How often does subsoil amelioration pay the bills?

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Key messages

- Crop water use and yield responses to subsoil amelioration vary considerably depending on the distribution of rainfall within the growing season, but not so much on total growing season or pre-season rainfall.
- Economic responses are common in situations where the soil constraint is severe, and can be fully ameliorated. Partial amelioration is a more common outcome, but will still provide a one-year positive return in 75% of cases where the constraint is severe.
- The level of constraint imposed by the soil is important information when devising amelioration strategies.

Aims

Subsoil constraints, such as acidity, compaction, sodicity, and salinity, have been identified as factors causing considerable yield losses in crop production in Western Australia (e.g. Gazey et al, 2014). Deep ripping, to loosen compact soils and aid the incorporation of ameliorants into subsoil layers, have become accepted farming practices. However, responses to deep ripping and other forms of deep soil disturbance will depend on (a) the level of constraint imposed by the subsoil conditions; and (b) the seasonal conditions experienced after subsoil amelioration. For these reasons, crop responses are variable. In this research, we use soil water sensors in established field trials to determine the impact of subsoil amelioration on patterns of crop water uptake. With this knowledge, we calibrate the APSIM crop model to determine the seasonal types where economic responses are modelled, and determine the frequency of these seasons in the long-term climate record.

Method

Field trials

Soil moisture probes have been installed in field trials in dozens of paddocks around the WA wheat belt. There are also many trials in WA where the amelioration of subsoil constraints has been targeted, often through the GRDC 'Subsoil Constraints' project. In this paper we focus on trials near Wubin (with the Liebe Group) and Dandaragan (with the West Midlands Group) (Table 1).

Site location	Treatments	Depths and frequency of measurement
West Wubin	Control Lime&Dolomite Spaded Spaded + Lime&Dolomite	20-130 cm at 10-20 cm intervals Logged at 30 minute intervals
Dandaragan	Control Lime 5 t/ha Rip&Spade Rip&Spade + lime 5 t/ha	15, 25, 35, 45, 55 cm Logged at 15 minute intervals

Table 1. Details of soil moisture probe locations in subsoil constraints trials at Wubin and Dandaragan.

Data is available for a wheat (2015) / barley (2016) / wheat (2017) rotation at Dandaragan, and a wheat (2015) / wheat (2016) / wheat (2017) rotation at Wubin.

Crop modelling

In APSIM, root growth for a given soil layer is regulated by a parameter called the 'exploration factor' (xf), which can vary from a value of 0 for no root exploration to a value of 1 for a soil layer with unconstrained root growth. By adjusting this parameter so that the modelled patterns of soil water content match the measured soil water profiles, we can determine three things:

- the level of the constraint imposed by the original soil conditions;
- the level of constraint imposed by the ameliorated soil conditions;
- and what the crop yield would be in an unconstrained soil (xf = 1).

Measured data from Wubin and Dandaragan were used to determine the initial exploration factor, and then long-term simulations using a 60-year climate record were used to determine the probability of yield differences due to amelioration, based on either full profile amelioration (xf increased to 1.0 throughout the profile) or partial profile amelioration (xf increased from a value of 0.2 to 0.3), which is more in line with observed amelioration for acidic soils (Oliver and Ouzman, 2014).

Results

Measured soil water dynamics

Soil water measurements are available for three growing seasons at Dandaragan and Wubin, and the three different seasons have resulted in different patterns of water use, especially in the August – October period. At Dandaragan for example (Figure 1), soil water at 55 cm was extracted more rapidly in the ripped, spaded and lime treatment than in the control in 2015 and 2017, but not in 2016. At Wubin (Figure 2), the spaded treatments generally allowed faster uptake of soil water at 55 cm, but only in 2015 was more total water extracted from this depth. In 2016 and 2017, the total water extraction was similar (although with different timing) regardless of tillage treatment.

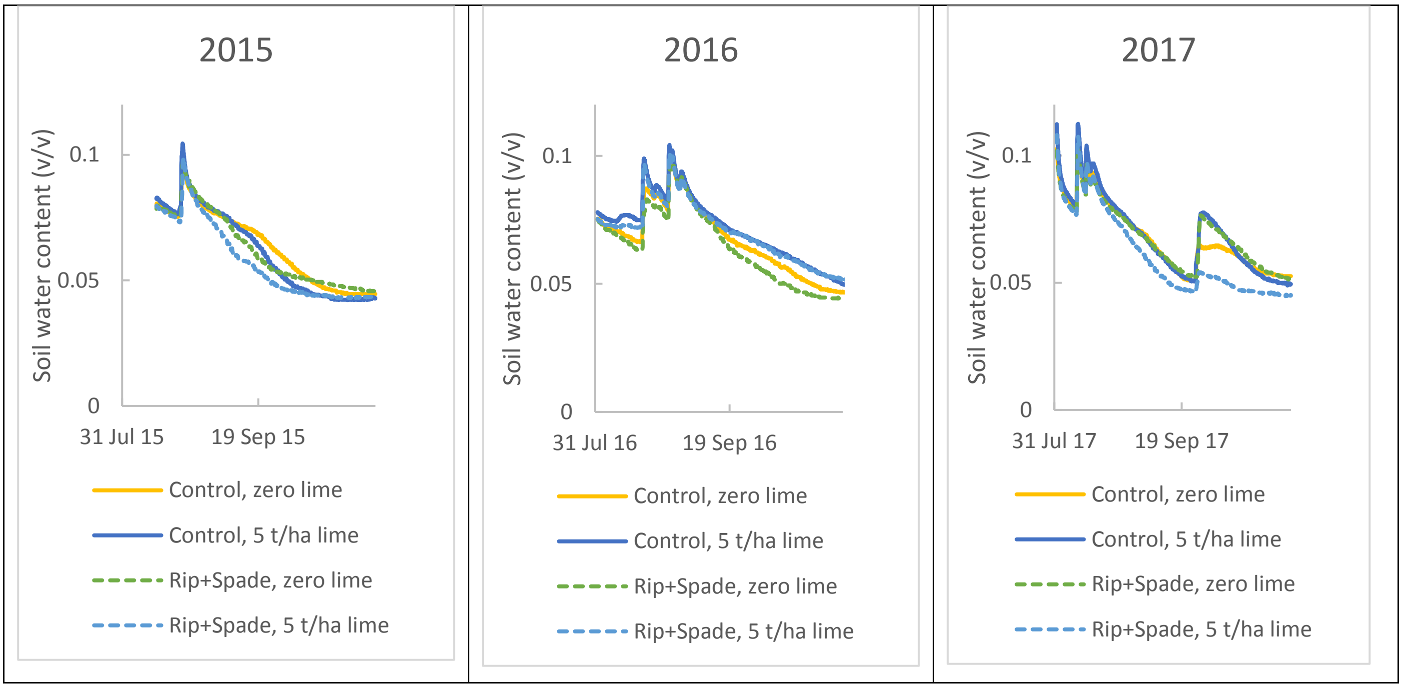

Figure 1. Soil water content at a depth of 55 in August – October in 2015, 2016 and 2017 at the Dandaragan site.

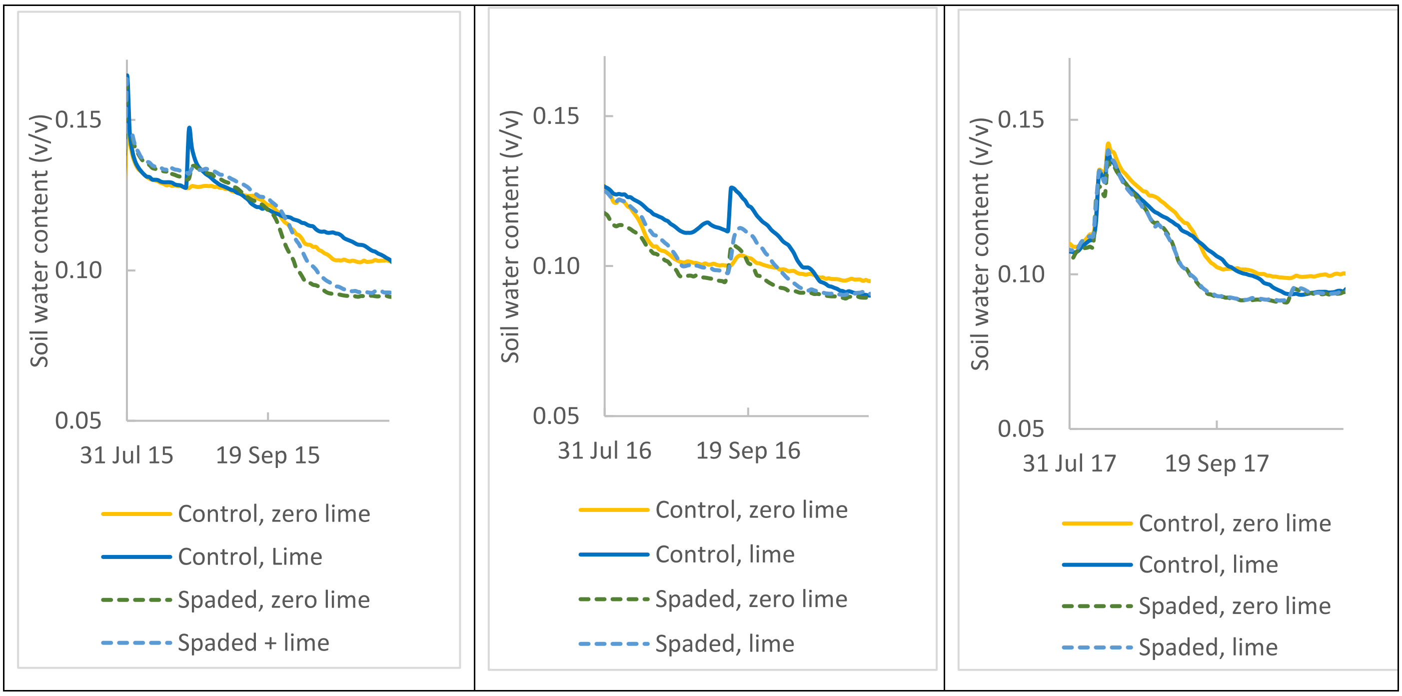

Fig 2. Soil water content at a depth of 55 in August – October in 2015, 2016 and 2017 at the Wubin site.

Different patterns of water use suggest different depths of root activity. Generally, better access to deep soil water allows better crop growth and yield, but in seasons with a dry finish, faster use of subsoil water may actually restrict crop growth and grain filling late in the season. Therefore, knowledge of seasonal types where subsoil amelioration confers a yield benefit (or penalty) is important, and this is why we use crop modelling.

Simulations of yield benefit from amelioration

Surprisingly, there was little correlation between pre-season or growing season rainfall and the yield benefit associated with subsoil amelioration (Figure 3), although there was a trend for higher yield differences in wetter seasons, as was also observed by Farre et al (2010). Therefore, the differences observed in yield response are more likely to be associated with the distribution of growing season rainfall, although this has not been fully investigated at this stage.

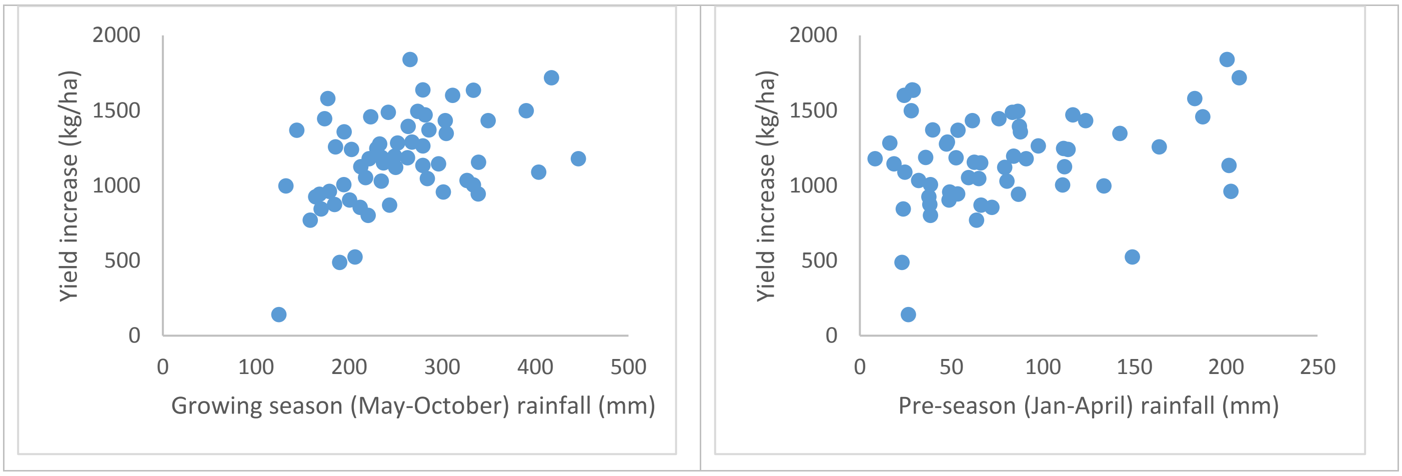

Figure 3. Modelled (60 years) yield increase at Dalwallinu after soil amelioration was only weakly related to growing season and pre- season rainfall.

In long-term simulations using a 60-year climate record (Figure 4), we assume that the soil was originally constrained to a depth of either 0.3m (green lines) or 0.4m (blue lines), with initial exploration factor of either 0.2 (severe constraint; solid lines) or 0.3 (moderate constraint; dashed lines), and that the soil was fully ameliorated (Figure 4a) or partially (exploration factor increased from 0.2 to 0.3) ameliorated (Figure 4b). Note that in an analysis of soil acidity (Oliver and Ouzman, 2014), partial amelioration was much more common than full amelioration.

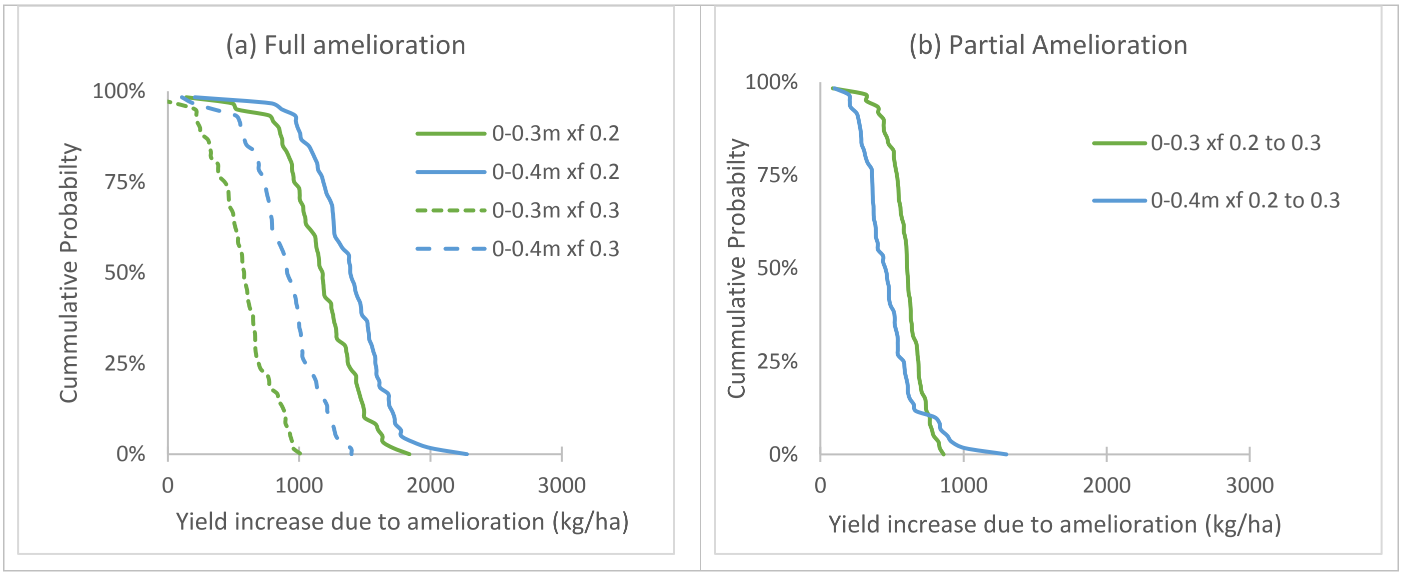

Figure 4. Yield increases after soil amelioration (Dalwallinu – 60 years, sand with long term average yield of 2.2 t/ha).

As an example, if the original soil had an exploration factor of 0.2 to a depth of 0.4 m, and this was fully ameliorated (the solid blue line in Figure 4a), our modelling suggests that there would be a yield response of at least 1000 kg/ha in about 95% of years, and a yield response of at least 1500 kg/ha in 50% of years. However, for a soil partially ameliorated where the original constraint was to a depth of 0.4 m (the blue line in Figure 4b), there was less than a 5% chance of getting a yield increase of at least 1000 kg/ha.

Economics

The cost of subsoil amelioration can vary enormously depending on soil type and techniques used (Blackwell et al 2016), but for a first analysis we have used an average value of $100 per ha. Therefore, in order to generate positive returns over a one-year period, the yield increase (assuming wheat at $250 per tonne) needs to be 400 kg/ha. Where there was originally a severe soil constraint (xf = 0.2 to a depth of 0.3 m or 0.4m), and where full amelioration was achieved, the required yield increase occurred in almost all seasons. However, where the original soil constraint was less severe (xf 0.3 to a depth of 0.3m), the required yield increase was obtained in 75% of years. When only partial amelioration was achieved, then the required yield was achieved in less than 50% of seasons. Effective soil mixing and sufficient lime are required to remove the compaction and acidity to increase likelihood of rapid return of investment.

Full amelioration is likely to be more expensive than partial amelioration. If we assume a cost of $200 per ha, then a yield increase of 800 kg/ha will be required, and this is still achieved in nearly all seasons where a severe constraint (xf = 0.2) occurs to a depth of 0.4 m. However, a more mild constraint (xf = 0.3) to a shallower depth (0.3 m) would only provide the required yield increase in about 10% of years. Therefore, it is important to know the level of soil constraint in order to determine appropriate amelioration strategies. This can be estimated from a comparison of actual yields with potential yields, where a severe constraint will commonly result in actual yields of less than 50% of potential yields.

Conclusion

Crop water use and yield responses to soil amelioration vary considerably depending on distribution of rainfall in the growing season, but not so much with total growing season or pre-season rainfall. The level of constraint imposed by soil conditions is an important parameter in devising appropriate soil amelioration strategies. Where the soil is severely constrained, economic returns are more likely. Farmers could get an indication of the level of constraint by comparing their actual yields with potential yields

Key words

Soil constraint, acidity, compaction, economic response

Acknowledgments

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