Improving a spatially-referenced crop simulation model by accounting for salinity

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Abstract

High levels of subsoil salinity, sodicity and boron are important limitations to crop growth and yield in the southern Mallee. Present crop simulation models perform poorly in this region, presumably due to their inability to account for subsoil limitations. Several years of yield maps from an 88 ha paddock in the Birchip area (35.98?S, 142.92?E) show high spatial variability in grain yield with consistently high and low yielding areas across the paddock. The objective of this work was to modify a spatially referenced Water and Nitrogen Management Model (WNMM) to take account of salinity by adjusting simulated crop water uptake, to explain spatial variation in wheat yield in this paddock. We collected data on various crop and yield parameters from forty points across the paddock. Soil cores were taken from these points and soil salinity was measured at four different depths. Several approaches were explored to modify the model to account for salinity. The salinity stress response function for crop water uptake proposed by van Genuchten (1987) was added to the model and significantly improved yield simulation across the paddock.

Keywords

Water uptake, salinity, modelling, WNMM

Introduction

In the Victorian Mallee, saline subsoils restrict crop growth by reducing the osmotic potential of soil water and water uptake, leading to reduced grain yield (Sadras *et al.,* 2002). Present crop simulation models perform poorly in the Birchip area, apparently due to their inability to account for subsoil constraints e.g., salinity. The level of subsoil salinity is significantly correlated with sodicity and boron, so it was used as a proxy for all of these subsoil limitations in this study. Our objective in this study was to modify the spatially referenced water and nutrient management model (WNMM) (Li, 2002) to account for the effect of salinity on water uptake by the crop and to simulate the effect of subsoil limitations and their spatial variability on wheat yield.

Methods

An experiment was conducted during 2004 in an 88 ha paddock near Birchip where crop properties and profiles of soil water and soil salinity were measured at 40 points selected on the basis of previous yield maps. The spatial data collected were a yield map and an electromagnetic (EM 38) survey for the whole paddock. The EM data were calibrated against laboratory-measured electrical conductivity (EC, in 1:5 soil suspension) for samples from four depths at each of the 40 points. Three approaches were explored in order to modify WNMM. The first approach was based on the hypothesis that salt affects yield by decreasing the osmotic potential thus reducing the amount of available soil water. This effect was simulated by increasing the lower limit for water uptake from the soil: using that derived from field experiment rather than that derived from soil particle size (Sadras *et al.,* 2003). In the second approach osmotic potential was calculated from soil salinity and added to matric potential and the moisture content corresponding to this total potential was taken as the lower limit in the model. In the third approach the salinity-stress response function for crop water uptake proposed by van Genuchten (1987) was used:

$$\alpha(h) = \frac{1}{1 + (\frac{h}{h_{50}})^p}$$

where the water stress response function α(h) is a prescribed dimensionless function of the soil water pressure head ($0 \leq \alpha \leq 1$), and h_{50} represents the pressure head at which the water extraction rate is reduced by 50%, and p is an experimental constant, found to be approximately 3. This approach was used in WNMM to modify transpiration as follows:

$$Trans = Trans * (1 / (1 + (EC / EC_{50})^3))$$

Results

Wheat yield simulated with the existing WNMM model was unrelated to observed yield across the 40 sampling points in the paddock. In the first modification of the model we could not find significant relationships between the soil lower limit derived from soil particle size and the one observed in the field, so this approach was abandoned. When the lower limit was modified using the second approach, the model did not simulate yield accurately. The third approach performed well in these conditions. Out of forty points, twenty points were selected randomly for calibration and the remaining twenty were used for model validation. Figure 1 shows that the modified model explained about one-half of the variability in grain yield and dry matter in the calibration and about one third of the variability in the validation data set. This approach also reduced RMSE to less than the value for the original model, indicating better performance.

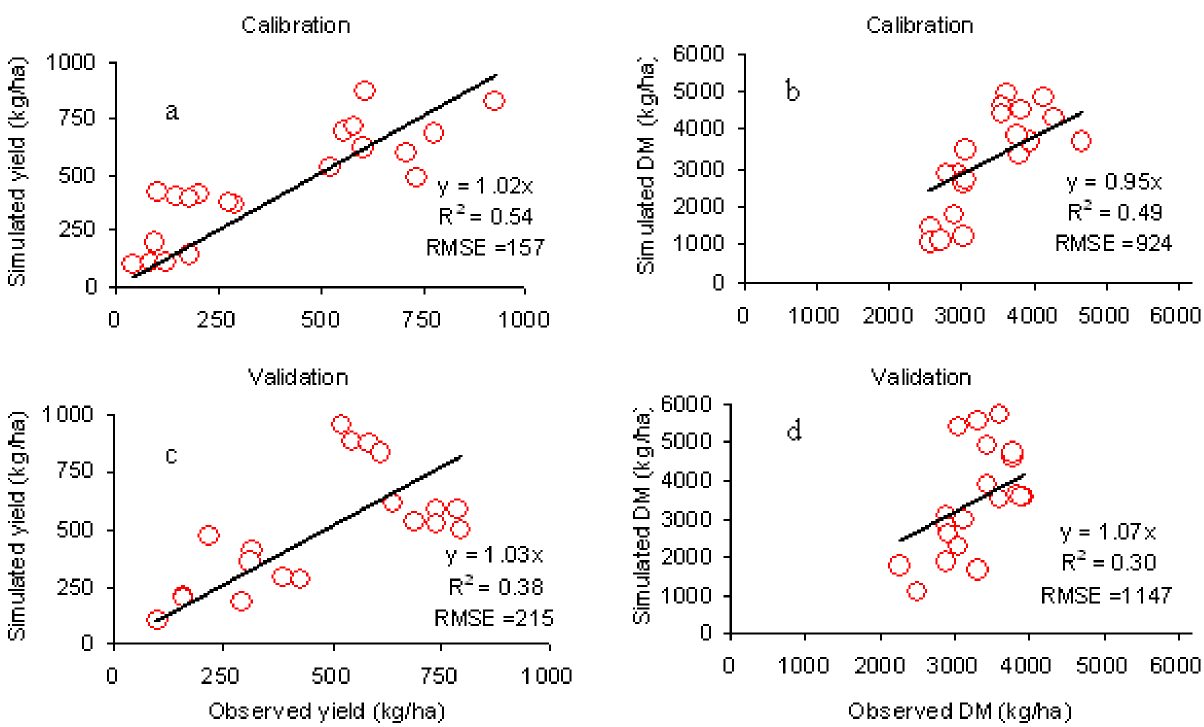

Figure 1. Observed and simulated yield and dry matter (DM) during calibration (a) and (b) and during validation (c) and (d) of WNMM with modified water uptake.

Conclusion

The improvement in the model's ability to simulate wheat yield supports the hypothesis that subsoil salinity limits crop performance in the southern Mallee. Of the three methods tested to simulate the effect of salinity, the response function for crop water uptake of van Genuchten (1987) was the most successful.

References

Sadras V, Roget D and O' Leary G (2002). On-farm assessment of environmental and management constraints to wheat yield and efficiency in the use of rainfall in the Mallee. Aust. J. Agric. Res., 53, 587-598.

Sadras V, Baldock J, Roget D and Rodriguez D (2003). Measuring and modelling yield and water budget components of wheat crops in coarse-textured soils with chemical constraints. Field Crops Res., 84, 241–260.

Van Genuchten M Th (1987). A numerical model for water and solute movement in and below the root zone. Unpub. Research Report, U.S. Salinity Lab., Riverside, CA, USA.

Li Y (2002). A spatially referenced model for identifying optimal strategies for managing water and fertiliser nitrogen under intensive cropping in the North China Plain. PhD Thesis. The University of Melbourne.