Removal of a subsoil constraint - When does it pay?

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Abstract

Subsoil constraints lead to a reduction in root growth which results in reduced yield. However, constraint removal can have positive or negative effects on yield depending on season, location, soil type and constraint severity. To investigate the impact of these factors, we use the APSIM-Wheat model to assess the yield response to the removal of a subsoil constraint for two soil types, three levels of constraint and thirty locations in south west Western Australia. The results show that large yield responses to constraint removal are more likely at high rainfall locations, in wet seasons and on light textured soils.

Introduction

Subsoil constraints such as compaction and soil acidity lead to a reduction in root growth and distribution which limits the ability of crops to access subsoil water and nutrients. This often results in reduced crop growth and grain yield, though the impact can vary markedly with season, location and soil type. Amelioration or removal of subsoil constraints, using practices such as deep ripping or liming can lead to increased uptake of water and nutrients, resulting in higher biomass production and therefore higher grain yields. However, negative effects on yield can occur in years with a dry finish when removal of the constraint causes greater early water use and biomass resulting in less water being available for grain filling later in the season.

Understanding the factors which determine the positive or negative responses to amelioration of subsoil constraints will allow farmers to determine under what circumstances it is worthwhile taking the risk to overcome the constraints. The aims of this work were: 1) to assess the impact of soil type, location and seasonal variation on the yield response of wheat to the removal of a subsoil constraint; 2) to assess the profitability of constraint removal; and 3) to generate maps of wheat responses to constraint removal if we assume a single soil type in south-west Western Australia.

Material and Methods

The validated crop simulation model APSIM-Wheat (Keating *et al*., 2003) was used to analyse the impact of subsoil constraints of varying severity on wheat growth and grain yield for several soil types at multiple locations. Long-term simulations for the period 1957-2006 were run for 30 locations across the south-west of Western Australia. Two of those locations, Mingenew, in the medium rainfall zone (mean April to October rain 350 mm), and Mullewa, in the low rainfall zone (mean April to October rain 270 mm) were selected for a more detailed analysis of yield responses to the amelioration of constraints. Two representative but contrasting soil types, a loamy duplex (heavy) and a loamy sand (light) soil were used for the simulations. Plant Available Water Content (PAWC) for the maximum crop root depth was 108 mm for the loamy duplex soil and 153 mm for loamy sand soil. Maximum root depth was 130 cm for the loamy duplex soil and 230 cm for the loamy sand soil. Crop management was simulated to reproduce best management practices in each rainfall zone. The complete dataset from the 30 locations was used to produce maps of crop response to amelioration for each soil type.

The subsoil constraints used in the simulation modelling slowed root growth in and through the 20 to 40 cm layer in the soil profile. There was no constraint to root growth above and below the 20-40 cm layer to imitate “pan” or “choke” like conditions caused by machinery. There was no constraint to root growth above and below the 20-40 cm layer to simulate the "pan" or "choke" conditions in the soils of Western Australia. In the APSIM-Wheat model, this was done by changing the soil hospitality factor (xf) in the 20-40 cm layer. Four levels of constraint were chosen: unconstrained (ameliorated) (xf = 1), typical constraint (xf = 0.2), severe constraint (xf = 0.1) and extreme constraint (xf = 0.01).

Results

Impact of subsoil constraint severity on wheat root growth

The different levels of subsoil constraint caused a reduction in the rooting depth reached by the crop compared to an unconstrained profile (Table 1). At the unconstrained and typical level of constraint, root depth varied markedly with season, but averaged 90-100 cm on the loamy duplex soil and 150-180 cm on the loamy sand soil. The extreme level of constraint was such that no roots went beyond 24 cm depth in any season or soil type. Average root depths were of the order of 10-15 cm deeper at Mingenew than Mullewa, probably reflecting differences in wetting depths, with deeper water at Mingenew than at Mullewa (Table 1).

Table 1. Average root depths (cm) for different levels of a constraint to root growth in the 20-40 cm layer, for loamy duplex and loamy sand soils at Mullewa and Mingenew. Average values for the period 1957-2006.

		?	**Level of constraint**		?
Location	**Soil type**	**none**	**typical**	**severe**	**extreme**
Mullewa	Loamy duplex	92	85	61	23
Mullewa	Loamy sand	167	154	86	23
Mingenew	Loamy duplex	102	95	70	23
Mingenew	Loamy sand	184	170	97	24

Impact of subsoil constraint amelioration on crop yield

The yield response to constraint removal varied between soil types and locations (Figure 1).

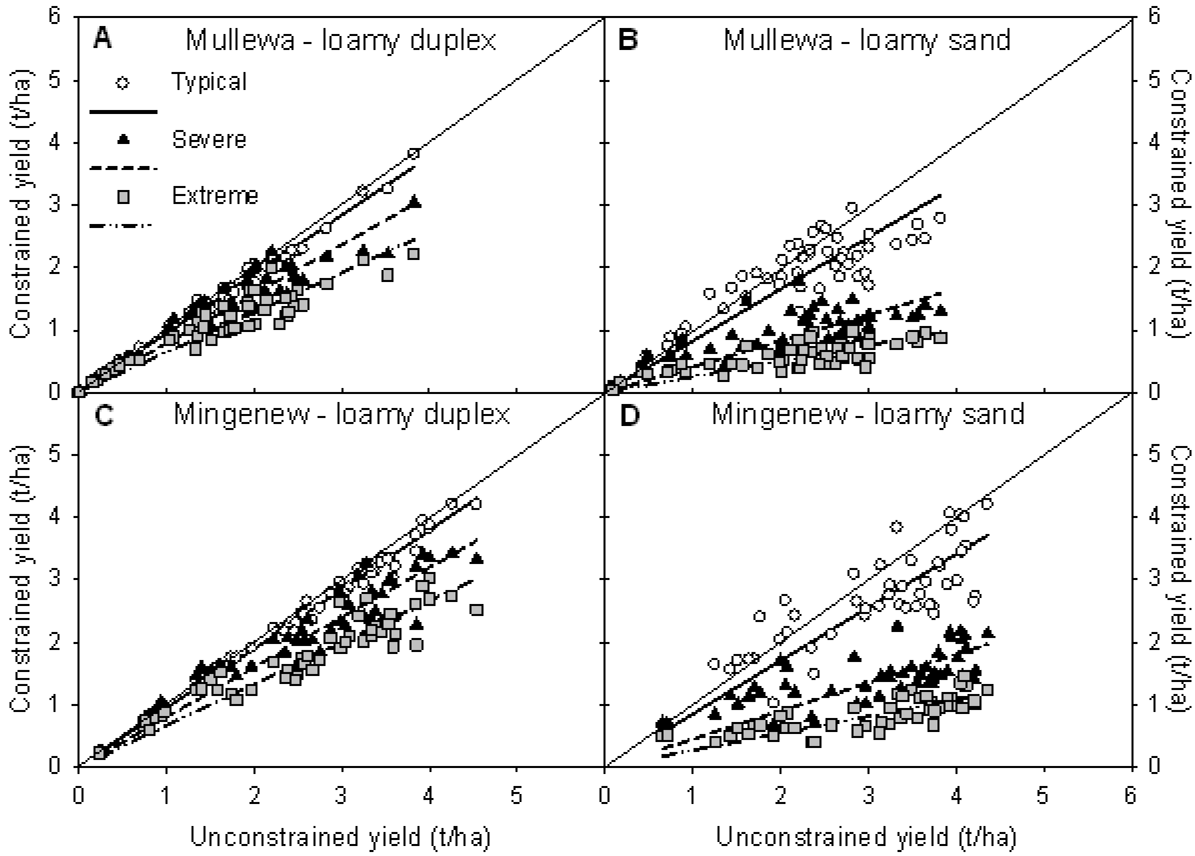

Figure 1. The effect of a typical, severe or extreme subsoil constraint on grain yield relative to the unconstrained yield for loamy duplex (A, C) and loamy sand (B, D) soils at Mullewa (A, B) and Mingenew (C, D).

Constraints on rooting depth decreased crop yields. However, even with a 23 cm root depth limit (extreme constraint) average yields were 67% of the unconstrained yields on the loamy duplex soil. The removal of the constraint gave positive yield responses in most years and in both soil types and locations (points below the 1:1 line in Figure 1). However, the removal of the typical level of constraint gave negative responses in some years (points above the 1:1 line in Fig 1 and points below the line in Fig 2). The negative responses occurred in some dry years, in which the removal of the constraint allowed greater root growth and greater water use pre-anthesis, leaving less water and nutrients available in the post-anthesis period for grain filling. The negative responses were more frequent on loamy sand soils than on loamy duplex soils (Figures 1 & 2). Crops on the loamy sand soil benefit more from soil amelioration because roots in the loamy sand soil are required to grow deeper compared to the loamy duplex soil to access the same amount of water. Season also influenced the impact of soil constraints on yield. Negative yield responses to constraint removal were more frequent in dry seasons (negative values in Figure 2) or in drier locations, where there was little or negative response to soil amelioration.

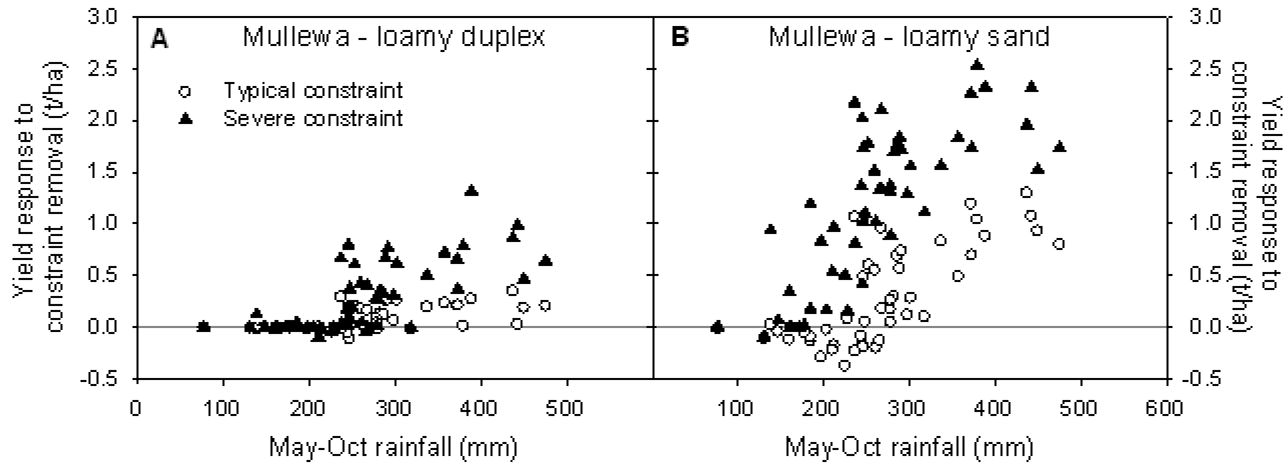

Figure 2. Yield response to removal of typical or severe constraint versus May to October rainfall on a loamy duplex (A) and loamy sand (B) soil in Mullewa.

Economics

In order to determine if it is economically viable to remove the subsoil constraint, it is necessary to know the magnitude of the yield response, the cost of amelioration and the price of grain. For this exercise (Figure 3) it was assumed that the cost of (unspecified) amelioration was $40/ha and the return was $250/t for the grain. Future returns (i.e. residual value of amelioration) were not taken into account. The vertical line of nil return would move left or right according to the price ratio (Figure 3). For our assumptions, on loamy duplex soils, the chances of getting significant, paying, short term, responses to amelioration of a typical constraint were small. On loamy sand soils, amelioration of severe and extreme levels of constraint paid in almost all seasons at both locations (Figure 3). The marked variation of profitability of amelioration with season (as reflected in the shallowness of the curves in Figure 3) suggested that better returns to amelioration could be generated if the nature of the season to come could be predicted. Positive returns to amelioration on soils of typical constraint were far more likely in wet (and/or high yielding – Figures 1 and 2) years than in dry years. The difference in probability of response between seasons diminishes markedly as the severity of the constraint increases.

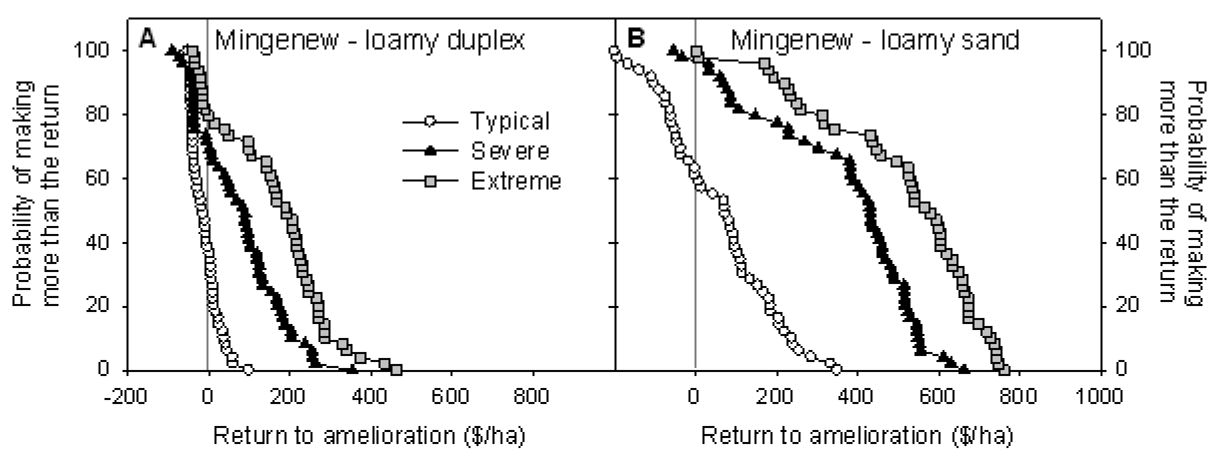

Figure 3. The probability of exceeding given levels of return to amelioration ($/ha) in the short-term (single season) from removing a typical, severe or extreme subsoil constraint for loamy duplex (A) and loamy sand (B) soils at Mingenew. Assuming a cost of amelioration of $40/ha and a grain price of $250/t.

Maps

The maps of average yield response and frequency of positive response to constraint removal (Figures 4 & 5) emphasize in a broader and more general geographic sense the principles shown earlier in the document with the detailed analysis of two locations. It was found that the more extreme the constraint, the larger the yield response to constraint removal (data not shown). Larger yield responses were seen in wetter locations than in drier locations (Figure 4). Soil type effect was important. Although greater yield responses occurred on the loamy sand soil than on the loamy duplex soil, the frequency of positive responses to constraint removal is lower on the loamy sand soil than on the loamy duplex soil (Figure 5).

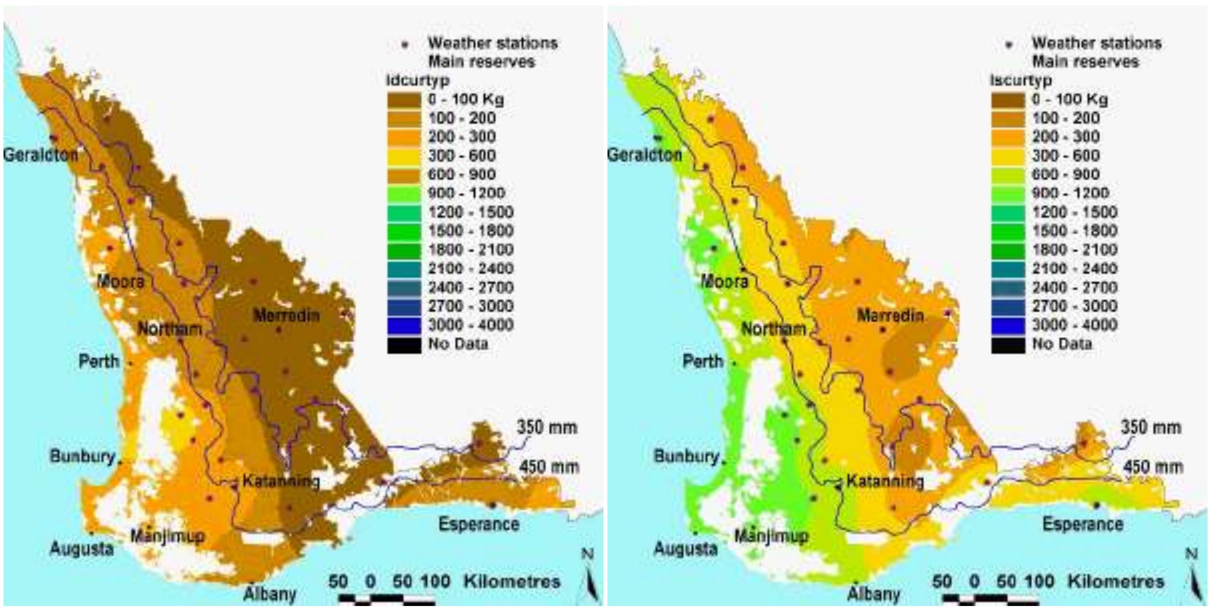

Figure 4. Maps of average yield response to constraint removal on a loamy duplex (A) and a loamy sand (B) soil for a typical constraint.

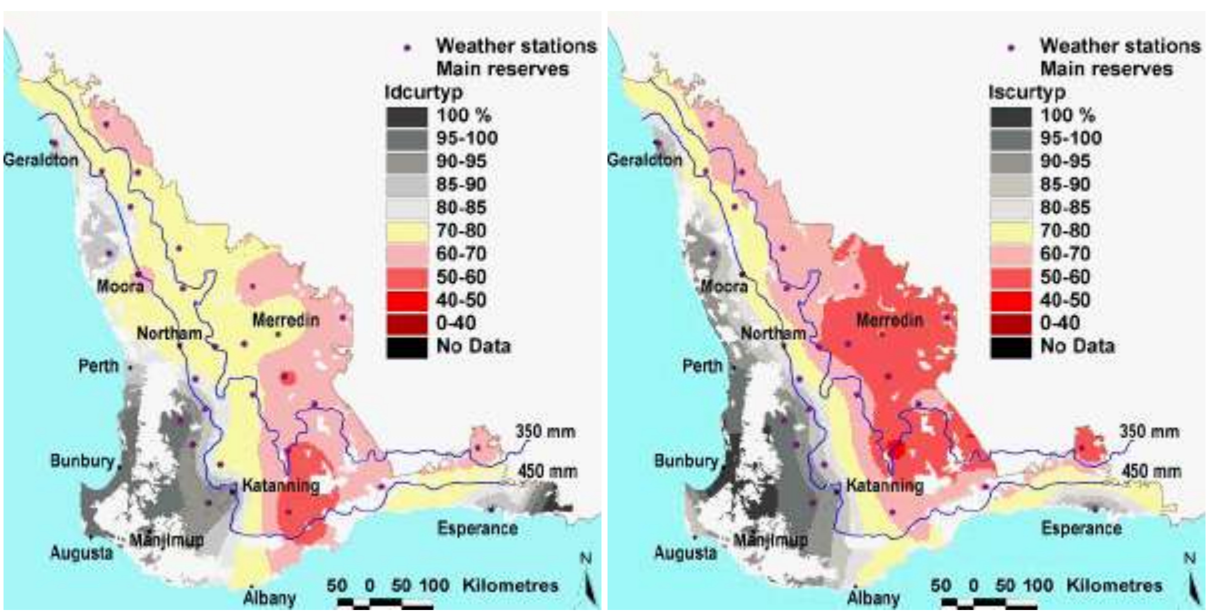

Figure 5. Maps of frequency of positive responses to constraint removal for a loamy duplex (A) soil and a loamy sand (B) soil for a typical constraint.

Conclusions

Simulation modelling can be used to give an indication of the level of risk associated with ameliorating non-specific subsoil constraints to crop root growth for various soil types, locations and seasons. Individual farmers who are making decisions on whether to ameliorate subsoil constraints or not need to assess the likely benefits and risks for their particular situation. This implies being able to adequately define their soil type and more importantly to diagnose the severity of the constraint. Analyses of the kind reported in this paper can indicate to growers what factors they need to consider when considering the likely benefits and risks associated with constraint removal.

References

Keating BA, Carberry PS, Hammer GL, Probert ME, Robertson MJ, Holzworth D, Huth NI, Hargreaves JNG, Meinke H, Hochman Z, McLean G , Verburg K, Snow V, Dimes JP, Silburn M, Wang E, Brown S, Bristow KL, Asseng S, Chapman S, McCown RL, Freebairn DM, Smith CJ (2003) An overview of APSIM, a model designed for farming systems simulation. *European Journal of Agronomy* **18**, 267-288.