Subsoil constraints and wheat production in Queensland: economic impacts and fertiliser management opportunities

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Abstract

Subsoil constraints (SSCs), identified in this study by chloride (Cl) levels, are substantial impediments to wheat production in the northern grains region. SSC mapping in Queensland shows that 61% the land used for cropping has at least a minor limitation (Cl>400 ppm) to root growth and function, while 24% of this land has very high SSCs (Cl > 1000 ppm) at approximately 80cm soil depth. R&D is being conducted with the aim of making the best of the situation, in terms of testing alternative crops and varieties, without necessarily being able to ease the constraint. If wheat growers are following 'best' management for their particular soils then there is no economic cost to the industry from the existing situation. R&D which may allow better adaptation to these constraints will be valuable to growers and the industry. If the SSCs limit the yield potential of wheat crops then growers could respond by reducing fertiliser inputs. Based on a marginal economic analysis of simulated wheat response to nitrogen, there are potential savings (losses avoided) from this adaptation if growers are unaware of their particular soil-constrained situation. Although actual fertiliser levels applied by farmers are not known, there are potentially $8 million per annum in savings from better fertiliser management. The priority for project work appears to be in areas of very high SSC soils.

Key Words

Subsoil constraint, wheat production, fertiliser management, marginal economic analysis

Introduction

The wheat industry in Queensland and northern NSW has developed over the past 40 years due, in part, to R&D and rapid adoption by growers of new farming systems technologies. Some limits to production remain, and SSCs are being studied in a GRDC-funded project *Combating Subsoil Constraints (SIP08)*, which commenced in 2002. The mainly-Vertosol soils in these regions are generally fertile, but they have been found to be affected by subsoil salinity and sodicity. The question addressed here is how these SSCs have limited the industry and what economically-feasible remedies might be available to growers. Controlled experiments and farm trials indicate that salinity expressed as Cl levels appears to be the main subsoil factor causing declines in wheat cropping yields.

Because of the nature of the general problem the main approach in the *SIP08* project has been to investigate ways of adapting to the situation, rather than trying to change or ease the SSC. New crops and varieties have been tested for suitability to local conditions. The results of these trials are still being finalised; in the meantime this paper considers the issue of potential economic impacts of SSCs to the wheat industry and presents results of a bio-economic analysis of potential savings to growers from reduced fertiliser inputs in response to reduced yield potential due to SSCs. We analyse results for Queensland in this paper.

Economic impacts of SSCs

Although a naturally-occurring constraint to production means that crop income is reduced below what it would be without the constraint, there is not necessarily an economic cost to the industry if growers are making their best decisions in the presence of the constraint. Comparisons with non-constrained regions are not valid if there is nothing that can be done about the SSC situation. If R&D leads to the adoption of new management practices in response to the constraint and this leads to increased crop profits, then this can be counted as an economic improvement due to the R&D investment by government and industry.

Here we examine the economic effects of possible fertiliser input reductions in response to the situation. If SSCs limit the yield potential of crops then it should follow that wheat growers can respond by reducing nitrogen (N) inputs on constrained soils. If growers have not adjusted their fertiliser strategies, then there is potentially an immediate gain from better information about more optimal management.

Methods

Subsoil constraints mapping

The approach first involves developing regional scale maps for southern and central Queensland that show the extent and area of soils with SSCs. As soil Cl seems to be the primary causal agent, maps of soil Cl at the nominal depth of approximately 80 cm have been chosen for this analysis. For the purposes here the soils are assumed to be Vertosols (Isbell 1996), which comprise >70% of soils used for dryland cropping in this region. Minimum critical values adopted for the Cl concentration of the soil are 400 ppm (minor constraint), 600 ppm (significant constraint) and 1000 ppm (major constraint).

Statistics for the actual area used for dryland cropping in Queensland (2,450,000 ha) are: Cl > 1000 ppm 592,186 ha (24% of area), Cl 600-1000 ppm 638,534 ha (26% of area), Cl 400-600 ppm 281,930 ha (12% of area), Cl < 400 ppm 652,451 ha (27% of area); and unallocated 284,288 ha (12% of area). Of the total cropping area, 62% is estimated to have Cl > 400 ppm. Of the area of very high SSC, 519,699 ha were in an area south of Taroom and 72,486 ha were in the north. A map of the predicted Cl concentration in the GRDC project area in Queensland is shown in Figure 1. It should be noted that although the SSC map is produced using the best available soil mapping and the most current soils database, it involves a certain degree of modeling. It is therefore most useful for regional analyses rather than assessments at the paddock scale.

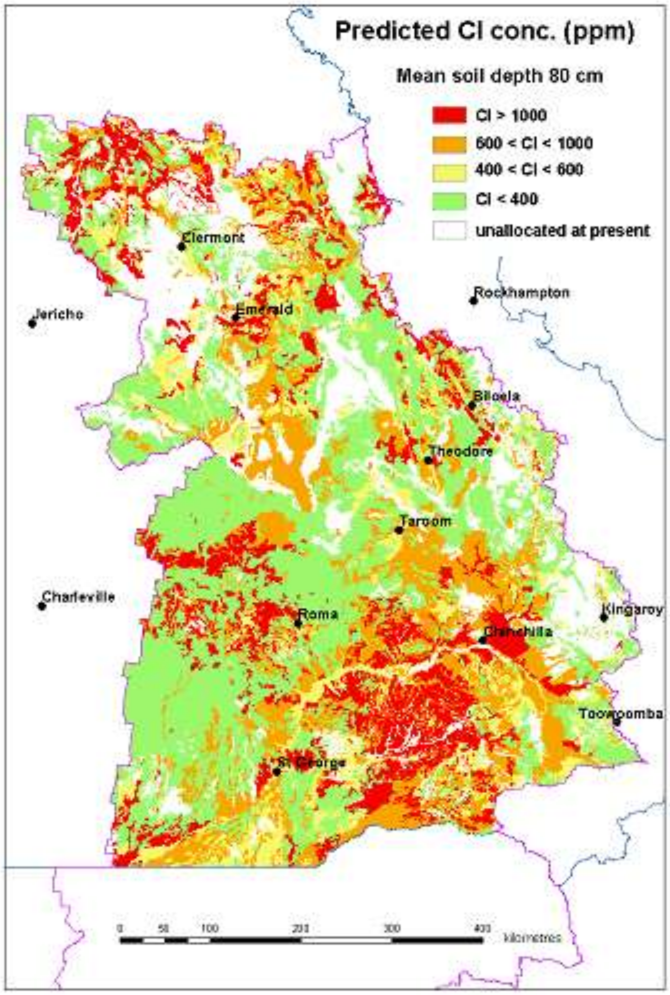

Figure 1. Estimated soil Cl concentrations in central and southern Queensland

Experimental setup

The APSIM model (McCown *et al*. 1996, Probert *et al*. 1998) was used to predict wheat response to N in the presence of SSCs for sites at the southern (Goondiwindi) and northern (Emerald) portions of the Queensland grains region. Each site had a grey Vertosol soil which was tested with different levels of SSCs (Hochman *et al.* 2006) for wheat yield and protein response to total nitrate N. The simulations were run over 45 years, from 1957 to 2002. A continuous wheat cropping system was assumed, with clean fallows and zero tillage. A crop was sown on the first opportunity after 1 May (15 mm rain in a 3-day period). Rates of N were determined at sowing to provide for 30, 60, 90, 120 and 150 kg N/ha in the top 50 cm of the soil profile.

Economic analysis

A marginal economic analysis was conducted on the averaged responses to determine the optimum level of N in each SSC case, given a 75% return on investment criterion (CIMMYT 1988). Wheat pool prices for Australian Hard according to protein content with 5% screenings were used from the AWB Golden Rewards price grid (see http://www.awb.com.au/growers/nationalpool/goldenrewardscurrentseason/). A $50/t deduction for freight, fees and levies was applied. Fertiliser was costed at $1.20/kg N. The net crop revenue advantage from using the best N level was calculated as wheat revenue less the variable N cost;

all other costs were assumed to be unchanged. The analysis aimed to find whether there was a large difference in net wheat revenue when moving around the yield response curve for each SSC. The question is whether knowledge of the soil SSC status would change the optimal N rate, and whether acting on this knowledge can improve wheat profits.

Results

The predicted yield responses to total nitrate N at Goondiwindi and Emerald are shown in Figure 2. It is at very high levels of SSC that the crop response to N is severely affected. Protein responses (not shown) were also estimated. Using the above prices and investment criterion the optimal total N input levels were determined as shown in Table 1. The actual level of N applied to reach the target is less due to the contribution from mineralisation of soil N and because the entire amount of available N is not necessarily used in any given season. A 'net revenue' figure for the best N strategy on each soil type is shown. At each location the optimal level of N is lowest for the very high SSC case.

Table 1. Optimum N input levels and financial differences between SSC cases

Location and SSC level	Optimal total N (kg/ha)	N applied (kg/ha)	Gross wheat income - N cost at the optimum ($/ha)	Profits saved by knowing SSC ($/ha)[a]
Goondiwindi				
Low SSC	120	87	379	
Mid SSC	120	85	371	
High SSC	120	79	328	
Very High SSC	60	37	180	13
Emerald				
Low SSC	90	59	222	
Mid SSC	90	58	216	
High SSC	60	41	181	
Very High SSC	30	17	100	27

[a] For a very high SSC soil compared to being fertilised for a mid-level SSC response

If all growers expect to have a mid SSC soil on their farm, then the question is how much money they might lose by fertilising for this soil type compared to the best N application for their actual SSC case. In an economic sense this saving is the expected value of perfect information (Anderson *et al*. 1988). The losses avoided include saved N inputs and an adjustment in wheat income. There is only a measured profit saving (loss avoided) for the very high SSC soils. In Table 1 the losses avoided (on a very high SSC soil when fertilising for a mid-SSC soil type) are $13/ha and $27/ha for Goondiwindi and Emerald respectively. These results are calculated by adjusting for N around the very high SSC yield responses, rather than comparing between the yield responses. Using these figures and the areas of very high SSC soil types above, the annual losses saved would be in the order of $6.6 million and $2 million for Goondiwindi and Emerald respectively.

At the commencement of the SIP08 project a survey was undertaken to benchmark then-current knowledge, attitudes, skills and aspirations and practices (Buck *et al*. 2006). A significant number of growers (39%) manage soil with SSCs differently, and of those 13% indicated that they used a different fertiliser program. More generally 84% of growers surveyed indicated that they would change their fertiliser program if this was economically viable. However, the actual levels of fertiliser application are unknown.

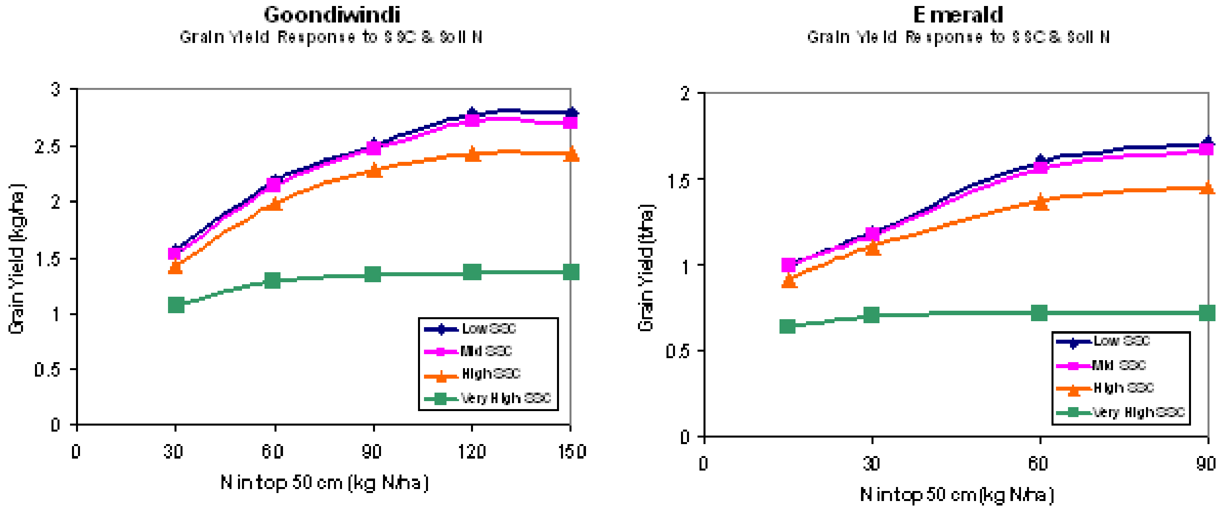

Figure 2. APSIM predicted yield responses to nitrate N and SSC

Given that we don't know actual levels of N fertilisation used by wheat growers on Vertosols with differing levels of SSC, this analysis is hypothetical. The results do, however, provide some valuable information for the *SIP08* project. The main result is that in terms of production responses to N fertiliser the main area of priority appears to be soils of very high SSC. For the project, further investigation of agronomic responses (including fertiliser strategies) for these areas could be given higher priority. And given the potential annual losses calculated, there is scope for further extension work in these very high SSC areas. If better information can be gathered on actual fertiliser usage, then a more detailed economic analysis could be conducted.

Conclusion

This analysis has considered the potential improvement in net revenue associated with use of appropriate fertiliser strategies for soils with differing levels of SSC. Soils with very high levels of SSC are those that lose the most from inappropriate N fertilisation; hence they are indicated as a priority for future project effort. However, since we don't have information on actual N strategies this is an indicative analysis only. Better information on actual fertiliser practices in these areas would enable a more prescriptive economic analysis.

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