the risk of further rises of the watertable in this catchment, as rates of < 1mm/year is the capacity of similar catchments in this region to export groundwater (15). The average long-term deep drainage rate therefore must be less than the discharge capacity to be sustainable.

Conclusion

Large proportions of the wheat-belt of Western Australia is threatened by rising watertables and salinity due to high rates of deep drainage under current cropping systems. To reduce deep drainage to sustainable levels with no further watertable rise, substantial modifications, such as the revegetation of large areas with perennials, will be required.

Acknowledgement

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