Can subsoil constraints be combated economically?

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Key Messages

- Greatest financial return realised after three consecutive seasons comes from the treatments cultivated by the Grizzly Tiny.
- Care must be taken in interpretation of results due to pH variation across the site.

Aim

To determine which combination of ameliorant and cultivation practice improves subsoil constraints and crop yield economically.

Background

It is estimated that more than 11 million hectares in the Western Australian Wheatbelt are moderately to strongly affected by acidity (Petersen, 2016), making acidity one of the major limiting production factors to modern day farming systems. In monetary terms, this is estimated to cost Western Australian growers $141/ha/year ($1.6 billion/year in lost production potential), while other constraints such as compaction is said to cost the industry just under $1.0 billion/year (Petersen, 2016). Lime has therefore been one of the major inputs in broadacre farming over the last 20 years, with 100% of Liebe members liming in 2012 (Hollamby, 2012).

This trial was designed by a Liebe Group project committee to determine the most effective liming strategy to maximise the return on investment in the Liebe region. The trial is located west of Wubin on a poor performing paddock that has the potential to improve once subsoil constraints have been addressed. A target pH of 5.5 to a depth of 300mm was identified and entered into the Liebe Group's Lime Calculator, along with the baseline soil pH results. The Lime Calculator generated a recommendation for lime rates required to achieve the target pH of 5.5. Dolomite has a lower neutralising value than limesand therefore; more product is required in order to reach the target pH of 5.5 (see trial details).

The trial was implemented in 2015 and consists of four replicates of different mixing practices (untreated, spaded, grizzly) with products applied (untreated, lime, dolomite and lime + dolomite) (Table 1). The different cultivation equipment used perpendicular to the direction of top dressing. In 2015, the pH was measured to a depth of 1m in a selection of the plots.

An automated weather station and moisture probes have been installed at the site to monitor the impacts of treatments, giving further insight into cultivation methods and their effect on yield. The soil moisture probes were installed in July 2015 in the three replicates of the combinations of spaded and untreated mixing with nil product and lime + dolomite (treatment numbers 1, 2, 10 and 11).

Trial Details

Property	AJ & JA Barnes, west Wubin
Plot size & replication	11.65m x 14m x 4 replications
Soil type	Yellow tammar sand
Soil pH ($CaCl_2$)	Table 3
EC (dS/m)	Table 2
Sowing date	15/06/2017
Seeding rate	65 kg/ha Mace wheat
Incorporation	23/02/2015: Grizzly Tiny Offset (36 inch discs) 05/03/2015: Spader
Lime History	Pre-trial 2009: 1 t/ha lime Pre-trial 2014: 1.5 t/ha lime 2015: 3.2 t/ha lime only plots, 3.4 t/ha dolomite only plots, 1.65 t/ha each lime & dolomite plots
Paddock rotation	2013 wheat, 2014 fallow, 2015 wheat, 2016 wheat, 2017 fallow
Fertiliser	7/03/2017: 40 kg/ha MOP spread 15/06/2017: 50 kg/ha AgYield Trace 21/08/2017: 50 L/ha Flexi N
Herbicides & Fungicides	15/06/2017: Treflan 2.5 L/ha, Sakura 118 g/ha, Sharpen 10 g/ha, Roundup 450 2.5 L/ha 4/08/2017: Velocity 1 L/ha + 1% MSO spray oil 21/08/2017: Jaguar 1 L/ha
Growing season rainfall	130 mm

Table 1 Treatments including two variables - Amelioration product and Cultivation Type

Treatment Number	Lime Treatment	Cultivation Type
1	Nil	No Till
2	Nil	Spader
3	Nil	Offsets
4	Limesand	No Till
5	Limesand	Spader
6	Limesand	Offsets
7	Dolomite	No Till
8	Dolomite	Spader
9	Dolomite	Offsets
10	Lime & Dolomite	No Till
11	Lime & Dolomite	Spader
12	Lime & Dolomite	Offsets

Results

Now in its third year, crop establishment was far better with a consolidated seed bed. The trial has a number of factors influencing the results with variable soil acidity profiles and a large weed burden. Both factors are believed to have had an impact on yield and quality, and as a result care must be taken when interpreting data.

Limesand was applied to the paddock on two occasions prior to the trial being implemented in 2009 (1 t/ha) and 2014 (1.5 t/ha). From the baseline soil results (Table 2), it can be observed that this lime has not moved through the profile and is still sitting in the 0-5cm layer of topsoil.

Table 2 Baseline soil properties (0-40 cm) collected prior to treatments being imposed, February 2015

Depth (cm)	pH	EC (dS/m)	Organic Carbon (%)	NH_4 (mg/kg)	$N0_3$ (mg/kg)	Phosphorus Cowell (mg/kg)	Potassium Cowell (mg/kg)	Sulphur (mg/kg)	Aluminium (meq/100g)
0-5	5.6	0.104	0.79	3	23	38	42	15.4	0.12
5-10	5.5	0.048	0.71	1	13	36	24	9.7	0.24
10-20	5.2	0.029	0.36	1	7	16	22	11.6	0.42
20-30	4.8	0.025	0.28	1	5	6	17	19.4	0.34
30-40	4.9	0.025	0.16	2	4	3	18	24.7	0.24

Variability of pH across the trial

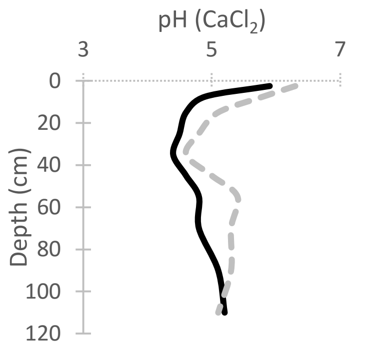
The pH was measured in 10 plots across the trial in 2015 and was grouped into two types of pH profile:

1) Non-acid subsoil - Soils which are acidic in 0 to 30 or 40cm depth and were not acidic below these depth.
2) Acid subsoil - Soil which were acidic from 0 cm to 60cm or deeper

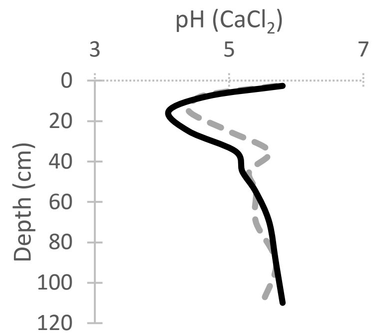
After the application of mixing and lime treatments, the soil was re-classified according to whether the profile had been ameliorated (pH increase above 5 in topsoil and 4.5 in subsoil). An example of some of the pH profiles are shown in Table 3.

Table 3. Soil pH profiles after treatments applied for acid subsoil and non-acid subsoil plots, with the most common treatment relating to these pH profiles in 2015 (solid) and after ammendment in 2016 (dotted).

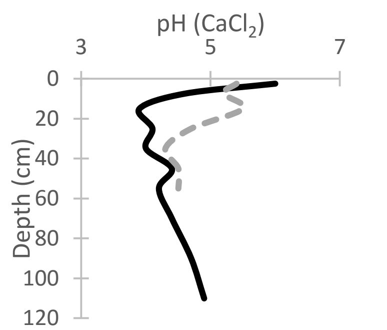
<table>
<tr><th>Amelioration</th><th>Acid subsoil</th><th>Non Acid subsoil</th></tr>
<tr><td>More acidic in topsoil</td><td>Mixing + no ameliorant (3)</td><td>2 plots</td></tr>
<tr><td>No Change</td><td>Total = 2 plots,
Untreated + no ameliorant (2)



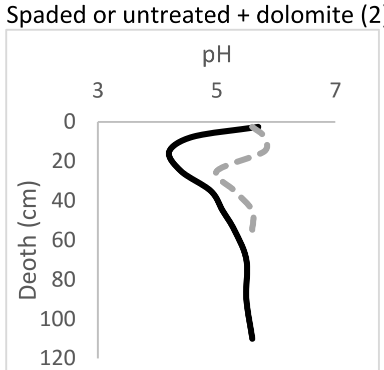
</td><td>Total = 13 plots,
Untreated +/- ameliorant (10)



</td></tr>
<tr><td>Ameliorated to 20cm</td><td>Total = 7 plots
Grizzly/spaded + ameliorant (6)

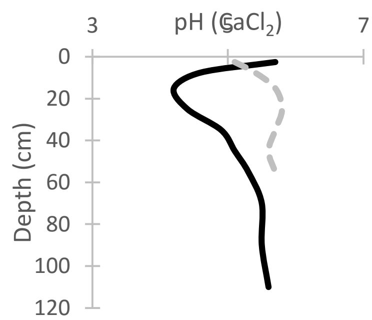


</td><td>Total = 2 plots
Spaded or untreated + dolomite (2)



</td></tr>
<tr><td>Ameliorate to 30/40cm</td><td>Total = 3
Spaded (2)+3

No graph available</td><td>Total = 16
Spaded/Grizzly + Ameliorant (11)
Grizzly untreated (3)



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Crop establishment and weed burden

The 2017 growing season rainfall (May-October) was 130mm, however the site also received 117mm of summer rainfall (January-April) (Table 4). The break of the season was late, with 1.6mm on 30 June followed by 7.2mm on the 1 July. Due to the late rain the trial was not sown until 15 June. The rest of the paddock was deep ripped and left to chemical fallow.

Table 4 Trial site 2017 rainfall (electronic rainfall gauge)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2016	72.0	0	57.4	34.0	39.6	37.2	32.0	40.4	27.2	9.0	1.6	0.8
2017	75.6	26.0	15.6	1.0	4.6	3.8	35.4	50.8	15.4	19.8	16[a]	

[a] up to 15/11/2017

The crop establishment measurements, taken on July 26 2017, ranged from 48-86 plants/m^2. Such low plant numbers was an early indication that yield in 2017 had been compromised by the late start. There was no difference between lime treatments but there was a higher plant density on the no till treatments (Table 5). The site had a large weed burden, particularly brome grass, ryegrass and radish in the some of the lime and dolomite plots, however due to the plot variation there was no influence of treatment on this weed burden.

Table 5 Impact of soil ameliorant product on wheat density weed burden

Product	Wheat/m²	Brome grass/m²	Radish/m²	Ryegrass/m²
Untreated	67	68	5	108
Lime	68	78	4	105
Dolomite	64	77	1	103
Lime + Dolomite	67	62	37	81
Pvalue	*0.95*	*0.94*	*0.37*	*0.93*
LSD	*NS*	*NS*	*NS*	*NS*

Table 6 Impact of cultivation on wheat density and weed burden

Treatment	Wheat/m²	Brome grass/m²	Radish/m²	Ryegrass/m²
No till	81[a]	54	6	64
Spaded	62[b]	68	4	99
Offsets	56[b]	91	25	133
P value	*0.00004*	*0.34*	*0.52*	*0.17*
LSD		*NS*	*NS*	*NS*

NS=Not significant.

Harvest results

Grain yields were low in 2017 due to the late break of season, low rainfall and low wheat plant density. The yields were not significantly different for the interaction between tillage and lime treatments (Table 7 and 8). The individual effect of cultivation saw a lower yield on the no-till plots compared to those treatments which were cultivated by the spader and Grizzly Tiny (Table 8). There was no impact of the treatments on grain quality.

Table 7 Effect of soil ameliorant on grain yield and quality of Mace wheat at west Wubin, 2017

Treatment Number	Lime Treatment	Yield (t/ha)	Protein (%)	Hectolitre (kg/hL)	Screenings (%)
1, 2, 3	Control	0.59	9.9	80.9	3.0
4, 5, 6	Limesand	0.61	9.6	81.5	3.2
7, 8, 9	Dolomite	0.61	9.9	81.2	2.9
10, 11, 12	Lime & Dolomite	0.58	10.0	80.5	3.1
P value		*0.95*	*0.11*	*0.23*	*0.66*
LSD		*NS*	*NS*	*NS*	*NS*

NS=Not significant.

Table 8 Effect of cultivation on grain yield and quality of Mace wheat at west Wubin, 2017

Treatment	Cultivation Type	Yield (t/ha)	Protein (%)	Hectolitre (kg/hL)	Screenings (%)
1, 4, 7, 10	No Till	0.52 [b]	9.88	81	2.9
2, 5, 8, 11	Spader	0.64 [a]	9.73	80.7	3
3, 6, 9, 12	Offsets	0.63 [a]	9.94	81.3	3.2
P value		*0.023*	*0.26*	*0.35*	*0.68*
LSD			*NS*	*NS*	*NS*

NS=Not significant.

Comparing the imagery to site data

There was high variability in the plot data, which may have been due to the variation in subsoil pH profiles across the trial. NDVI imagery was used to explore this variation across the plots. The NDVI images were provided by Stratus Imaging in July for base line and emergence, August for growth, and October for peak biomass.

Ground measurements have been compared to the NDVI image across the plots (Figures 1-3). In July, the NDVI results were compared with the plant counts conducted in the same week (Figure 1). Some visual trends indicated the higher plant counts (dark grey) matched the higher NDVI values in some plots (more green).

The August NDVI was compared to the weed count, as this dominated the cover and biomass of the plots in August (Figure 2) however there was not an identifiable pattern. The October NDVI was compared to the plot yields, again with a limited visual correlation as the crop had already begun the ripening process.

Further comparison with the NDVI and pH profiles is still underway, looking at the plot values of the NDVI values as well as percentage of NDVI class within a plot. The late break of season, low yields and high weed burden at the trial contributed to interference with the usual relationships between the ground data and the imagery in 2017. Hopefully the imagery to be collected in 2018 can be a valuable tool for comparing the lime and tillage treatments across this variable trial.

57	84	72	61
84	54	95	52
48	98	78	47
57	59	85	57
79	46	94	52
79	47	59	58
61	67	42	83
63	76	52	59
91	79	87	46
53	80	72	77
52	90	64	57
43	63	85	47

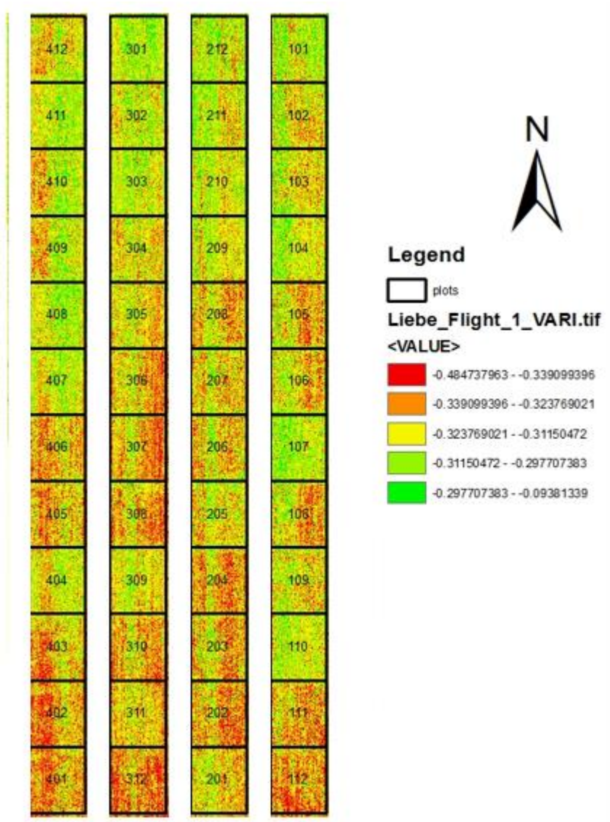

Figure 1 Flight 1 – July NDVI compared to wheat plant counts 26 July (with colour coding for low 0-50 plants/m^2 (white), medium 50-70 plants/ m^2 (pale grey) and high > 70 plants/m^2 (dark grey) plant density**.**

480	270	140	70
330	250	180	70
380	180	140	140
780	240	60	50
130	230	180	0
40	260	130	70
150	110	110	10
120	510	290	90
130	40	70	10
60	30	80	130
540	80	100	100
550	340	150	110

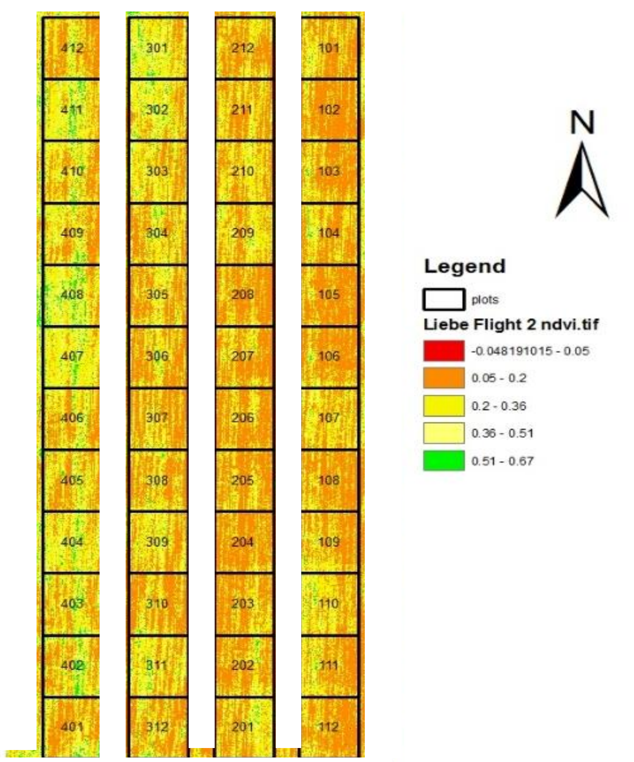

Figure 2 Flight 2 – August 2017 NDVI imagery compared to total weed/m2 in August with low weeds <140 plant/m^2) (white), and high weeds >140 plants/m^2 (grey**)**

Harvest yield

0.65	0.77	0.73	0.61
0.50	0.73	0.00	0.73
0.73	0.71	0.61	0.68
0.65	0.69	0.56	0.68
0.48	0.67	0.58	0.64
0.46	0.70	0.59	0.71
0.71	0.74	0.59	0.64
0.58	0.65	0.54	0.79
0.39	0.53	0.54	0.77
0.49	0.65	0.52	0.52
0.44	0.47	0.52	0.75
0.44	0.56	0.43	0.53

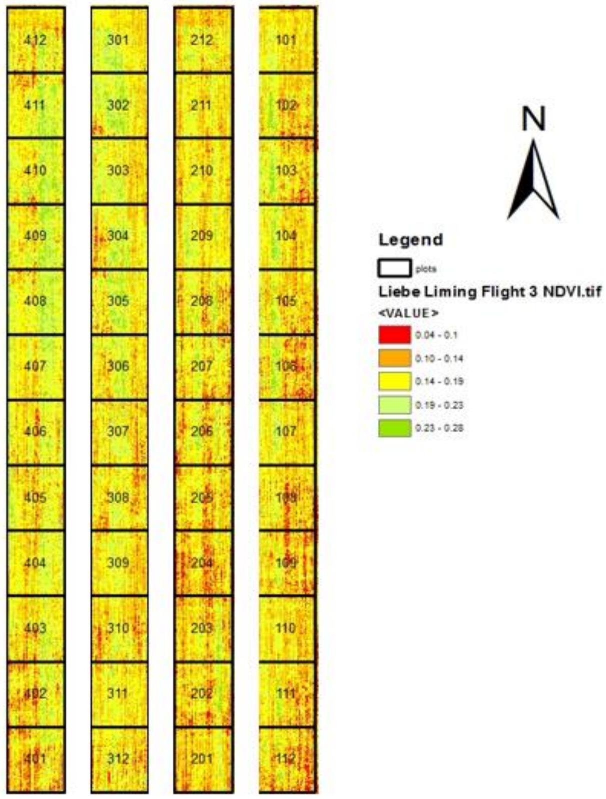

Figure 3 Flight 3 – October 2017 NDVI imagery and the plot yield data, with the yields > 0.7 t/ha highlighted in grey.

Soil water probes

In 2017, only the probes in replicate 4 were working (plots 405, 406, 407, 408 in the western plots of the trial). The rainfall is clearly seen in the increase in the water content in the 55cm layer (Figure 4). The water content decreased at an earlier date, and at faster rate, for the spaded treatments at the 55cm layer compared to the untreated control. This indicates the roots were able to grow faster through the spaded plots to access the water earlier than the no-tilled plots. This is likely due to the removal of compaction and some reduction in acidity/aluminium in the spaded plots. Earlier and greater access to water can allow the crops to grow during drought periods and often leads to higher yields.

None of these plots however were classed as fully ameliorated and the root growth was not at the potential rate compared to APSIM modelling of the site. The spaded sites best fit a reduction in root growth rate to 30% of potential while the no-till sites were best fit by a reduction in root growth rate to 20% of potential (data not shown). In long term modelling with APSIM, this often leads to an average yield increase of 0.6 t/ha, as long as no other management constraint exists (data not shown).

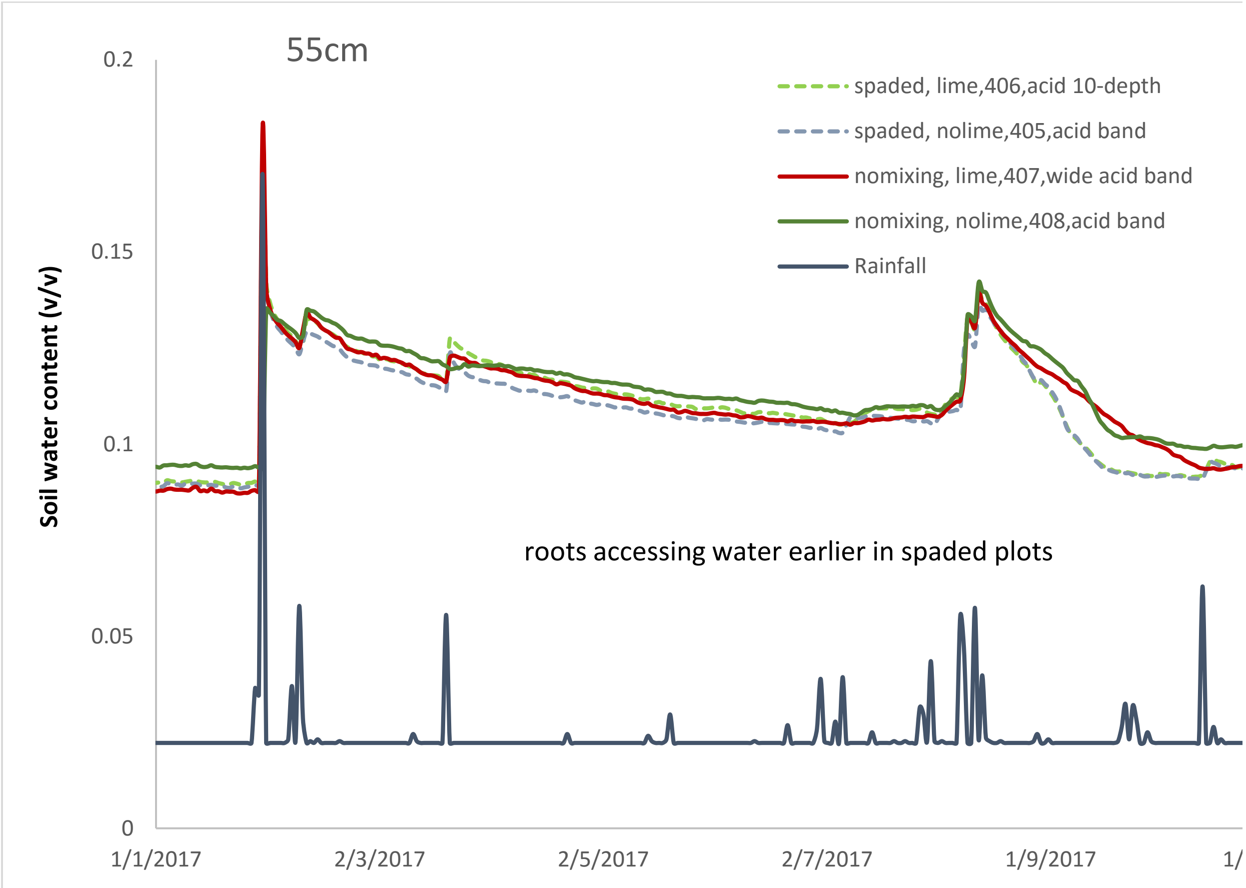

Figure 4 Soil water content (v/v) at 55cm depth in the spaded, spaded and lime plots compared to the no tillage with and without lime plots.

Economic Analysis

For a third consecutive season Treatment 4, Limesand with no cultivation, resulted in the highest gross Return on Investment (ROI) at 451% since the initial investment was made in 2015. After a difficult dry season in 2017, this still returned a net benefit of $142/ha (Table 9). Treatment 7 has also proven to perform positively with an average ROI at 399% however, the net benefit at $61/ha is reflective of the low initial investment costs of the Dolomite. Financial benefits also continued to be seen under treatments where the offsets were used as a method of cultivation. There was no significant impact on financial return where lime was included (treatment 6) or not included (treatment 3) under cultivation with the offsets.

Table 9 Economic analysis of different soil ameliorant treatments at west Wubin, 2015-2017, with analysis of combined average Return on Investment (ROI %).

Treatment #	Lime Treatment	Cultivation Type	2015 Investment (cultivation)	2015 Investment (product)	Total Investment	Yield 2017	Average Profit 2017	ROI % 2017	Combined Profit 2015-2017	Extra Profit/year from Investment	Average ROI %	Net Benefit
1	Nil	No Till	$0.00	$0.00	$0.00	**0.50**	-$219	0%	-$118			-$118
2	Nil	Spader	$120.00	$0.00	$120.00	**0.62**	-$192	22%	$24	$142	118%	-$96
3	Nil	Offsets	$85.00	$0.00	$85.00	**0.64**	-$188	37%	$186	**$304**	**358%**	**$101**
4	Limesand	No Till	$0.00	$74.20	$74.20	**0.23**	-$193	36%	$216	**$334**	**451%**	**$142**
5	Limesand	Spader	$120.00	$74.20	$194.20	**0.62**	-$190	15%	$230	$348	179%	$36
6	Limesand	Offsets	$85.00	$74.20	$159.20	**0.72**	-$172	30%	$269	**$387**	**243%**	**$110**
7	Dolomite	No Till	$0.00	$60.00	$60.00	**0.59**	-$200	32%	$121	**$239**	**399%**	**$61**
8	Dolomite	Spader	$120.00	$60.00	$180.00	**0.63**	-$191	15%	$139	$257	143%	-$41
9	Dolomite	Offsets	$85.00	$60.00	$145.00	**0.61**	-$192	19%	$52	$170	117%	-$93
10	Lime & Dolomite	No Till	$0.00	$84.15	$84.15	**0.53**	-$208	13%	-$107	$11	13%	-$191
11	Lime & Dolomite	Spader	$120.00	$84.15	$204.15	**0.65**	-$188	15%	$10	$128	63%	-$194
12	Lime & Dolomite	Offsets	$85.00	$84.15	$169.15	**0.57**	-$201	11%	$65	$183	108%	-$104

Note: Grain prices based on farm gate price, standard across all treatments.

Total Cropping Costs based on the actual Fertilisers and Chemicals applied plus the 2017 Farmanco Profit Series low and medium rainfall average crop costs including fixed costs of $117/ha and excluding Fertiliser and Chemical have been utilised.

Table 10: Economic analysis of different lime treatments at west Wubin, 2015 - 2017 with combined average Return on Investment (ROI%).

Product	2015 Investment (Cultivation)	2015 Investment (Product)	Total Investment	Yield 2017	Average Profit 2017	ROI % 2017	Combined Profit 2015-2017	Extra Profit/year from Investment	Average ROI %	Net Benefit (Combined Profit - Investment)
Control	$68.33	$0.00	$68.33	0.59	-$200	0%	-$52			-$120
Limesand	$68.33	$74.20	$142.53	0.66	-$184	11%	$157	$209	146%	$14
Dolomite	$68.33	$60.00	$128.33	0.61	-$194	4%	$22	$73	57%	-$107
Lime + Dolomite	$68.33	$84.15	$152.48	0.58	-$199	1%	-$92	-$41	-27%	-$245

Table 11: Economic analysis of different cultivation treatments at west Wubin, 2015- 2017 with combined average Return on Investment (ROI%).

Tillage	2015 Investment (Cultivation)	2015 Investment (Product)	Total Investment	Yield 2017	Average Profit 2017	ROI % 2017	Combined Profit 2015-2017	Extra Profit/year from Investment	Average ROI %	Net Benefit (Combined Profit - Investment)
No Till	$0.00	$54.59	$54.59	0.56	-$206	0%	-$55			-$109
Spader	$120.00	$54.59	$174.59	0.63	-$201	3%	$8	$59	54%	-$167
Offsets	$85.00	$54.59	$139.59	0.64	-$190	11%	$59	$110	82%	-$81

2017 yield results have had a negative impact on the 2017 profit and ROI however, there remains a noticeable positive trend in return for treatments using Limesand and cultivation using the offsets as reported in tables 10 and 11. This supports the economic return for treatments 3 and 6 (Table 9), where there was a significantly positive ROI where the offsets were used with or without limesand. Therefore the financial benefit being recognised is directly linked to the cultivation breaking the compaction layer. Further soil testing will be required to quantify the amount of return that is attributed to the limesand.

Comments
Poor seasonal conditions, late sowing and the overwhelming competitiveness of winter weeds such as ryegrass and brome grass, led to less than ideal conditions for this trial site to thrive in 2017; resulting in low yields and quality.

Without soil testing for base nutrients at the beginning of 2017, no trend in amelioration could be measured. Comprehensive soil testing will be conducted in 2018 to ensure the amelioration effect, if any, is being captured and recorded.

All soil moisture probes will be checked and calibrated prior to seeding in 2018, to ensure all soil moisture profiles are being recorded throughout the season.

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Petersen, E. (2016). Economic analysis of the impacts and management of subsoil constraints. Presented at the 2016 GRDC Grains Research Updates.

Soil acidity management strategies throughout Western Australia are available for download from: http://www.liebegroup.org.au/working-together-to-deliever-multiple-benefit-messages-to-growers-through-a-whole-systems-approach-to-soil-management/

Free for download Liebe Lime Calculator: http://www.liebegroup.org.au/lime-profit-calculator/