Long-term responses to soil amelioration – benefits will last more than 10 years!

Stephen Davies, James Hagan, Chad Reynolds, Virginia Smee, WA Department of Agriculture and Food Western Australia; **Wes Lefroy, Joel Andrew,** Precision SoilTech; **Peter Newman**, PlanFarm.

Key messages

1) One-off soil amelioration can provide long-term benefits (8 years or more) when it improves important drivers of soil productivity including soil pH, fertility, nutrient availability and soil function.
2) Improved crop productivity in the early years following soil amelioration can have flow-on benefits for soil fertility, root growth and weed competition that can help sustain productivity benefits over the long-term.
3) Soil amelioration that addresses multiple constraints, such as water repellence, subsoil acidity and compaction can increase the size, longevity and profitability of the benefits.

Aims

One-off soil inversion using a mouldboard plough is principally being implemented to bury herbicide resistant weeds and water repellent topsoil but also removes compaction, can incorporate lime into acidic subsoils, enhances subsoil root growth and can improve nutrient access.

Method

In 2007 a soil inversion and lime incorporation replicated plot trial was established on deep yellow sandy earth, in a cropping paddock near Mingenew. The average soil pH (in $CaCl_2$) of untreated soil at the site in 2007 was 5.2 at 0-10cm, 4.1 at 10-20cm and 3.9 at 20-30cm. The site had subsoil acidity, mild water repellence and a weed burden consisting mainly of wild radish and ryegrass. One-off soil inversion to a depth of 25-30 cm was achieved using a 3-furrow Kvernerland mouldboard plough (MBP). Limesand sourced from Dongara was applied to selected treatments at a rate of 2 t/ha. Treatments applied in 2007 were as follows:

1. Untreated control
2. 2 t/ha surface applied lime
3. Mouldboard plough (no lime)
4. 1 t/ha lime then Mouldboard plough then another 1 t/ha lime
5. Mouldboard plough then 2 t/ha lime
6. 2 t/ha lime then Mouldboard plough

The site was sown to cover crop of barley in 2007. In 2008 the site was sown to canola using the DAFWA coneseeder. From 2009-2014 the site has been sown across using the growers seeder. From 2007-2009 and 2013-2014 the plots were harvested individually with a plot header and samples collected for grain quality. In 2010-2012 (between projects) bulk yields of ploughed and unploughed blocks were harvested by the grower, so detailed treatment effects could not be assessed. In 2014 the entire site was deep ripped by the grower to depth of 30-35 cm. Hand harvest samples were taken at crop maturity in 2014 and assessed for shoot biomass, yield components and ryegrass biomass. Soil sampling to measure soil pH and other properties was undertaken after harvest from the same locations the hand harvest samples had been taken. Crop rotations and growing season rainfall (April-October) over the 8 seasons the experiment has been running are shown in Table 1.

Results

Responses to mouldboard ploughing, lime incorporation and economic returns

In 2007, the first season, the Stirling barley cover crop was sown late, 28 July, so yields were low with the untreated control yielding 680 kg/ha. Despite the low yields mouldboard ploughing had 20% higher yield at 807 kg/ha. In 2008 canola was sown across the site using a coneseeder but sinkage on the mouldboard plots significantly reduced establishment and yields were slightly reduced. Since then there have been significant yield responses in each of the cereal years with yield increases due to ploughing ranging from 300-600 kg/ha (Table 1). In 2009 there was no response to lime applications either surface applied or incorporated but there was a significant wheat yield response to mouldboard ploughing. In 2013 a response in wheat was measured to incorporated lime only and it has been assumed that this was the start of the lime responses. The broadleaf break crop species, canola and lupin, have not responded to either mouldboard ploughing or lime in this experiment (Table 1).

Table 1. Benefits Following Soil Amelioration

Crop type, growing season rainfall (GSR), yield changes and additional income benefits for 2007-2014 seasons following soil amelioration with a combination of mouldboard ploughing and lime applied once-only in 2007. (n.m. = not measured)

Year	GSR (mm) April-October	Crop type	Crop price $/t	MBP t/ha over NIL	Lime t/ha over MBP	NPV MBP Benefit $/ha	NPV Lime Benefit $/ha
2007	233	Barley	220	0.1	0	22	0
2008	313	Canola	625	-0.1	0	-59	0
2009	384	Wheat	250	0.6	0	131	0
2010	257	Lupin	200	0	n.m.	0	n.m
2011	361	Wheat	310	0.4	n.m.	91	n.m
2012	313	Lupin	250	-0.1	n.m.	-17	n.m
2013	350	Wheat	330	0.3	0.2	58	38
2014	226	Barley	260	0.4	0.6	52	77
					Total $ returns (NPV)	**279**	**116**

Additional income benefits from the treatments have been determined over the course of the experiment using September grain prices for each growing season (Table 1), with benefits after the first year discounted by an assumed interest rate of 6%, to generate its value in year 1 (Net Present Value). This has not taken into account the cost of the amelioration treatments which is estimated at $150/ha for mouldboard ploughing and $50/ha for application of lime at 2 t/ha. Returns over the 8 seasons of the experiment have more than covered these costs with returns from liming providing an additional $116/ha over the past 2 seasons alone (Table 1). Overall the additional income generated from the soil amelioration treatments has been almost $400/ha over the course of the experiment.

2013 - Wheat yield and quality

In 2013 wheat yields were increased by an average 300 kg/ha due to mouldboard ploughing with an additional 200 kg/ha yield increase where lime was applied in conjunction with the ploughing (Table 2). Lime application strategy in conjunction with ploughing did not significantly impact on the yield outcome whether applied before or after ploughing or split between the two. Surface lime application did not significantly increase wheat yield in the absence of MBP (Table 2). In addition to the increase in yield mouldboard ploughing also significantly increased grain protein by 0.7% or more. This was in conjunction with a decline in screenings for all but one of the mouldboard treatments and trend towards larger grain size in these treatments which had a combination of both mouldboard ploughing and lime (Table 2).

Table 2. Wheat grain yield and quality in the 2013 cropping season in response to combinations of mouldboard ploughing and lime treatments applied in 2007.

Treatments (applied 2007)	Grain yield (t/ha)	Protein (%)	Screenings (%)	Thousand grain weight (g)
Untreated control	2.80	10.1	4.5	42.2
2 t/ha surface lime	2.82	10.2	3.8	42.1
Mouldboard	3.12	10.8	3.5	42.6
1 t/ha lime + MBP + 1 t/ha lime	3.33	11.2	4.1	43.7
MBP + 2 t/ha lime	3.31	11.5	3.6	45.6
2 t/ha lime + MBP	3.25	11.1	3.6	43.2
Least Significant Difference (0.05)	0.13	0.4	0.7	2.1

2014 – Soil pH

Soil pH in the untreated control plots was below the recommended targets of 5.5 in the topsoil and 4.8 in the subsoil (Table 3). Application of 2 t/ha of surface lime in 2007 has maintained the topsoil pH above the target at 5.8, and the

subsurface, 10-20cm layer of soil at 4.9. Mouldboard ploughing without the addition of lime brought more acidic subsoil to the surface but has increased productivity so the topsoil pH of 4.8 is the lowest of all the treatments and the subsoil pHs are now similar to the control treatment (Table 3). Those treatments including both ploughing and lime have the best overall pH profiles ranging from 5.2 to 5.6 in the topsoil, 4.9 to 5.1 at 10-20cm and 4.5 to 4.6 at 20-30cm (Table 3). For all the treatments the soil pH in the deeper 20-30cm and 30-40cm layers is still too low and it is clear that more lime is needed at the site irrespective of treatment.

Table 3. Soil pH ($CaCl_2$) measured in December 2014 in response to combinations of mouldboard ploughing and lime treatments applied in 2007.

Note that Least Significant Difference (LSD) for Treatment x Soil Depth interaction (0.05) = 0.2

Treatments (applied 2007)	Soil depth 0-10cm	Soil depth 10-20cm	Soil depth 20-30cm	Soil depth 30-40cm
Untreated control	5.1	4.4	4.3	4.3
2 t/ha surface lime	5.8	4.9	4.4	4.4
Mouldboard	4.8	4.4	4.4	4.3
1 t/ha lime + MBP + 1 t/ha lime	5.2	5.1	4.5	4.4
MBP + 2 t/ha lime	5.6	4.9	4.5	4.4
2 t/ha lime + MBP	5.2	5.1	4.6	4.4

2014 – Barley yield

In 2014 a more acid soil sensitive Fleet barley crop was grown. Barley yields were increased by around 300 kg/ha for both surface liming and mouldboard ploughing without additional lime (Fig. 1). In combination mouldboard ploughing and lime increased barley yield around 1 t/ha in 2014 (Fig. 1) and like the previous year's wheat crop (Table 2) the order with which the lime was applied in relation to ploughing was not significant at this site.

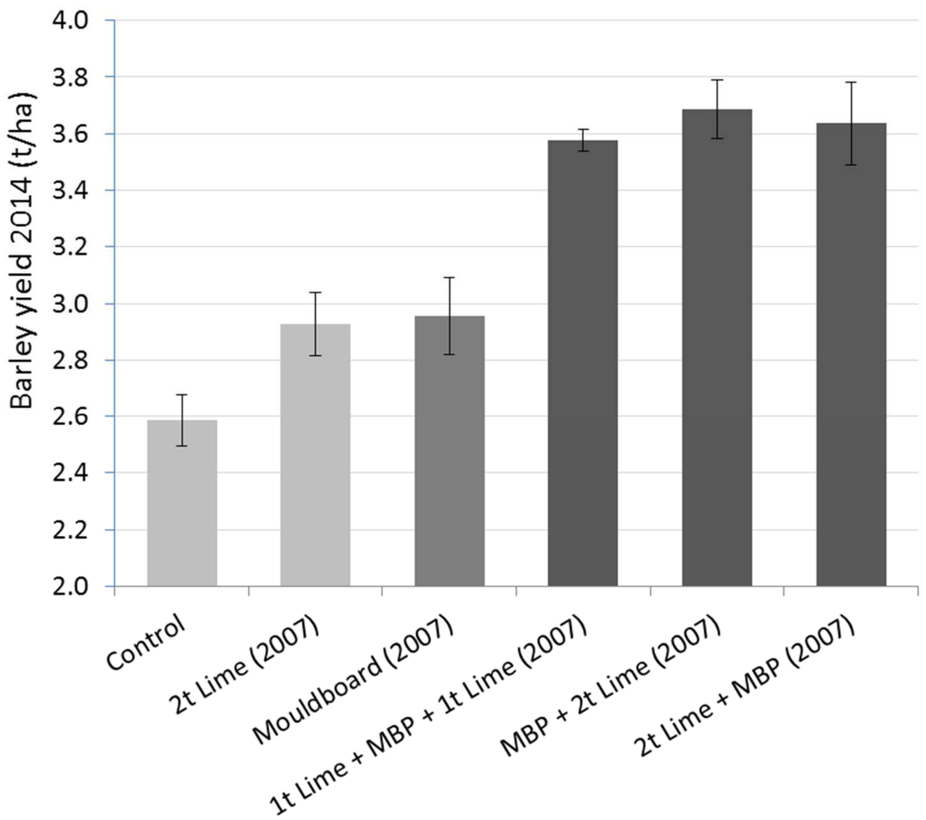

Figure 1. Impact of lime application and mouldboard ploughing in 2007 on barley grain yield in 2014.

2014 - Impact on ryegrass

In 2014 ryegrass biomass was measured in each treatment as visual differences in ryegrass density across the treatments were evident. Ryegrass shoot biomass was highest in the untreated control at just over 500 kg/ha (Fig. 2).

Mouldboard ploughing on its own had 36% lower ryegrass biomass but the impact of surface liming was even greater with a 54% reduction in ryegrass biomass (Fig. 2). The combination of mouldboard ploughing with lime further reduced ryegrass biomass by up to 75%, with a trend towards lower biomass where some lime had been applied after mouldboard ploughing (Fig. 2).

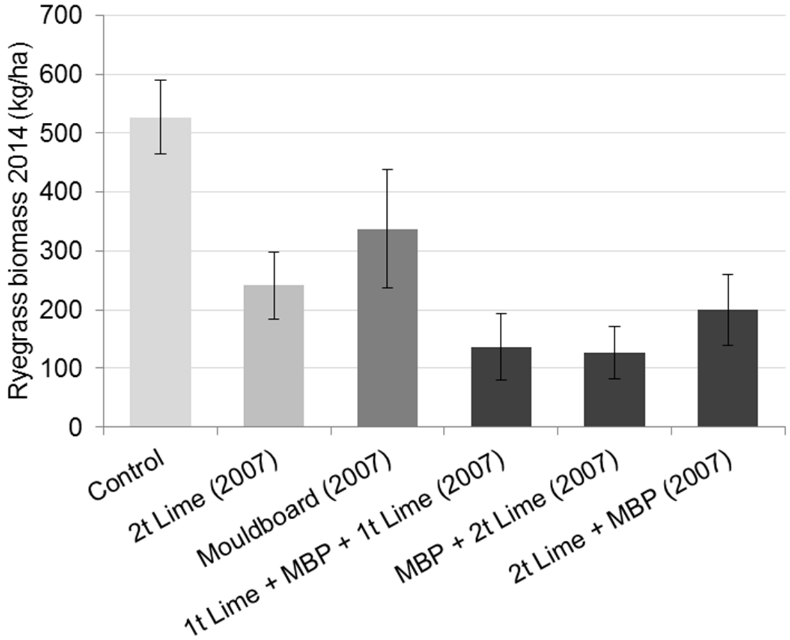

Figure 2. Impact of the lime application and mouldboard ploughing in 2007 on above-ground ryegrass biomass in 2014.

The impact of liming on barley biomass in relation to ryegrass biomass (Fig. 3), demonstrates that, in addition to weed seed burial, liming was a critical driver in improving crop competition and reducing ryegrass biomass. Overall the average ryegrass biomass of the limed treatments was 180 kg /ha compared to 460 kg/ha of ryegrass for the un-limed treatments. By comparison the average whole shoot biomass of the barley was 8.0 t/ha for all of the limed treatments and 5.9 t/ha of barley biomass for the un-limed treatments.

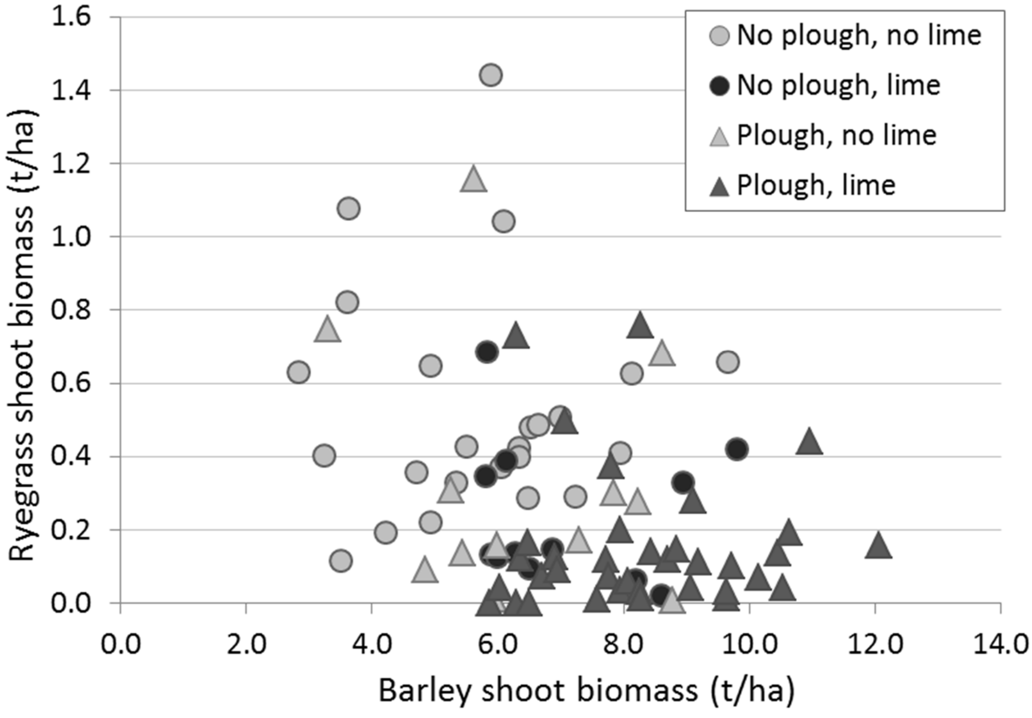

Figure 3. Relationship between total above ground biomass of ryegrass and barley in 2014 for limed and un-limed treatments and with or without soil inversion using a mouldboard plough (Plough). Lime and plough treatments were applied once only in 2007.

Conclusion

The results of this experiment indicate that the likelihood of achieving ongoing benefits from one-off soil amelioration for 10 years or more are good, provided a combination of critical soil constraints are addressed. In this experiment improvements in soil pH from liming and lime incorporation, overcoming of a mild water repellence constraint and reductions in the weed burden have resulted in continuation of significant productivity benefits in the cereal crops. Improved crop growth and biomass indicates improved water use efficiency and uptake of nutrients and would enhance organic matter inputs back into the soil, which may result in improved soil fertility (soil analyses were not available at the time of writing). Improved crop competition in combination with the carryover benefits of weed seed burial from soil inversion and possible improvements in herbicide efficacy as a result of liming and soil inversion are likely to see ongoing benefits in terms of reduced weed burdens. This benefit is likely to be reduced in a small plot experimental setting where the weed seed burden from neighbouring untreated areas act as an additional source of weed seed in treated areas but the fact that a benefit can still be measured after 8 seasons is encouraging. Some other long term soil amelioration experiments on more water repellent soils that include mouldboard ploughing, rotary spading and claying have shown ongoing crop productivity benefits for at least 5 years. A number of these have shown significant growth and yield benefits in the lupin years also, so increased biological nitrogen fixation as a result is likely to follow through to improved soil fertility and yields of the non-legume crops in the rotation. This work demonstrates that provided multiple soil and agronomic constraints are corrected or reduced when undertaking one-off soil amelioration the chances of the benefits lasting for 10 years or more are promising. It is encouraging that in this trial, even though the soil pH of the profile is not ideal and there are still weed problems there are significant crop productivity and profitability benefits.

Key words

Soil pH, mouldboard plough, lime, wheat, barley, ryegrass

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